CARIBBEAN EXAMINATIONS COUNCIL

Caribbean Advanced Proficiency Examination®

SYLLABUS

GREEN ENGINEERING

CXC A36/U2/16

Effective for examinations from May–June 2017

CAPE®

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Please check the website www.cxc.org for updates on CXC's syllabuses.

Introduction

The Caribbean Advanced Proficiency Examination® (**CAPE®**) is designed to provide certification of the academic, vocational and technical achievement of students in the Caribbean who, having completed a minimum of five years of secondary education, wish to further their studies. The examinations address the skills and knowledge acquired by students under a flexible and articulated system where subjects are organised in 1-Unit or 2-Unit courses with each Unit containing three Modules. Subjects examined under **CAPE®** may be studied concurrently or singly.

The Caribbean Examinations Council offers three types of certification at the **CAPE®** level. The first is the award of a certificate showing each **CAPE®** Unit completed. The second is the **CAPE®** Diploma, awarded to candidates who have satisfactorily completed at least six Units, including Caribbean Studies. The third is the **CXC®** Associate Degree, awarded for the satisfactory completion of a prescribed cluster of *eight* **CAPE®** Units including Caribbean Studies, Communication Studies *and Integrated Mathematics. Integrated Mathematics is not a requirement for the* ***CXC®*** *Associate Degree in Mathematics.* The complete list of Associate Degrees may be found in the **CXC®** Associate Degree Handbook.

For the **CAPE®** Diploma and the **CXC®** Associate Degree, candidates must complete the cluster of required Units within a maximum period of five years. *To be eligible for a* ***CXC®*** *Associate Degree, the educational institution presenting the candidates for the award, must select the Associate Degree of choice at the time of registration at the sitting (year) the candidates are expected to qualify for the award.* Candidates will not be awarded an Associate Degree for which they were not registered.

Green Engineering Syllabus

♦ RATIONALE

Engineering has broad environmental, social and economic impacts. In fact, every day engineers and scientists make technical decisions which have significant impact on the environment. These decisions can either move us in the direction of sustainability or contribute to the growing problems. Application of the principles of Green Engineering is considered a new paradigm that allows for the incorporation of the concept of sustainability and the application of science and design solutions to problems created by conventional engineering. Green Engineering can be defined as environmentally conscious attitudes, values, and principles, combined with science, technology and innovation directed towards improving local and global environmental quality. It is the design of materials, processes, systems and devices with the objective of minimising overall environmental impact over the entire life cycle whilst meeting required performance, economic and societal constraints.

The study of **CAPE®** Green Engineering will therefore enable students to acquire the knowledge, skills, values and attitudes needed to sustain the natural environment. It will provide students with a suite of tools to improve their approach to, and effectiveness at, solving real world problems. Students will develop their creativity and innovative skills which are especially important in today's society and will undoubtedly have an influence on future generations. This course of study will enable students to apply Scientific, Technological, Engineering and Mathematical (STEM) principles to improve their environment at the local, regional and global levels. This inter-disciplinary and cross-disciplinary course of study will contribute to a Caribbean person who is empowered to finding solutions to current and future environmental problems. The study of Green Engineering will enhance quality of life for present and future generations, while providing wealth creation through new and innovative job opportunities and other economic possibilities including entrepreneurship. By pursuing this course, students will develop twenty-first century engineering skills and ethics required for sustainable development. The syllabus is designed to provide the knowledge, skills and competencies that are required for further studies, as well as for the world of work.

Moreover, based on the attributes of the Ideal Caribbean Person as articulated by CARICOM, this course of study in **CAPE®** Green Engineering can contribute to the development of a Caribbean person who is aware of living in harmony with the environment; demonstrates a positive work ethic, multiple literacies, independent and critical thinking, questions the practices of past and present and brings this to bear on the innovative application of science and technology to problem solving; and values and displays the creative imagination in its various manifestations and nurtures its development in economic and entrepreneurial spheres in all other areas of life. With reference to the UNESCO Pillars of Learning, the study of Green Engineering will contribute to a person who will learn to know, learn to do, learn to live together, learn to be and learn to transform themselves and society.

♦ AIMS

This syllabus aims to:

1. enhance students' awareness of the broad environmental, social and economic impact of engineering;

2. create an understanding of how to incorporate the principles of sustainability into engineering practices;

3. promote an understanding of the principles of Green Engineering and Industrial Ecology;

4. develop an understanding of the interdisciplinary and multi-disciplinary nature of environmental problems related to engineering;

5. promote awareness of the global challenges related to environment and the impact of our decisions on present and future generations;

6. apply the principles of Green Engineering and Industrial Ecology to manage and solve environmental problems related to engineering in the Caribbean context;

7. apply Scientific, Technological, Engineering and Mathematical (STEM) principles to improve the environment at the local, regional and global levels;

8. design solutions to address environmental problems related to engineering;

9. develop the capacity for critical thinking, creativity and innovation, problem solving, contextual learning, collaboration, emotional intelligence, entrepreneurial skills and technological competence through authentic learning experiences; and,

10. integrate information, communication and technological (ICT) tools and skills.

♦ SKILLS AND ABILITIES TO BE ASSESSED

The skills and abilities that students are expected to develop on completion of this syllabus have been grouped under three headings:

(a) Knowledge and Comprehension;

(b) Application of Knowledge; and,

(c) Practical Ability.

Knowledge and Comprehension

Knowledge	The ability to identify, remember, and grasp the meaning of basic facts, concepts and principles.
Comprehension	The ability to: - select appropriate ideas, match, compare and cite examples of facts, concepts and principles in familiar situations; - explain familiar phenomena in terms of theories, laws and principles.

Application of Knowledge

Application	The ability to: - use facts, concepts, principles and procedures in unfamiliar situations; - transform data accurately and appropriately; - use common characteristics as a basis for classification; and, - use formulae accurately for computations.
Analysis and Interpretation	The ability to: - identify and recognise the component parts of a whole and interpret the relationships between those parts; - identify causal factors and show how they interact with each other; - infer, predict and draw conclusions; and, - make necessary and accurate calculations and recognise the limitations and assumptions of data.
Synthesis	The ability to: - combine component parts to form a new meaningful whole; and, - make predictions and solve problems.
Evaluation	The ability to make reasoned judgements and recommendations based on the value of ideas and information and their implications.

Practical Ability

Practical Ability	The ability to use Green Engineering concepts, principles and procedures in familiar and novel situations to design and construct or improve viable solutions.

♦ PREREQUISITES OF THE SYLLABUS

Any person with a **good** grasp of the contents of the syllabus of the Caribbean Secondary Education Certificate (**CSEC®**) General Proficiency course in subjects such as Agricultural Science, Biology, Chemistry, Construction Technology, Integrated Science, Mathematics, and Physics or equivalent, should be able to undertake the course. However, successful participation in the course will also depend on the possession of good verbal and written communication skills.

♦ STRUCTURE OF THE SYLLABUS

The subject is organised in two (2) Units. A Unit comprises three (3) Modules each requiring fifty (50) hours. The total time for each Unit, is therefore, expected to be one hundred and fifty (150) hours. Each Unit can independently offer students a comprehensive programme of study with appropriate balance between depth and coverage to provide a basis for further study in this field.

UNIT 1: INTRODUCTION TO GREEN ENGINEERING

Module 1 - CONCEPTS AND ISSUES

Module 2 - THEORETICAL FRAMEWORK OF GREEN ENGINEERING

Module 3 - GREEN ENGINEERING IN PRACTICE

UNIT 2: APPLICATION OF GREEN ENGINEERING PRINCIPLES

Module 1 - UTILISATION OF SUSTAINABLE MATERIALS AND ENERGY

Module 2 - SUSTAINABLE DESIGNS

Module 3 - GREEN ENGINEERING SOLUTIONS

♦ UNIT 1: INTRODUCTION TO GREEN ENGINEERING

MODULE 1: CONCEPTS AND ISSUES

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand the concepts of sustainable development, sustainability and efficiency and current trends related to the utilisation of natural resources;
2. comprehend the concept of risk in the engineering environment;
3. be aware of the consequences and challenges of engineering;
4. appreciate the need for sustainability; and,
5. understand life cycle frameworks.

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Concepts of Sustainable Development, Sustainability and Efficiency	
1. explain the concepts of sustainable development, sustainability and efficiency in Green Engineering;	(a) Definition of concepts. (b) Three pillars of sustainability. (c) Examples of sustainability and resource efficiency.
Current Trends Related to the Utilisation of Natural Resources	
2. differentiate the categories of natural resources;	Types of natural resources (renewable, non-renewable).
3. discuss the current trends related to the utilisation of natural resources;	Resource consumption and depletion (energy, water, forest, minerals).
4. discuss the consequences of resource utilisation in the context of sustainability;	Main findings and the Millennium Ecosystem Assessment. (a) Pollution (land, air, water and energy). (b) Climate change (especially global warming). (c) Public health and safety Issues.

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
The Concept of Risk in the Engineering Environment	
5. examine different lifestyles and the implications for resource efficiency and environmental quality impact;	Lifestyle (sustainable and unsustainable consumption patterns, efficient and inefficient use of materials and energy).
6. describe the concept of risk in the engineering environment;	(a) Definition. (b) Nature.
7. examine the types of risks within engineering and production processes;	Occupational Health and Safety; commercial market failure, public acceptance, competition, market access; environmental (use of hazardous materials, spills and others).
Consequences and Engineering Challenges	
8. outline the consequences associated with different types of risks;	Injury; loss of life (Occupational Health and Safety); discontinuation of product line (commercial); ecosystem disruption (environmental).
9. discuss the challenges associated with different types of risks;	Technical capacity (lack of maintenance of machinery, human resource, handling of materials), awareness and knowledge, failure to implement regulations and standards, inadequate financing.
The Need For Sustainability	
10. justify the need for sustainability in manufacturing and production processes;	Risks related to people, planet and profit.
11. discuss interventions to achieve sustainability in manufacturing and production processes;	Policies, capacity development, financing, monitoring, evaluation and enforcement, Environmental Management Systems.

UNIT 1
MODULE 1: CONCEPTS AND ISSUES (cont'd)

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Sustainable Design Tools	
12. examine the tools for sustainable designs; and,	Life cycle framework (goal and scope, life cycle inventory, life cycle impact assessment and interpretation): (a) Carbon footprinting: reduction of greenhouse gases (GHG) in the creation of products and services as well as in processes. Tools for calculating your personal carbon footprint. (b) GHG Protocol standards. GHG accounting and reporting principles.
13. outline the sustainability issues associated with each stage of the lifecycle framework.	Issues including population growth, resource consumption, waste generation, pollution, energy consumption and reduction of carbon footprint.

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives in this Module, teachers are advised to engage students in the following teaching and learning activities.

1. Invite guest lecturers to address issues of sustainability.
2. Facilitate group discussions on categories of natural resources and their sustainability implications.
3. Discuss the Millennium Ecosystem Assessment Report.
4. Debate issues on sustainability and engineering system design.
5. Use ICT, video clips on sustainability and engineering design.
6. Conduct field trip to compare products sold or used in the product lifecycle and carbon footprint models.

RESOURCES

Allen, D. T. and Shonnard D. R.	*Green Engineering: Environmentally Conscious Design of Chemical Processes*. New Jersey: Prentice Hall Incorporated, 2001.
Daily, Gretchen C. and Paul E.	'Population, Sustainability, and Earth's Carrying Capacity'. *BioScience*, November 1992: pp. 761-764, 770, 771.
Goldman, Daniel	*Ecological Intelligence*. Broadway: New York Books, 2009.
Hawken, P., Lovins, A. and Lovins, L.H.	*Natural Capitalism: Creating the Next Industrial Revolution*. Boston: Little, Brown and Company, 1999.
Lovins, A.B., Lovins, L.H. Hawken, P.	'A Road Map for Natural Capitalism'. *Harvard Business Review*. May/June 1999: 145-158.
McKibben, B.	*Eaarth: Making a Life on a Tough New Planet*. New York: St Martin's Griffin, 2011.
Mwasha, A.	*Practical Guide to Green Technology for Ground Engineering*. Shawbury, Shrewsbury, UK : Smithers Rapra, 2011.
Sarte, B	*Sustainable Infrastructure: The Guide to Green Engineering and Design*. New Jersey: John Wiley & Sons, Inc, 2010.
Senge, P.	*The Necessary Revolution: How Individuals and Organisations are Working Together to Create a Sustainable World*. New York: Crown Business, 2010.
Wackernagel, M. and Rees, W.	*Our Ecological Footprint.* Gabriola Island, B.C. Canada: New Society Publishers, 1996, pp. 61-124.
Wallace, B.	*Becoming Part of the Solution: The Engineer's Guide to Sustainable Development*. American Council of Engineering Companies, 2005.
Zimmerman, J. and Anastas, P.	*Innovations in Green Chemistry and Green Engineering*. New York: Springer, 2013.

Sustainable Development in the United States: An Experimental Set of Indicators, A Progress Report Prepared by the US Interagency Working Group on Sustainable Development Indicators. Washington, DC, December, 1998.

Prof. Satish V. Kailas, Material Science – Specific Objective 12
http://nptel.iitk.ac.in/courses/Webcourse-contents/IIScBANG/Material%20Science/pdf/Module18.pdf

The Brundtland Commission and Herman E. Daly http://acwi.gov/swrr/whatis-sustainability-wide.pdf

Ecological Footprint: http://www.rprogress.org/programs/sustainabilityindicators/ef/quiz/

Genuine Progress Indicator: http://www.rprogress.org/publications/2000_gpi_update.pdf

Living Planet Report 2002 WWF: http://www.panda.org/downloads/general/LPR_2002.pdf

Overview of Major Environmental Sustainability Issues:
http://css.snre.umich.edu/css_edu_resources.htm

Suggested video clips

Renewable Energy and the Energy Transition https://www.youtube.com/watch?v=25bmXpEPosc

Sustainability explained https://www.youtube.com/watch?v=_5r4loXPyx8

Handing on a sustainable futurehttps://www.youtube.com/watch?v=xrXyRJV96mk

UNIT 1
MODULE 2: THEORETICAL FRAMEWORK OF GREEN ENGINEERING

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand the principles of Green Engineering and the supporting mechanisms/technologies and guidelines;
2. understand the principles of Industrial Ecology;
3. appreciate the interrelationship between Green Engineering and Industrial Ecology; and,
4. be aware of technologies, guidelines and mechanisms for collaborative design and product lifecycle management.

Please note, that where possible, laboratory-based exercises should be undertaken.

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Principles of Green Engineering	
1. discuss the principles of Green Engineering;	(a) Inherent rather than circumstantial. (b) Prevention instead of treatment. (c) Design for separation. (d) Maximise efficiency. (e) Output-Pulled versus Input-Pushed. (f) Conserve complexity. (g) Durability rather than immortality. (h) Meet need, minimise excess. (i) Minimise material diversity. (j) Integrate material and energy flows. (k) Design for commercial "Afterlife". (l) Renewable rather than depleting.

UNIT 1
MODULE 2: THEORETICAL FRAMEWORK OF GREEN ENGINEERING (cont'd)

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Principles Of Green Engineering (cont'd)	
2. relate each principle to real life scenario;	
Supporting Green Engineering Mechanisms/Technologies and Guidelines	
3. describe supporting mechanisms, technologies and guidelines;	Environmental management systems technologies and guidelines including ISO 14000 family of standards particularly 14040 and 14044, American Standard for Testing Materials (ASTM), Sustainable Assessment Tools (including: LEED, Breeam, EMAS, Green Star).
4. distinguish among management systems, technologies and guidelines;	
Principles of Industrial Ecology	
5. explain the principles of Industrial Ecology;	(a) Definition of the concept of Industrial Ecology. (b) Principles: (i) create industrial ecosystems; (ii) balance industrial inputs and outputs to natural levels and capacity; (iii) dematerialisation of industrial output; (iv) improve the efficiency of industrial processes; and, (v) energy use. (c) Align policies with the Industrial Ecology concept.

UNIT 1
MODULE 2: THEORETICAL FRAMEWORK OF GREEN ENGINEERING (cont'd)

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
6. identify the opportunities for integration of processes and material flows during the product design phase;	Such as energy and material recovery, and reuse.
7. discuss the benefits and limitations of integration of processes and material flows during the product design phase;	Benefits: (a) cost savings; (b) improve environmental protection; (c) material savings; (d) income generation; (e) enhance corporate image; (f) improve relation with other industries and organisations; and, (g) market advantages. Limitations: (a) no market for materials; (b) lack of support from government and industry; (c) reluctance of industry to invest in appropriate technology; (d) legal implication; and, (e) reluctance to move to another supplier.
8. discuss the inter-relationship between Green Engineering and Industrial Ecology;	Concept of efficiency, energy use, waste management, balance input and output of energy and material.
Technologies For Collaborative Design and Product Lifecycle Management	
9. examine types of software used to simulate product features; and,	Including MATLAB, AutoCAD, Simulink, Labview, GEO 5, Slope 5, STAAD PRO, Finite Elements and Athena.
10. justify the use of each software.	Description and application of software listed.

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives in this Module, teachers are advised to engage students in the following teaching and learning activities.

1. Conduct research on the principles of Green Engineering and Industrial Ecology.

2. Invite guest lecturers with knowledge of environmental management systems, technologies and guidelines including ISO 14000 family of standards particularly 14040 and 14044, and ASTM standards.

3. Use ICT to demonstrate simulations for the collaborative design and product lifecycle management.

4. Organise field trip to an ISO accredited organisation or a LEED accredited infrastructure.

5. Organise field trip to an organisation that upholds the Principles of Green Engineering and/or Industrial Ecology.

6. Assess the engineering infrastructure in their immediate environment for the Principles of Green Engineering and Industrial Ecology.

7. Conduct lectures/discussions on theoretical aspects of Green Engineering and Industrial Ecology.

RESOURCES

Allen, D. T. and Shonnard D. R.	*Green Engineering: Environmentally Conscious Design of Chemical Processes*. New Jersey: Prentice Hall Incorporated, 2001.
Allenby, Braden R.	'Achieving Sustainable Development through Industrial Ecology'. *International Environmental Affairs* 4(1): 56-68.
Cote, R.P. and Cohen-Rosenthal, E.	'Designing eco-industrial parks: a synthesis of some experiences'. *J. Cleaner Production* (1998) 6: 181-188.
Ehrenfeld, J. and Gertler, N.	'Industrial Ecology in Practice: The Evolution of Interdependence at Kalundborg'. *Journal of Industrial Ecology* (1997) 1(1): 67-79.
Goldman, D.	*Ecological Intelligence*. Broadway: New York Books, 2009.
Henrickson, C.; et. al.	'Economic Input-Output Models for Environmental Life-Cycle Assessment'. *Environmental Sci. & Tech.*, (1998) 32: 184A-191A.
Jelinski, L.W., Graedel, T.E., Laudise, R.A., McCall, W., Patel, C. and Kumar N.	'Industrial Ecology: Concepts and Approaches, Proceedings'. *National Academy of Sciences*, USA 89 (February 1992): pp. 793-797.

Hunt, R. G., Sellers J. D., and Franklin, W.E.	'Resource and Environmental Profile Analysis: A Life Cycle Environmental Assessment for Products and Procedures'. *Environmental Impact Assessment Review*, Spring (1992): pp. 245-269.
Iwaro, J., Mwasha, A. Williams, R.G., and Zico R.	'An Integrated Criteria Weighting Framework for the sustainable performance assessment and design of building envelope'. *Renewable and Sustainable Energy Reviews* 29, 417-434.
McKibben, B.	*Eaarth: Making a Life on a Tough New Planet*. New York: St Martin's Griffin, 2011.
Sarte, B.	*Sustainable Infrastructure: The Guide to Green Engineering and Design*. New Jersey: John Wiley & Sons, Inc, 2010.
Wallace, B.	*Becoming Part of the Solution: The Engineer's Guide to Sustainable Development*. American Council of Engineering Companies, 2005.
Zimmerman, J. and Anastas, P.	*Innovations in Green Chemistry and Green Engineering*. New York: Springer, 2013.

ISO 14040 International Standard, Environmental management – Life cycle assessment – Principles and framework, 1997-06-15.

The Brundtland Commission and Herman E. Daly http://acwi.gov/swrr/whatis-sustainability-wide.pdf

Suggested video clip

Biomimicry: 12 sustainable design ideas from nature
https://www.youtube.com/watch?v=n77BfxnVlyc

UNIT 1
MODULE 3: GREEN ENGINEERING IN PRACTICE

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand sustainability issues related to the product design;
2. appreciate the types of materials and the forms of energy utilised for the product design;
3. understand the components of product design; and,
4. be cognisant of legislation, guidelines/standards and principles utilised for product or infrastructure design and policies that enable or constrain the commercialisation of the product.

Please note that some examples of case studies for this Module can be found on pages 38–54. Other case studies may include solar panels used in Barbados and hydroelectric plants in Jamaica. Importantly, a minimum of three case studies should be reviewed.

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
1. assess sustainability issues outlined by the design in case studies;	Sustainability issues including: cost (inefficiency and efficiency), performance, resource (inefficiency and efficiency), waste minimisation and utilisation, level of social responsibility.
2. identify the types of materials utilised in the product or infrastructure design in case studies;	Renewable, non-renewable, organic, inorganic (including ceramic, metallic, non-metallic and composites).
3. perform calculations relevant to the design process;	Energy, material properties (including strength, thermal properties, acoustic, light), loading.
4. justify the choice of materials in case studies;	Affordability, availability, accessibility, reusability, utility, environmental soundness, social acceptability.
5. list the type(s) and form(s) of energy utilised in the product or infrastructure design in case studies;	Renewable, non-renewable.

UNIT 1
MODULE 3: GREEN ENGINEERING IN PRACTICE (cont'd)

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
6. investigate related principles and processes relevant to case studies used;	For example, measuring voltage and current from a small solar panel at different times of the day; generation of biogas using different substrates; testing the properties of the materials.
7. justify the selection of the type and form of energy used in the product or infrastructure design in case studies;	Affordability, availability, accessibility, reusability, utility, impact on the health of the environment, social acceptability.
8. indicate the specific guidelines/ standards and principles followed in the product or infrastructure design in case studies; and,	ISO 9000, ISO 14000, ISO 26000, Principles of Green Engineering and Industrial Ecology.
9. identify the specific legislation that enables or constrains the commercialisation of the product or infrastructure in case studies.	ASHRAE and any existing national legislation.

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives in this Module, teachers are advised to engage students in the following teaching and learning activities.

1. Organise debates or panel discussions on the issues highlighted in case studies.
2. Conduct lecture/discussion on issues highlighted in case studies.
3. Encourage students to write a short reflection on each case study.
4. Conduct research on similar case studies from different climatic zones around the world.

UNIT 1
MODULE 3: GREEN ENGINEERING IN PRACTICE (cont'd)

RESOURCES

Allen, D. T. and Shonnard, D. R. — *Green Engineering: Environmentally Conscious Design of Chemical Processes*. New Jersey: Prentice Hall Incorporated, 2001.

Goldman, D.l — *Ecological Intelligence*. Broadway: New York Books, 2009.

McKibben, B. — *Eaarth: Making a Life on a Tough New Planet*. New York: St Martin's Griffin, 2011.

Mwasha, A. and Maharaj, D. — An analysis of the effect of temperature on the pattern of wind energy distribution in the Caribbean region http://www.wudpeckerresearchjournals.org/JESWR/pdf/2012/August/Mwasha%20and%20Maharaj.pdf

Sarte, B. — *Sustainable Infrastructure: The Guide to Green Engineering and Design*. New Jersey: John Wiley & Sons, Inc, 2010.

Wallace, B. — *Becoming Part of the Solution: The Engineer's Guide to Sustainable Development*. American Council of Engineering Companies, 2005.

Zimmerma, J. and Anastas, P. — *Innovations in Green Chemistry and Green Engineering*. New York: Springer, 2013.

A New Paradigm for Caribbean Development, Transitioning to a Green Economy. Caribbean Development Bank 2014.

The Brundtland Commission and Herman E. Daly http://acwi.gov/swrr/whatis-sustainability-wide.pdf

Prof. Satish V. Kailas, Material Science – Specific Objective 12
http://nptel.iitk.ac.in/courses/Webcourse-contents/IIScBANG/Material%20Science/pdf/Module18.pdf

Zimmerman, J; Anastas, P; Case Studies Illustrating the Twelve Principles of Green Engineering, http://www.thesustainabilitysociety.org.nz/conference/2004/Session5/68%20Zimmerman.pdf

♦ UNIT 2: APPLICATION OF GREEN ENGINEERING PRINCIPLES

MODULE 1: UTILISATION OF SUSTAINABLE MATERIALS AND ENERGY

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand the sustainable utilisation of materials and energy;
2. comprehend the utilisation of different sources of energy;
3. understand the environmental consequences of the utilisation of different energy sources;
4. understand the different types of organic and inorganic materials;
5. appreciate the role of entropy in the manufacturing process; and,
6. appreciate the role of policies and decision making in the manufacturing process.

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
The Sustainable Utilisation of Materials and Energy	
1. discuss the importance of selecting the appropriate materials;	Materials in 4 states of matter: (a) solid; (b) liquid; (c) gas; and, (d) plasma
2. justify the utilisation of materials in particular states;	Affordability, availability, accessibility, reusability, utility, environmental soundness, social acceptability.
3. discuss the importance of selecting the appropriate energy sources;	Energy sources, including fossil fuel, water, solar, wind, bio energy and geothermal.
4. justify the utilisation of energy sources;	Affordability, availability, accessibility, reusability, utility, environmental soundness, social acceptability.
5. evaluate the environmental consequences of utilising different energy sources;	Waste generation, pollution, resource consumption, hazards and risks.

UNIT 2
MODULE 1: UTILISATION OF SUSTAINABLE MATERIALS AND ENERGY (cont'd)

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
The Sustainable Utilisation of Materials and Energy	
6. categorise the different types of organic and inorganic materials;	(a) Organic including bio polymer and synthetic polymer. (b) Inorganic including ceramic, metallic, non-metallic and composites. (c) Introduction to nano materials and their applications.
7. differentiate inorganic and organic materials;	(a) Properties and basic structure of inorganic and organic materials. (b) Limited life materials.
8. conduct experiments to determine the physical, chemical and mechanical properties of materials;	For example, corrosion, temperature deformation, conductivity (electrical and thermal) and combustibility.
The role of Entropy	
9. discuss the laws of thermodynamics;	Brief discussion on the 1st and 2nd Laws of Thermodynamics (basic calculations required). Latent heat of phase transition.
10. discuss the concepts of entropy and enthalpy;	Brief discussion on the role of entropy in the production process.
11. conduct experiments to demonstrate the concepts of entropy and enthalpy;	For example, converting ice to steam and then reverse the process.
12. relate embodied energy to the manufacturing and construction processes; and,	Minimisation of energy use in the manufacturing process.

UNIT 2
MODULE 1: UTILISATION OF SUSTAINABLE MATERIALS AND ENERGY (cont'd)

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Policy and Decision Making	
13. outline policies and decision making in manufacturing and utilisation of natural resources.	Key elements: (a) rationality; (b) cost; (c) effectiveness; (d) incentives (tax, low interest loans); (e) land administration; (f) public safety; (g) legislation (compulsory and non-compulsory); and, (h) stakeholders' participation.

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives in this Module, teachers are advised to engage students in the following teaching and learning activities.

1. Use ICT (including video clips and websites) to observe the behaviour of materials used for manufacturing and construction.

2. Conduct lecture/discussion on materials and energy used for manufacturing and construction, the development and enforcement of legislation and the implications of these for sustainability.

3. Organise field trips to manufacturing entities and material testing facilities.

4. Invite guest lectures to do presentations on manufacturing and testing processes.

RESOURCES

Allen, D. T. and Shonnard, D. R. — *Green Engineering: Environmentally Conscious Design of Chemical Processes*. New Jersey: Prentice Hall Incorporated, 2001.

Arunaye, F.I., Mwasha A. — 'On behavior of limited life Geotextile materials for reinforcing embankment on soft ground'. *World Journal of Engineering* 8 (2), 195-199.

Goldman, D. — *Ecological Intelligence*. Broadway: New York Books, 2009.

Iwaro J., and Mwasha, A. — 'Towards energy sustainability in the world: the implications of energy subsidy for developing countries'. *International Journal of Energy and Environment* 1 (4), 705-714.

McKibben, B. — *Earth: Making a Life on a Tough New Planet*. New York: St Martin's Griffin, 2011.

Sarte, B. — *Sustainable Infrastructure: The Guide to Green Engineering and Design*. New Jersey: John Wiley & Sons, Inc, 2010.

Wallace, B. — *Becoming Part of the Solution: The Engineer's Guide to Sustainable Development*. American Council of Engineering Companies, 2005.

Zimmerman, J. and Anastas, P — *Innovations in Green Chemistry and Green Engineering*. New York: Springer, 2013.

The Brundtland Commission and Herman E. Daly
http://acwi.gov/swrr/whatis-sustainability-wide.pdf

Center for Sustainable Systems (formerly the National Pollution Prevention Center) http://www.css.snre.umich.edu/

Suggested video clip

Materials and Technologies for a sustainable future
https://www.youtube.com/watch?v=uELKK4oly6I

UNIT 2
MODULE 2: SUSTAINABLE DESIGNS

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand the principles related to product design;
2. appreciate the stages of the product design process;
3. appreciate biomimicry in product design;
4. demonstrate the application of biomimicry in product design; and,
5. appreciate the safety considerations related to product or engineering infrastructure design.

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Principles Related to Designing Products and Infrastructure	
1. explain the principles related to designing products and infrastructure;	(a) Equitable in use. (b) Flexibility in use. (c) Simple and intuitive. (d) Perceptible information. (e) Tolerance for error. (f) Low physical effort. (g) Size and space for approach and use.
2. discuss issues related to water harvesting and purification processes;	(a) The role of STI (Science, Technology and Innovation) in water resource efficiency (including: water harvesting for residential and commercial areas, desalination, filtration, distillation and reverse osmosis, biological and chemical treatments including bio-filtration and anaerobic treatment.

UNIT 2
MODULE 2: SUSTAINABLE DESIGNS (cont'd)

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Principles Related To Designing Products and Infrastructure	
3. discuss issues related to sustainable transportation;	(a) Promotion of energy efficiency and renewable energy (including: electric vehicles, fuel cells, hot air, steam, hydrogen, helium and solar power). (b) Pollution control (catalytic converters, link to carbon footprint).
4. explain the concept of biomimicry;	Description of concept. Innovation inspired by Natural Systems (emulating natural forms, processes and eco systems to create more sustainable designs).
5. discuss the use of biomimicry;	Examples including honeycomb, spiders' web, early warning sounds, termites' nest, plant roots, artificial leaf and locomotion.
Stages of Product Design	
6. discuss the stages of the product design process; and,	(a) Concept development including Life Cycle Assessment (LCA). (b) Product simulation. (c) Prototype development/pilot testing. (d) Product development (relate to LCA). (e) Manufacturing process development. (f) Product testing/evaluation. (g) Product commissioning. (h) Product commercialisation.
7. discuss the inherent safety issues related to the design of products or engineering infrastructure.	Suitable material, processes. Manufacturing/ construction, use and disposal/dismantling of product.

UNIT 2
MODULE 2: SUSTAINABLE DESIGNS (cont'd)

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives in this Module, teachers are advised to engage students in the following teaching and learning activities.

1. Conduct research on biomimicry.
2. Invite guest lecturers to discuss issues related to sustainable designs.
3. Conduct laboratory experiments to determine the suitability of materials or procedures, and the biological treatment of waste water.
4. Use ICT (including video clips and websites) to demonstrate, for example, the suitability of materials or procedure, biological treatment of waste water and biomimicry.
5. Organise field trips to an entity that is involved in product design and/or an infrastructure that utilises biomimicry.

RESOURCES

Allen, D. T. and Shonnard D.R.	*Green Engineering: Environmentally Conscious Design of Chemical Processes*. New Jersey: Prentice Hall Incorporated, 2001.
Benyus, J. M.	*Biomimicry: Innovation Inspired by Nature*. New York: Quill, 1998.
Esty, D. C. and Winston, A.	*Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value, and Build Competitive Advantage*. New Jersey: Wiley, 2009.
Iwaro, J., Mwasha, A., Williams,R.G. and Wilson, W.	'An integrated approach for sustainable design and assessment of residential building envelope: part I'. *International Journal of Low-Carbon Technologies, ctu002.*
Goldman, D.	*Ecological Intelligence*. Broadway: New York Books, 2009.
McKibben, B.	*Eaarth: Making a Life on a Tough New Planet*. New York: St Martin's Griffin, 2011.
Sarte, B.	*Sustainable Infrastructure: The Guide to Green Engineering and Design*. New Jersey: John Wiley & Sons, Inc, 2010.
Wallace, B.	*Becoming Part of the Solution: The Engineer's Guide to Sustainable Development*. American Council of Engineering Companies, 2005.
Zimmerman, J. and Anastas, P.	*Innovations in Green Chemistry and Green Engineering*. New York: Springer, 2013.

The Brundtland Commission and Herman E. Daly
http://acwi.gov/swrr/whatis-sustainability-wide.pdf

Brewing a Sustainable Industry. New Belgium Brewing Company Aims for Zero Emissions.
http://www.terrain.org/articles/9/wann.htm

Suggested video clip
Biomimicry
https://www.youtube.com/watch?v=ZODvr_GzNc4

Life Cycle Assessment as part of Strategic Sustainability for Product Design
https://www.youtube.com/watch?v=fGhoInz-VUs

UNIT 2
MODULE 3: GREEN ENGINEERING SOLUTIONS

GENERAL OBJECTIVES

On completion of this Module, students should:

1. understand issues related to energy efficiencies;
2. be cognisant of mechanisms to improve energy efficiencies;
3. appreciate the utilisation of appropriate materials for the design and construction of a product or engineering infrastructure; and,
4. design and create a specific product or engineering infrastructure to address sustainability.

Please note that the activities for Specific Objectives 5, 6 and 7 are the requirements for the School-Based Assessment (SBA).

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Efficient Utilisation of Energy and Materials	
1. propose solutions to inefficiencies related to energy utilisation within the engineering infrastructure and/or product;	Solutions include passive cooling and lighting; thermal resistivity (R); the material used and the source of lighting (natural and artificial); building orientation; location and elevation. Include green walls, hanging gardens, landscape engineering, social and cultural aspects.
2. evaluate proposed solutions to energy inefficiencies;	Cost effectiveness, availability, accessibility and affordability of the technology.
3. propose the appropriate materials to be utilised in the engineering infrastructure and/or product;	Cost effectiveness, availability, accessibility and affordability of the material, carbon footprint, toxicity, durability.
4. justify the selection of appropriate materials utilised in the engineering infrastructure and/or product;	Cost effectiveness, properties, toxicity, availability and accessibility of the material.

UNIT 2
MODULE 3: GREEN ENGINEERING SOLUTIONS (cont'd)

SPECIFIC OBJECTIVES	CONTENT
Students should be able to:	
Design and Construction of a Proposed Solution	
5. design a product or engineering infrastructure based on specific conditions;	(a) Properties of different material. (b) Material behaviour under different conditions.
6. justify the design from a Green Engineering perspective;	
7. construct a model that encapsulates the product design process; and,	
8. discuss the occupational health and safety issues related to the manufacturing of products and construction of engineering infrastructure.	Safe handling of tools, equipment and material.

Suggested Teaching and Learning Activities

To facilitate students' attainment of the objectives in this Module, teachers are advised to engage students in the following teaching and learning activities.

1. Conduct research on the product or infrastructure design process.
2. Conduct laboratory sessions to test physical properties of selected materials.
3. Use ICT including video clips and simulation to support students' presentation.

RESOURCES

Allen, D.T. and Shonnard D. R.	*Green Engineering: Environmentally Conscious Design of Chemical Processes.* New Jersey: Prentice Hall Incorporated, 2001.
Goldman, D.	*Ecological Intelligence.* Broadway: New York Books, 2009.
McKibben, B.	*Eaarth: Making a Life on a Tough New Planet.* New York: St Martin's Griffin, 2011.
Mwasha, A.	*Practical Guide to Green Technology for Ground Engineering.* Shawbury, Shrewsbury, UK : Smithers Rapra, 2011.
Sarte, B.	*Sustainable Infrastructure: The Guide to Green Engineering and Design.* New Jersey: John Wiley & Sons, Inc, 2010.
Wallace, B.	*Becoming Part of the Solution: The Engineer's Guide to Sustainable Development.* American Council of Engineering Companies, 2005.
Zimmerman, J. and Anastas, P.	*Innovations in Green Chemistry and Green Engineering.* New York: Springer, 2013.

The Brundtland Commission and Herman E. Daly
http://acwi.gov/swrr/whatis-sustainability-wide.pdf

Suggested Video Clips

How to reuse, reduce, recycle in your everyday life!
https://www.youtube.com/watch?v=BaAnfy9ueeQ

Product design advice to students
https://www.youtube.com/watch?v=acXHSTU2-2I

♦ OUTLINE OF ASSESSMENT

Each Unit will be assessed separately. The scheme of assessment for each Unit will be the same. A candidate's performance on each Unit will be reported as an overall grade as well as a grade on each Module of the Unit. Grades will be awarded independently for each Unit. The assessment will comprise two components, external and internal (School-Based Assessment).

(70 per cent)

EXTERNAL ASSESSMENT

Paper 01 (1 hour 30 minutes)	The paper *comprises forty-five* compulsory, *multiple-choice items, fifteen based on each* Module.	(30%)
Paper 02 (2 hours 30 minutes)	The paper *comprises six compulsory* questions, *two based on* each Module.	(40%)

SCHOOL-BASED ASSESSMENT (SBA) FOR EACH UNIT **(30 per cent)**

Paper 031

The School-Based Assessment in respect of each Unit will contribute 30 per cent to the total assessment of a candidate's performance on that Unit. Students are encouraged to work in groups.

UNIT 1

The assessment for Unit 1 will be in the form of a report. The report should be based on an industry or an engineering infrastructure such as buildings, roads and bridges in the student's territory. It should examine sustainability issues such as conservation and efficiency and provide recommendations for improvement. The report should reflect the specific objectives from each of the three Modules in the Unit and incorporate the relevant writing skills.

UNIT 2

The design project requirements identified in Module 3 at Specific Objectives 5, 6, and 7 will form the basis for the SBA. The project will consist of a written design report and a scaled model that is representative of the product. This model should be made from readily available materials. The design project should be based on a problem that has been identified. It should seek to solve that problem by creating a product following the stages of the design process. The design project should reflect the specific objectives from each of the three Modules in the Unit and incorporate the relevant writing and psychomotor skills.

Paper 032

Private candidates are required to write an Alternative paper – Paper 032. Details are on page 58.

MODERATION OF THE SCHOOL-BASED ASSESSMENT

All School-Based Assessment Record of Marks must be submitted online using the SBA data capture module of the Online Registration System (ORS). A sample of assignments will be requested by **CXC®** for moderation purposes. These samples will be re-assessed by **CXC®** Examiners who moderate the School-Based Assessment. Teachers' marks may be adjusted as a result of moderation. The Examiners' comments will be sent to schools.

Copies of the students' assignments that are not submitted must be retained by the school until three months after publication by **CXC®** of the examination results.

ASSESSMENT DETAILS

External Assessment by Written Papers (70% of Total Assessment)

Paper 01 (1 hour 30 minutes – 30 per cent of Total Assessment)

1. Composition of Paper

The paper *comprises forty-five (45) compulsory multiple-choice items, fifteen (15) items based on each Module.*

2. Syllabus Coverage

(a) Knowledge of the entire syllabus is required.

(b) The intention of this paper is to test candidates' knowledge across the breadth of syllabus.

3. Question Type

Questions may be based on diagrams, data, graph, *photographs* or prose.

4. Mark Allocation

(a) One mark will be assigned for each item.
(b) The maximum mark available for this paper is forty-five (45), weighted to ninety (90) marks.
(c) This paper contributes 30 per cent towards the final assessment.
(d) The marks will be awarded for Knowledge and Comprehension, Use of Knowledge, and Practical Ability.

5. Use of Calculators

Candidates will be allowed to use a non-programmable calculator in the examinations. Each candidate is responsible for providing his/her own calculator and to ensure that it functions throughout the examinations.

Paper 02 (2 hours 30 minutes – 40 per cent of Total Assessment)

1. Composition of Paper

The paper is arranged into three sections. Each section represents one of the three Modules of the Unit. Each section contains *two compulsory questions.*

2. Syllabus Coverage

(a) Comprehensive knowledge of the entire syllabus is required.
(b) Each question may focus on a single theme or develop a single theme or several unconnected themes.

3. Question Type

Questions in this paper will focus on higher order thinking skills such as application, analysis, synthesis and evaluation. Questions may be based on diagrams, data, graph, *photographs* or prose. *Responses* are to be written in the *question* booklet in the spaces provided.

4. Mark Allocation

(a) Each question is worth 20 marks and the marks allocated to each sub-question will appear on the examination paper.
(b) The maximum mark for this paper is 120.
(c) This paper contributes 40 per cent towards the final assessment.
(d) The marks will be awarded for Knowledge and Comprehension, Use of Knowledge, and Practical Ability.

5. Use of Calculators

Candidates will be allowed to use a non-programmable calculator in the examinations. Each candidate is responsible for providing his/her own calculator and to ensure that it functions throughout the examinations.

SCHOOL-BASED ASSESSMENT **(30 per cent)**

School-Based Assessment is an integral part of the students' assessment of the course of study covered by this syllabus. It is intended to assist the students in acquiring certain knowledge, skills and attitudes that are associated with the subject. The activities for the School-Based Assessment are linked to the syllabus and should form part of the learning activities to enable the students to achieve the objectives of the syllabus.

During the course of study for the subject, students obtain marks for the competence they develop and demonstrate in undertaking their School-Based Assessment assignments. These marks contribute to the final marks and grades that are awarded to the students for their performance in the examination.

The guidelines provided in this syllabus for selecting appropriate tasks are intended to assist teachers and students in selecting assignments that are valid for the purpose of School-Based Assessment. The guidelines provided for the assessment of these assignments are also intended to assist teachers in awarding marks that are reliable estimates of the achievements of students in the School-Based Assessment component of the course. In order to ensure that the scores awarded are in line with the **CXC®** standards, the Council undertakes the moderation of a sample of the School-Based Assessments marked by each teacher.

School-Based Assessment provides an opportunity to individualise a part of the curriculum to meet the needs of the student. It facilitates feedback to the student at various stages of the experience. This helps to build the self-confidence of the students as they proceed with their studies. School-

Based Assessment also facilitates the development of the critical skills and abilities emphasised by this **CAPE®** subject and enhances the validity of the examination on which the students' performance is reported. The School-Based Assessment, therefore, makes a significant and unique contribution to both the development of the relevant skills and the testing and rewarding of the student.

REQUIREMENTS OF THE SCHOOL-BASED ASSESSMENT

School-Based Assessment marks are NOT transferable across Units. The School-Based Assessment for each Unit is based on skills and competencies related specifically to the Modules of that Unit. However, students who repeat the same Unit in a subsequent sitting may reuse their School-Based Assessment marks.

UNIT 1

Managing the report

The report is worth 30 per cent of the candidate's total mark. Teachers should ensure that sufficient time is allowed for teaching the research skills contained in the Unit, explaining the requirements of the School-Based Assessment, discussing the assessment criteria and monitoring and evaluating the report.

Planning

It is important to start planning for the activities of the SBA component early. Agreed deadlines should be established.

Length of the report

The length of the report should be maximum 1500 words, not including appropriate quotations, sources, charts, graphs, tables, pictures, references and appendices.

Guidance

The teacher is expected to provide guidance at all stages of the report including arranging for visits to industries or engineering infrastructure for the purpose of examining sustainability issues. The teacher should also guide students in selecting the appropriate methodology and data collection technique.

Adequate class time should be allocated to the teaching and reinforcement of key components to be included in the report. The assessment criteria should be discussed with students. The report should reflect the content of the modules. Assessment should be conducted on a continuous basis and feedback given to students for further improvement.

Teachers and students should set agreed deadlines for the submission of the various components of the report.

Authenticity

Teachers should ensure that the report presented is the work of the student or group. This can be achieved by systematic monitoring of student's/group's work throughout the development of the report. This will guard against plagiarism and ensure that the work is the intellectual property of the student/group.

Authenticity can also be ensured by:

1. discussing the report and creating an outline with timelines;

2. offering guidance and timely feedback to students; and,

3. allocating some class time for students to work on the reports.

FORMAT OF THE REPORT

1. Length: maximum 1500 words.

2. Structure: Cover Page (Title, Name, Date); Acknowledgements.

3. Table of Contents:

   (a) Introduction;

   (b) Methodology;

   (c) Analysis and Discussion;

   (d) Recommendations;

   (e) Conclusion;

   (f) References; and,

   (g) Appendices.

Allocation of Marks for the Report

Marks will be allocated according to the following scheme:

Assessment Criteria	**Marks**	
Introduction - Context of appraisal - Overview of the industry or infrastructure - Objectives	 2 1 1	4
Methodology Desk review of available literature, direct observation and key informant interviews: - Detailed description - Vague description Instruments Checklist (created by students)	 (2) 2 1 (4)	8

Assessment Criteria	Marks	
- Includes the 4 – 5 headings - Includes 3 of the headings - Includes 2 of the headings - Includes 1 of the headings Semi-structured interview schedule - 4 – 6 open-ended questions - 1 – 3 open ended questions	4 3 2 1 (2) 2 1	
Analysis and Discussion - Relates to the 5 headings on the checklist - Relates to 4 headings on the checklist - Relates to 3 headings on the checklist - Relates to 2 headings on the checklist - Relates to 1 heading on the checklist	 12 – 14 9 – 11 6 – 8 3 – 5 1 – 2	14
Conclusion - Clear, based on finding(s), valid and related to the purpose of the report - Clear, based on finding(s)	 2 1	2
Recommendation - Very relevant to the issues identified - Somewhat relevant to the issues identified - Barely relevant to the issues identified	 5 – 6 3 – 4 1 – 2	6
Presentation - Excellent presentation using appropriate tools (for example, pictures) with few spelling and grammatical errors - Good presentation using appropriate tools with some spelling and grammatical errors - Satisfactory presentation using appropriate tools with some spelling and grammatical errors	 4 3 1 – 2	4
References - Accurate and consistent use of referencing style	 2	2
Total		40

UNIT 2

Managing the Design Project

The design report and model comprise 30 per cent of the candidate's total mark. Adequate class time should be devoted, therefore, to Module 3 on which the design project is based. Teachers should ensure that: sufficient time is allocated to the design of the solution and creation of the model; the requirements of the School-Based Assessment are explained; the assessment criteria are discussed;

and the project work is monitored and evaluated.

Planning

It is important to start planning for the activities of the SBA component early. Agreed deadlines should be established.

Length of the report

The length of the report should be maximum 1500 words, not including appropriate quotations, sources, charts, graphs, tables, pictures, references and appendices.

Guidance

The teacher is expected to provide guidance at all stages of the design project specifically in formulating an appropriate solution.

Adequate class time should be allocated to the teaching and reinforcement of key components to be included in the design project. The assessment criteria should be discussed with students. The design project should be integrated in the teaching of the subject; assessment should be conducted on a continuous basis; and feedback should be given to students for further improvement.

Teachers and students should set agreed deadlines for the submission of the various components of the design project.

Authenticity

Teachers should ensure that the design project presented is the work of the student/group. This can be achieved by systematic monitoring of students' work throughout the development of the design project. This will guard against plagiarism and ensure that the work is the intellectual property of the student/group.

Authenticity can also be ensured by:

1. discussing the design project and creating an outline with timelines;

2. offering guidance and timely feedback to student/group; and,

3. allocating some class time for students to work on the design project.

FORMAT OF THE DESIGN PROJECT

1. Length: maximum 1500 words.

2. Structure: Cover Page (Title, Name, Date); Acknowledgements.

3. Table of Contents:

   (a) Introduction;

   (b) Problem statement;

   (c) Benchmarking;

   (d) Relevance;

   (e) Project plan and research;

   (f) Science Technology Engineering and Mathematics (STEM) linkages;

   (g) Resources needed;

   (h) Method of investigation;

   (i) References; and,

   (j) Appendices.

Allocation of Marks for the Design Project

Marks will be allocated according to the following scheme:

Assessment Criteria	**Marks**	
(A) Project Design		
Introduction - Background of the Project - Objectives	 2 1	3
Design Problem - Clearly articulated - Vaguely articulated	 2 1	2
Relevance - Very Relevant to the problem identified - Very little relevance to the needs of the problem identified	 2 1	2
Creativity and Innovation - Adopt, extend and transform a unique idea, question, format or product to create something new	 3	3

- Experiments with a unique idea, question, format or product - Successfully produces an appropriate idea, question, format or product with minimal changes	2 1	
Application of Principles in Green Engineering and Industrial Ecology - Excellent (clear and thorough) explanation of project challenge, background, and findings - Good explanation of project challenge, background, and findings - Satisfactory explanation of project challenge, background, and findings - Limited explanation of only one or two parts of project challenge, background, and findings -	 4 3 2 1	4
Application of the Design Process - Excellent, clear and thorough identification of project plan, design and implementation process - Very good identification of project plan, design and implementation process - Fairly good identification of project plan, design and implementation process - Limited identification of project plan, design and implementation process	 4 3 2 1	4
STEM Linkages - Good description of how topic relates to STI - Topic linked to STI, however, linkage is poorly described	 2 1	2
Presentation - Excellent presentation using appropriate tools (for example, pictures) with few spelling and grammatical errors. - Good presentation using appropriate tools with some spelling and grammatical errors. - Satisfactory presentation using appropriate tools with some spelling and grammatical errors.	 3 2 1	3
Reference - Accurate and consistent use of referencing style	 2	2
Sub- total Project Design		**25**
(B) Model		
Details of Representation (a) Proportionality (3) - Model constructed with precise accuracy. - Model constructed with accuracy. - Model is still work in progress	 3 2 1	6

(b) Level of details based on design (3) - Model accurately reflects the details of the design. - Model partially reflects the details of the design. - Model barely reflects the details of the design.	3 2 1	
Innovative construction materials, techniques - Exceptionally varied and innovative materials. - Some variety of innovative materials. Some creatively modified recycled materials. - Very few creative materials or modifications	 5 3–4 1–2	5
Model Quality - Extremely meticulous, complete, quality construction that provides excellent details - Complete with some very good details - Appears complete but could use more details - Appears complete but lacks finer details	 4 3 2 1	4
Sub-total Model		**15**
Total		**40**

Marks for the Unit 1 report and the Unit 2 design projects will be allocated across Modules in the ratio 1:1:1. The project will be marked out of a total of 40 marks. The marks earned by a student are assigned to each Module. For example, if a student earns 25 out of 40 for his School-Based Assessment, 25 marks will be assigned to Module 1, 25 marks to Module 2 and 25 marks to Module 3. The total score will be 25+25+25= 75 out of 120.

CASE STUDIES FOR UNIT 1, MODULE 3: GREEN ENGINEERING IN PRACTICE

CASE STUDY 1

THE MANUFACTURING AND THE TYPES OF TRINIDAD'S PORTLAND CEMENT

1.0 Introduction

Prior to 2007, Ordinary Portland Cement (OPC) was the most commonly used cement for general purpose applications. It is commonly used for general construction especially when making different types of concrete including Ordinary, Heavy Weight Concrete, High Strength Concrete, Pervious Concrete, Shortcrete, Self-Compacting Concrete (SCC), Precast and Pre-stressed Concrete. In Trinidad Portland Cement is manufacturing by Trinidad Cement Limited (TCL). The factory is located in Couva, Central Trinidad and Tobago, shown in Figure 1.

Figure 1 - The Location of TCL

1.1 Types of the Portland cement produced by the TCL

Trinidad Cement Limited produces the following types of cement

1. Premium Plus Cement.
2. Ordinary Portland Cement.
3. Type II Cement.
4. Class G HSR Cement.
5. Sulphate Resistant Cement.

1.2 Specification and the standards of the cement produced by the TCL

The TCL cement is specified according to the following standards
EN 197-1: 2000 CEM I 42.5N
TTS 584:2002 OPC
ASTM C 150 TYPE I

2.0 Manufacture of Portland cement

The manufacturing is simple, although high temperatures are involved. Initially chalk and clay are reduced to particle sizes of 75micron or less. The three main processes for manufacturing cement are:

1. wet process;
2. dry process; and,
3. semi-dry process.

2.1 Wet Process

If limestone is used, it is quarried and then crushed in a number of stages. In the final grinding stage the limestone which has been ground to a fine 'flour' consistency in a ball mill is mixed with clay and water. The resultant slurry is then pumped into storage tanks to await further processing. If chalk is used, the chalk and clay are initially broken down separately in wash mills before combining together in specific proportions to be stored as slurry prior to transfer to the kiln.

2.2 Dry Process

In this process, the raw materials are mixed together, dried and reduced in size via grinding to a fine powder, called 'raw meal'. Further blending, mixing and adjustment of the proportions occur in the blending silo using of compressed air. After which it is moved to a storage silo prior to transfer to the kiln.

2.3 Semi-Dry Process

This process is somewhat similar to the dry process. Instead of the blended raw material being transferred to the kiln it is transferred into a 'granulator' (a rotating dish) where water, approximately 12 per cent of meal weight, is added. This leads to the formation of pellets approximately 15mm in diameter. These pellets are then baked hard using pre-heated gases from the kiln prior to transfer into the kiln.

At this point the remaining process is the same for all three types.

The material (slurry or meal) is preheated before entering the kiln. The kiln is an inclined a rotary kiln. These kilns can be up to 7m in diameter and as long as 230m (dependent upon the process), kilns for the dry and semi dry processes are shorter due the smaller amount of water needed to be driven off. The meal or slurry is fed into the upper end of the kiln where, as it moves down the kiln it is heated to progressively higher temperatures, culminating at approximately 1450^{o}C – 1500^{o}C at the lower end.

3.0 Sustainability of the production of OPC

Sustainability of the cement manufacturing process is important to the well-being of our environment, continued growth, and human development. The most energy intensive stage of the Portland cement production is the clinker production stage. It accounts for most of the energy used and nearly all of the greenhouse gases (GHGs) released during cement production. Kiln systems evaporate inherent water from the raw meal and calcine the carbonate constituents during clinker pre-processing stage.

The production of one tonne of Portland cement produces about one tonne of CO_2 and other GHGs.

The significant amount of CO_2 is produced during the calcination process.

Sources of CO_2 and GHG emissions in the manufacturing of Portland cement are:

1. from calcinations of limestone and clay = ± 50 –55%;
2. from fuel combustion = ± 40 –50%; and,
3. from use of electric power = ± 0 –10%.

Limestone + Silica = Portland cement + carbon dioxide

(1450°C)
$5CaCO_3 + 2SiO_2$ $(3CaO.SiO_2)$ $(2CaO.SiO_2) + 5CO_2$

a. The approximate % Composition of Ordinary Concrete

COMPONENT NAME	%
Tri-calcium silicate C_3S	15-25
Di-calcium silicate C_2S	75-85
Tetra-calcium-alumino-Ferrite C_4AF	10-15
Calcium sulphate	1-4
Tri-calcium Aluminate C_3A	7-10
Calcium Carbonate	0-5
Magnesium Oxide	0-3
Calcium Oxide	0-1
Chromates	0-0.005

4.0 Recommended Applications of different types of Cement manufactured by the TCL

All general purposes: Driveways, pavements and sidewalks, reinforced concrete buildings, bridges, railway structures, tanks, reservoirs, culverts, precast concrete products, pipes and masonry units. TCL claims that they are committed to the preservation of the environment and demonstrates this through their operating procedures. As such they have implemented the **ISO 14001:2004 Standard,** an Environmental Management System, to which TCL has been certified in 2006.

4.1 Premium Plus Cement (Type IP) (Pozzolanic Cement)

In order to reduce the energy consumption as well as the greenhouse gas emissions, The Premium Plus cement was launched in 2009. The Premium Plus cement is a typical cement replacement or Pozzolanic admixtures or 'pozzolans', which contain reactive silica (SiO_2), and sometimes also reactive alumina (Al_2O_3). This product is a direct result of our commitment to continuous improvement and environmental responsibility. In fact, Premium Plus allowed TCL to significantly reduce the level of greenhouse gas emissions into the atmosphere, thereby reducing their carbon footprint. This cement

also gives the building community an eco-efficient cement option enabling them to “go green”. Premium Plus cement is manufactured to the following Standards: ASTM C 595 TYPE IPEN 197-1: 2000 CEM II/ B-P 42.5 N. Pozzolanic cement is usually known as cement replacement.

4.1.1 Cement replacement

Cement replacement or Pozzolanic admixtures or ‘pozzolans’, contain reactive silica (SiO_2), and sometimes also reactive alumina (Al_2O_3), which, in the presence of water, react with lime ($Ca(OH)_2$) to form a gel of calcium silicate hydrate (CSH gel) similar to that produced by the hydration of Portland cement.

Generally, the pozzolans may be subdivided into natural and by-product materials. The former are naturally occurring materials, and their processing is usually limited to crushing, grinding and sieving.

Such materials include:

1. Natural pozzolans

    (a) Volcanic ashes and lava deposits (for example, volcanic glasses and volcanic tuffs).

    (b) Diatomaceous earth, that is, an earth which is mainly composed of the silicious skeletons of diatoms deposited from either fresh or sea water.

2. By-product materials including industrial wastes. The most common materials in this group are:

    (a) pulverised fly-ash (PFA); and,

    (b) condensed silica fume (CSF).

4.1.2 Some of the benefits of Premium Plus cement include:

1. reduced carbon footprint;
2. decreased permeability;
3. greater durability and longevity;
4. improved workability (ease of use); and,
5. reduced risk of thermal cracking and also facilitates a smoother, harder finish.

4.1.3 The Recommended Applications of Premium Plus cement are:

All general purposes: driveways, pavements and sidewalks, reinforced concrete buildings, bridges, railway structures, tanks, reservoirs, culverts, water pipes and masonry units.

5.0 The composition and the Hydration process of OPC

5.1 The composition of the Portland cement

Four main compounds of Ordinary Portland cement.

1. *Tricalcium silicate* C_3S
2. *Dicalcium silicate* C_2S
3. *Tricalcium aluminate* C_3A
4. *Tricalcium aluminoferrite* C_4AF

5.2 The hydration process of the Portland cement

On mixing these compounds with water (H_2O) the following reaction known as "HYDRATION" takes place.

C_2S
$C_3S + H_2O = CSH + Ca(OH)_2$
C_3A
C_4AF

The result of hydration is a glue like substance known as Calcium Silicate Hydrate (CSH) and relatively weak bonding materials known as calcium hydroxide ($Ca(OH)_2$) are produced.

5.1 The effect of Pozzolanic material on OPC

$Ca(OH)_2 + (SiO2)/(Al_2O_3)_+ H_2O == CSH$

CSH Calcium Silicate Hydrate

*The reaction can be more complicated and balanced as shown below.

Pozzolanic reaction is acid-base reaction between calcium hydroxide (Portlandite), or ($Ca(OH)_2$), and silicic acid (H_4SiO_4)
$Ca(OH)_2 + H_4SiO_4 \text{ —> } Ca^{2+} + H_2SiO_4^{2-} + 2\ H2O \text{ —> } CaH_2SiO_4 \cdot 2\ H_2O$

Please NOTE: *The students are not required to memorise these equations.

6.0 Quality management and health and safety on using Portland cement

TCL states that quality is at the forefront of their business. Having been in the business of building a region for close to 60 years, they have learnt a thing or two about consistently manufacturing quality products. Their products have been used successfully in the building of; homes, schools, hospitals and bridges throughout Trinidad and Tobago and the Caribbean region for decades. TCL continues to be the brand of choice for users when it comes to making decisions on sheltering their families and loved ones. TCL's products have stood the test of time, not by chance, but simply because of the due

attention and care taken in the management of their systems, processes and raw materials. Their laboratory, LAS-003, was deemed an accredited laboratory on 2 November 2011 by the local accreditation body, TTLABS. This certifies that their laboratory fulfils the requirements of the ISO/IEC 17025:2005 Standard for physical testing, namely ASTM C109 and ASTM C191. A significant aspect of being an accredited laboratory is a thorough and continuous evaluation of the laboratory's Quality Management System against the ISO/IEC 17025 Standard for compliance in both Management and Technical criteria. Therefore, the products offered will meet or exceed local and international standards.

6.1 Dust Screens

Dust is screened by the use of a piece of equipment called the DustBoss which uses a high-pressure system to create an ultrafine mist of water which attracts dust particles, resulting in agglomerated particles falling to the ground or back onto the stockpile.

Potential Health Effects

Inhalation (Acute)
Breathing cement dust may cause nose, throat or lung irritation and choking. The severity of the effects depends on the degree of exposure.

Inhalation (Chronic)
Prolonged or repeated exposure may cause lung injury including silicosis. The product may contain crystalline silica, which is classified as a human carcinogen. Long term exposure resulting in silicosis may also lead to other health problems.

Eye Contact
The cement dust may cause eye irritation, severe burns and damage to the cornea.

Skin Contact
It may also cause dry skin, redness, discomfort, irritation, severe burns, allergic reactions and thickening of the skin (scleroderma).

Ingestion:
Ingestion of large amounts may cause intestinal distress.

6.2 First Aid measures

Inhalation
Move the individual to fresh air and seek medical attention.
Eye Contact
Thoroughly rinse the eyes with water. Seek medical attention for any abrasions.

Skin Contact
Wash the area with soap and water. Seek medical attention for burns. Use moisturising creams for irritation.

Ingestion
DO NOT INDUCE VOMITING. Drink plenty water. Seek medical attention.

6.3 Exposure control and personal protection

Engineering Controls
Use exhaust ventilation to maintain dust levels below the safe exposure limits in workspaces with poor ventilation and dusty conditions.

Personal Protection

Respiratory Protection
Under normal conditions no respiratory protection is required. Should a respirator be required a NIOSH approved respirator is recommended.

Eye Protection
Use tight fitting goggles/glasses in dusty environment to prevent dust contact with the eyes. Contact lenses are not recommended.

Skin Protection
Use impervious, abrasion and alkali-resistant gloves, shoes and protective clothing to prevent skin contact. Barrier creams could also be used. After working with the product workers should shower with soap and water.

6.4 Reduction of pollution

Figure 2-Trapping of dust and prevention of dust escaping into the outside environment.

Figure 3-Trapping of dust and prevention of dust escaping into the outside environment.

Figure 4-Guzzler in action at TCL

The "GUZZLER" is a VACCUM TRUCK which aids in effectively and efficiently cleaning spilled material which is then recycled back into our manufacturing process. This serves to significantly reduce particulate emissions which would otherwise have resulted from conventional cleaning methods.

Figure 5-Water run-off to suspend the solids

Water run-off from the plant is channelled through the settling ponds before exiting the compound. This allows for suspended solids to settle off and thus reduces the level of Total Suspended Solids in effluent.

Figure 6-Settling pond at TCL

A Closed Circuit Water Management system is utilised at our Mayo Quarry facility whereby all waste water is recovered and reused in the process. Thereby, resources are managed, wastage is reduced, pollution is prevented.

CASE STUDY 2

Demerara Distillers Limited

The story of Demerara Distillers Limited (DDL) began in 1670 when every sugar estate had its own rum still, and a group of sugar cane producers formed an exporting co-operative. The rum was produced mainly for use of the sailors of those days. In the seventeenth and eighteenth centuries, there were over 200 small distilleries operating in Guyana. Since each sugar plantation had its own distillery producing blends that were unique to each (Ref). These distilleries were eventually consolidated and in the early 1990s only three distilleries remained all, at Enmore, Uitvlugt and Diamond Sugar Estates under the ownership of Demerara Distillery Limited. These three distilleries were further consolidated at the Diamond location. Interestingly the unique stills and fermentation practices for some of the unique alcohols were relocated to Diamond so as to retain the access of these special spirits so vital for the manufacture of the world acclaimed blends of rum. In addition to these special spirits DDL has invested heavily into new production facilities and quality management.

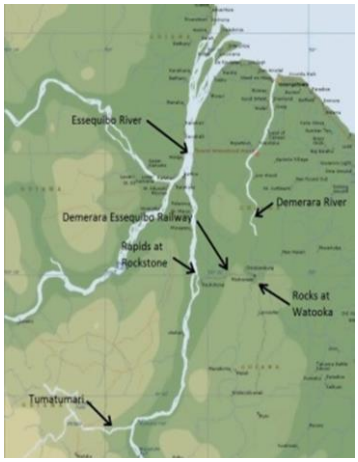


Figure 1-Location of the Estates

The Diamond Distillery has the capacity to produce in excess of 26 M litres of pure alcohol annually, and is the largest supplier of bulk rums and alcohols from the Caribbean to brand owners in Europe and North America. The company's impressive list of clientele includes companies such as Diageo, Jim Beam Brands, Hiram Walker, Allied Distillers, and Corby's.

In addition to the manufacture of spirits DDL is also one of the leading manufacturers of non-alcoholic beverages such as soft drinks and fruit juices.

The process of alcohol production can be divided into fermentation, distillation and blending (including aging). The fermentation and distillation is done at the distillery. These processes are very complex and lend themselves to many issues which can have significant negative environmental impacts if ignored. Over the years DDL has shown an increasing sense environmental responsibility; which led to the increased efficient use of the input materials, by-products/waste and energy utilisation.

One of the main reasons for the construction of a distillery on the sugar estates in ancient times was to utilise the blackstrap molasses which was produced in very large quantities as the main by-product of the sugar manufacturing process. This molasses is the essential feedstock for the fermentation process to produce ethanol the main components of all rums and other strong alcoholic beverages. Fermentation converts the sugar in the molasses to ethanol and carbon dioxide.

$C_{12}H_{22}O_{11} + H_20 \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$
Sucrose Water Glucose Fructose

$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow 4C_2H_5OH + 4CO_2$
Glucose Fructose Ethanol Carbon Dioxide

The ethanol is removed from the fermentation mixture by fractional distillation while the carbon dioxide is captured and processed.

Figure 2-Unique Wooden Still
(http://www.cocktailsoldfashioned.de/2011/02/demerara-distillers-limited-guyana-rum/ (accessed Oct 07, 2014)

The distillation process requires large amounts of heat and produces huge amounts of liquid waste rich in organic material called stillage or vinasse. The improper disposal of this vinasse can have significant negative consequences for the environment especially the waterways. The large amounts of organic material lead to eutrophication and unpleasant odours. To address this vinasse disposal issue DDL has installed a biomethanisation plant which converts the vinasse into biogas which is rich in methane and other combustible gases. Since the biomethanisation process coverts the organic material via bacterial processes the organic load of the vinasse is reduced significantly and the liquid waste is now rendered less harmful to the environment. This waste may now be utilised as an organic fertiliser.

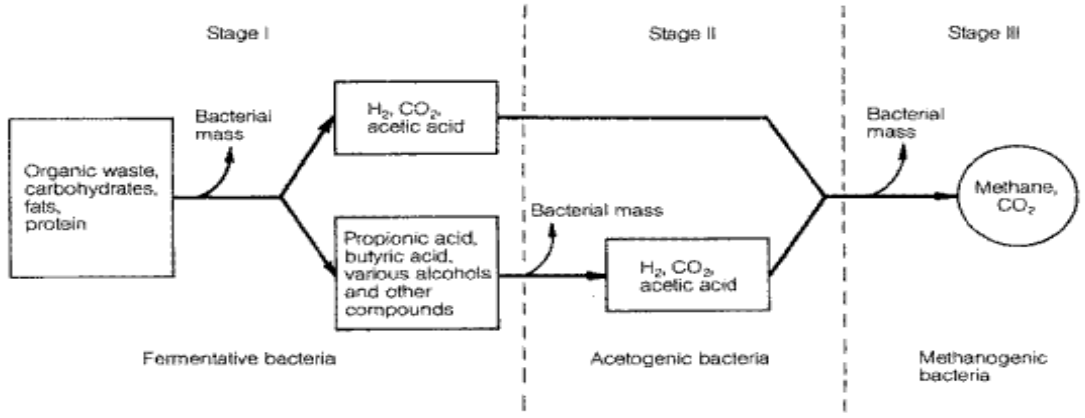


Figure 3-The three-stage anaerobic fermentation of biomass (GTZ project Information and Advisory Service on Appropriate Technology (ISAT)

This biogas, which is a green fuel, is used to fire the boilers to supply the steam required for the distillation process at the distillery. Currently the biomethanisation plant supplies approximately 70 per cent of the fuel utilised by the boilers on a daily basis.

Figure 4-Biomethanisation Plant
(http://www.cocktailsoldfashioned.de/2011/02/demerara-distillers-limited-guyana-rum/
(accessed Oct 07, 2014)

The carbon dioxide captured is processed to remove any entrained alcohol and other organic compounds leaving pure carbon dioxide gas. This purified carbon dioxide gas is cooled liquefied and stored for further use. The major use of the carbon dioxide is in the carbonated beverages manufactured by DDL, therefore DDL produces carbonated beverages with a green source of carbon dioxide. Additionally, a small amount of the carbon dioxide gas is used to manufacture the solid carbon dioxide called dry ice which is used as a cooling agent. Also, many fabrication facilities utilise carbon dioxide gas as the inert gas in the MIG (metal inert gas) welding process. This gas is also used to refill carbon dioxide fire extinguishers.

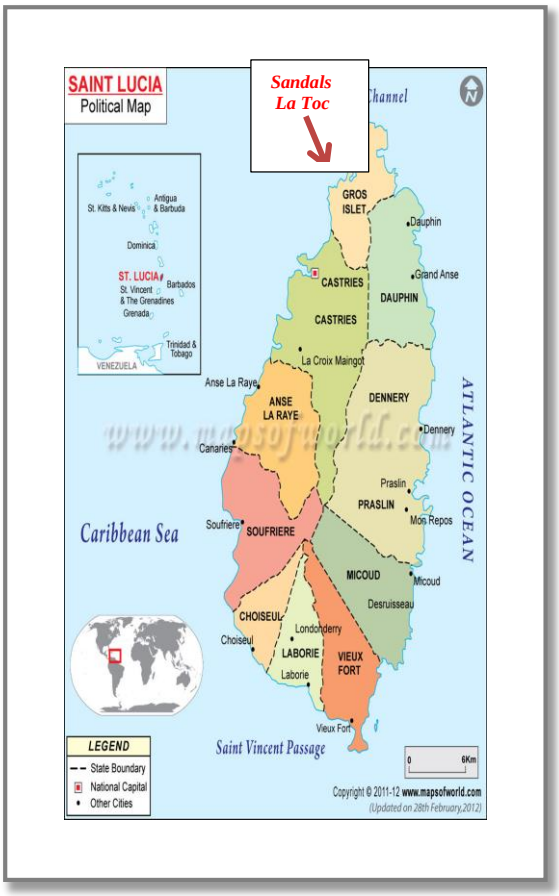
While DDL has moved a long way towards greening its production process it was not without challenges. Some of the major challenges included the high cost to introduce the new technology and infrastructure. There was also the lack of in-house skills. This required that the company investing in training its staff to manage and maintain the equipment and processes. Therefore it can be concluded that DDL has been addressing potential environmental problems by utilising waste materials to manufacture world class spirits and beverages, supplying energy and other useful services to the wider community.

CASE STUDY 3

Sandals La Toc

The utilisation of natural resources in the tourism industry can be categorised in two core groups, construction and operation. The Sandals La Toc is located along St Lucia's north-western coast in a community called La Toc close to the city centre. The area was previously home to forestry, wildlife, and natural minerals before the 220-acre Sandals development.

Sandals La Toc has 331 rooms and four main blocks. It caters to the high-end luxury market and is exclusively a couples resort. The property spreads over 220 acres. The cost of a room ranges from USD 596 to USD 2,923, per day for the millionaire suites. Two other Sandals resorts are located in St Lucia. The Grand has 301 rooms and the Halcyon 169 rooms. The average occupancy of the hotel per year is about 80 per cent. Sandals also has hotels in Jamaica, the Bahamas and Barbados.



Every Sandals Hotel has an Environmental Manager who deals with issues of energy conservation and use. This Manager reports to a regional head and corporate director. The energy director for the chain of hotels is based in Jamaica, and has responsibility for all the hotels and for identifying the opportunities for EE and RE. The Manager analyses business operation across the various territories and identify areas for risk mitigation and energy optimisation to reduce environmental impact. Many external factors can affect decisions on whether to invest in environmental projects. These include the condition of the national and international economy; the price of oil and electricity; and the room occupancy rate. A combination of these factors is used in determining the feasibility of EE and RE projects.

The environmental department has existed at Sandals La Toc for 15 years. The hotel became Green Globe certified in 2003, and is now Platinum Certified with Earth Check, the standard that has replaced Green Globe as the measure of environmental excellence in the hotel industry. Certification must incorporate annual measurement of operational indicators related to energy, emissions, water, waste, community involvement, paper use, cleaning and pesticide use.

Sustainability claims need to be backed by third party verification, undertaken by a suitably qualified auditor. Earth Check Business Planning and Design System measures the following:

1. greenhouse gas emissions;

2. EE, conservation and management;

3. management of social and cultural issues;

4. land-use planning and management;

5. air quality and noise control;

6. waste water management;

7. solid waste management; and,

8. environmentally harmful substances.

The environmental goals are clearly stated in the hotel mission statement and are reinforced in posters and notices throughout the hotel. The hotel also has a large “energy wheel” which can be seen by all the guests. This displays the energy used in the hotel daily, and gives an indication of the target of maximum efficiency.

An energy budget has been allocated to all the hotels. The environmental and maintenance unit in each department is responsible for budget management. The Environmental Manager has an environmental action plan, and is required to identify specific projects to attain energy conservation goals. This is communicated to all department heads. Once the planned activity can be funded by the budget, the project is implemented.

The environmental department has a mandate for energy conservation, and has embarked on a number of projects to enhance EE in lighting and air conditioning. Solar water heating units are used extensively on the property, and the hotel has a programme also aimed at water conservation and waste management.

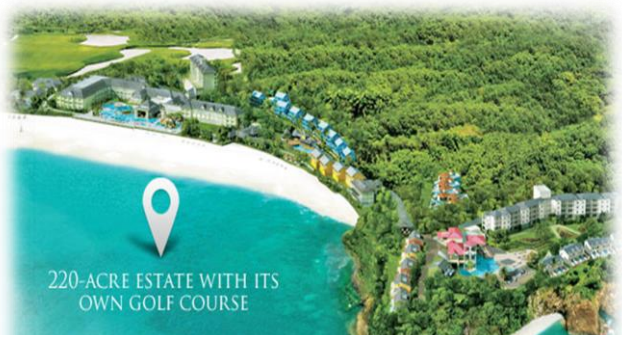
Other EE and conservation projects include an automatic key card that shuts off all appliances and lights when a guest leaves the room. Also, linen reuse cards have been issued to encourage guests to conserve on laundry use.

In the area of RE, there was one pilot project with respect to solar air conditioning. The solar unit was provided by Solar Connections, a local company. It and used solar thermal energy to satisfy 70 per cent of its energy requirements and the national grid to satisfy the remaining 30 per cent.

We will attempt to quantify the environmental impact of a Sandals La Toc which is 70 per cent Renewable Powered and 30 per cent supplied by St Lucia Electric Company Limited. We will proceed by calculating an estimate of the amount of energy the hotel consumes when all rooms are occupied.

The hotel determined that this particular unit was not appropriate as it did not have the potential to reduce energy use significantly enough. Additionally, if the hotel was to adopt these air conditioning units, it would need to install one in each room. This would mean that the hotel would not be able to benefit from economies of scale through use of a centralised system as it currently does.

Number of Rooms = 331
Power Consumed / Room = 3000W
Total Energy Consumed =
No. of Rooms x Power/room
= 331 x 3000W
= 993000W
= 993kW
This electrical energy is consumed each hour therefor will be written as 993kWh
1 barrel of oil (boe) = 1628.2kWh
xboe = 993kWh
1628.2x = 993
x = 993/1628.2
= 0.6099 boe



.`. Sandals La Toc consumes less than 1 barrel of oil / hour. Since there are 24 hours in a given day the total number of barrels of oil consumed per day would be
boe consumed/day = 0.6099 x 24
= 14.64 boe
boe consumed/year = 5,327 boe
Consider 1 boe costs US$100 we can calculate the cost for energy for the year
Cost for oil = 5327*$100
= $532,700

Sandals La Toc would pay USD0.53million per year to purchase power from St Lucia Electric Company Limited for the purchase of oil to supply energy to the facility when it is at full capacity. This does not include cost for energy transmission, inefficient energy generation or energy losses in the distribution process.

An energy audit, undertaken by the hotel in 2005, forms the basis of decisions on EE programmes that have been embarked on since then. The hotel has implemented a significant lighting programme through which 95 per cent of the incandescent lights have been replaced by Light-emitting Diodes (LED) lighting. Additionally, many fixtures were eliminated in areas that were over lit.

The Environmental Manager at the hotel, noted that guests did not necessarily see environmentally friendly hotels as better hotels. There are some clients who value the environmental work; but it is generally not a deal breaker. Sandals, however, recognises the direct financial benefits of being environmentally friendly.

It is apparent that the developments in Sandals La Toc, although spurred by external hotel policy, have much to do with the drive that the Environmental Manager brings personally to environmental management. She came to the hotel having experience in health and safety, but always had a personal interest in the environment, having been involved in environmental clubs at school and university. When speaking of how environmental issues were viewed when she joined the organisation, she recalled that environmental awareness was often seen as a matter of pest control and garbage removal. A lot of staff education was needed.

CASE STUDY 4

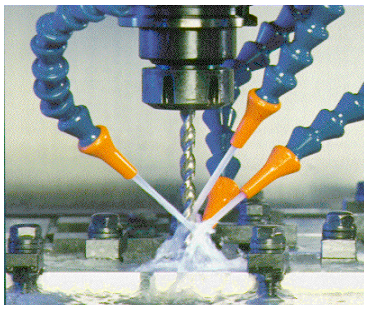
ILLUSTRATING THE TWELVE PRINCIPLES OF GREEN ENGINEERING (*Modified from*: *Julie B. Zimmerman, PhD and* Paul *T. Anastas, PhD)*

http://www.pressreleasefinder.com/primages/CLAPR489a_3848157.jpg

PRODUCT DESIGN

At the inception of the product design process, the designer has the ability to influence the type of materials and energy that will be used, not just in the manufacture of the product, but throughout the lifecycle. By designing products based on inherently benign, renewable materials and energy as described by the Principles of Green Engineering, the designer will also play a significant role in the preventing the exposure of toxic or hazardous materials to the end-user as well as those associated in the manufacture, assembly, distribution, maintenance, or repair of the product. Lifecycle considerations are critical to the implementation of the Principles of Green Engineering in designing products to maximise environmental benefit. A lifecycle approach will also provide an opportunity to highlight any potential trade-offs that arise from applying the Principles to the design of a product for the use phase rather than across the entire product cycle.

The following demonstrates the application of the Principles of Green Engineering to the design of an industrial product, a metalworking fluid, used in machining operations. Metalworking fluids (MWFs) cool and lubricate during metal forming and cutting processes increasing the productivity and quality of manufacturing operations. MWFs represent significant human health and environmental impacts with over two billion gallons sold annually in North America. Given that machining and manufacturing will continue to play a vital role in the global economy for the foreseeable future, the human health and environmental impacts associated with MWFs can be eliminated 1) by discontinuing or limiting the use of metalworking fluids or 2) by designing new MWFs products with improved health and environmental characteristics. Currently, replacing MWF function has proven challenging and dry/damp machining may carry with it negative environmental and economic effects of its own. As such, designing next generation MWFs through the Principles of Green Engineering represents an important opportunity to improve the environmental and health aspects of a widely used and necessary product.



http://www.biodeterioration-control.com/articl2.gif

Four types of MWFs have used in practice to accommodate the differences in severity of various machining operations: straight oils, oil-in-water emulsions (soluble oils, semi-synthetics), and true solutions (synthetics). The emulsifiable MWFs are defined by the ratio of water to oil in the formulation, which represents the balance of cooling to lubrication desired for a given machining process. Given that semi-synthetics account for approximately 40 per cent of the market with continuing increases in market share expected; recently, a semi-synthetic MWF product was designed using an approach consistent with the Principles of Green Engineering. The most significant contributions of this research include the substitution of MWF components with alternatives that are more inherently benign than traditional MWF ingredients and the prevention of premature MWF failure leading to excessive environmental impacts due to frequent MWF disposals.

The new MWF formulations are based on oil and nonionic surfactants that can be produced from renewable, bio-based resources that may be less toxic than traditional emulsion systems. This is based on data for the fathead minnow (*Pimephales promelas*), which indicate that the traditional anionic surfactant has an LC50 of 0.4 mg/L after 48 hours while anionic in the newly designed MWF has an $_{LC50}$ of 14.1 mg/L after 48 hours. By including anionic surfactants in the formulations, the emulsions can be destabilised by the addition of a simple salt, allowing oil separation as well as oil recovery and reuse in the next MWF formulation or for other uses.

In addition, the newly developed MWFs are more hard water stable, a common cause of traditional MWF disposal and subsequent environmental impacts. This stability is achieved by designing the new formulations based on a twin-headed anionic surfactant that has twice as many of moles of anionic head groups to provide electrostatic repulsive, than the traditional surfactant. The improved hardwater stability is achieved even with the removal of two components found in current MWF formulations to improve emulsion stability: ethylenediaminetetraacetic acid (EDTA, $C_{10}H_{16}N_2O_8$), a chelating agent, and butyl carbitol [$C_4H_9(OCH_2CH_2)_2OH$], a coupler. By eliminating these two components from the formulation, the overall life cycle environmental impact is likely to be reduced. In addition, there are concerns specific to the disposal of MWFs containing EDTA since EDTA does not readily biodegrade and once introduced into the general environment, EDTA can remobilise heavy metals allowing heavy metals to re-enter and re-circulate in the food chain. Also EDTA can mobilise heavy metals in tool coatings, providing a route for these metals to enter the environment. For these reasons, the removal of EDTA form MWF formulations would serve well toward the design of greener metalworking fluids.

Before a product can be designed in accordance with the Principles of Green Engineering, a fundamental understanding of the desired characteristics and current performance criteria must be developed. Performance is a critical parameter to consider. If the product designed based on the Principles does not meet or exceed the current performance criteria, it is highly unlikely that the product will realise any human health or environmental benefits since it will not be competitive, and therefore adopted, in the marketplace.

As such, the newly developed MWFs, designed with fewer and benign as well as renewable components, were evaluated for several key performance criteria including hard water stability and machining performance. As shown in Figure 1, when increasing amount of calcium chloride ($CaCl_2$), two commercially available semi-synthetic MWFs (SS1 and SS2) shows a trend of increasing particle size with increasing calcium concentration, behavior indicative of emulsion instability in the presence of hard water. In fact, when 0.008 M of $CaCl_2$ was introduced to SS2, the MWF emulsion was completely destabilised and split into separate oil and water phases. However, in the case of the MWFs designed in accordance with the Principles of Green Engineering, the particle size at 1000 ppm calcium concentration was measured to be statistically identical to the MWF with no calcium present. In other words, the new formulations are stable at hard water concentrations above those expected in the field, demonstrating an improvement in both performance and environmental effects. In addition, the machining performance of the MWFs developed in accordance with the Principles was evaluated and compared to that of commercially available MWFs. As shown in Figure 2, all of the newly developed MWFs had a higher machining efficiency than SS1 or SS2.

The research to design new MWFs based on the Principles resulted in a product that is competitive in terms of machining performance with currently available products. These MWF formulations offer the likelihood of extended lifetime under hard water conditions while utilising more inherently benign and renewable components. Experience has shown that MWF lifetime extension reduces environmental and economic impacts related to MWF production and disposal. This case study provides an example of environmental and economic “win-win” by designing a replacement

product in accordance with the Principles and demonstrating identical or improved performance to currently available products.

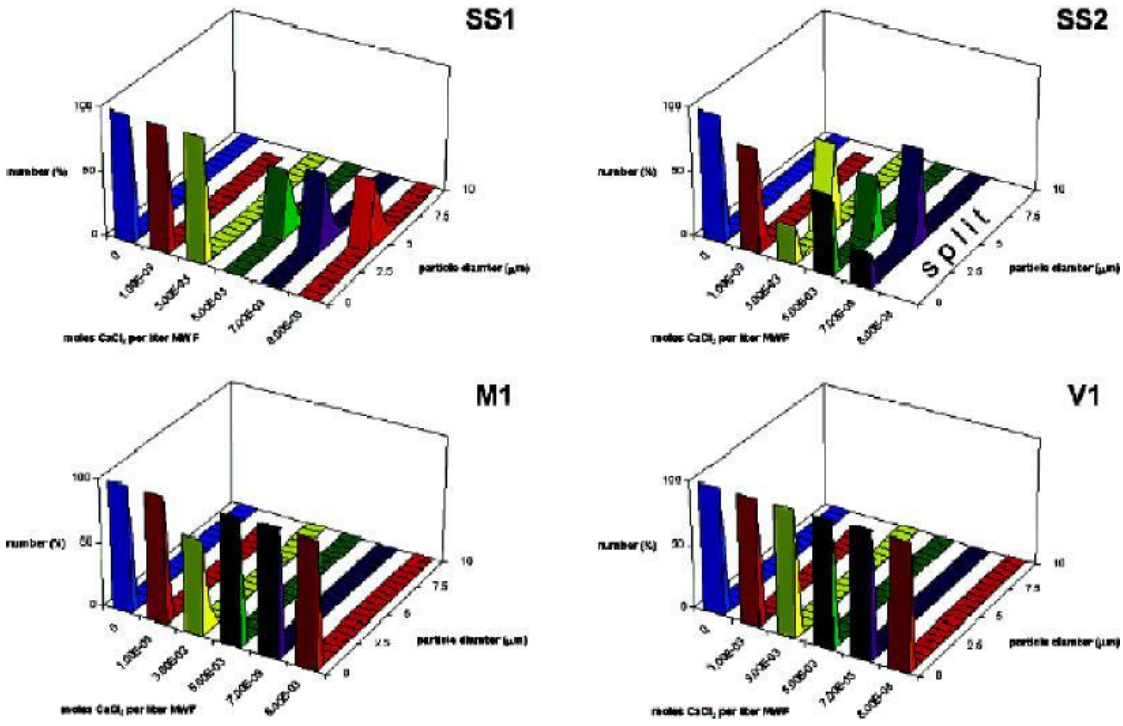


Figure 1-Particle size of SS1, SS2, and representative mineral oil- and vegetable oil-based formulations (M1 and V1) formulated with a twin-headed anionic surfactant as a function of calcium chloride salt molar concentration. For systems where oil-water split occurs, particle size data are not available.

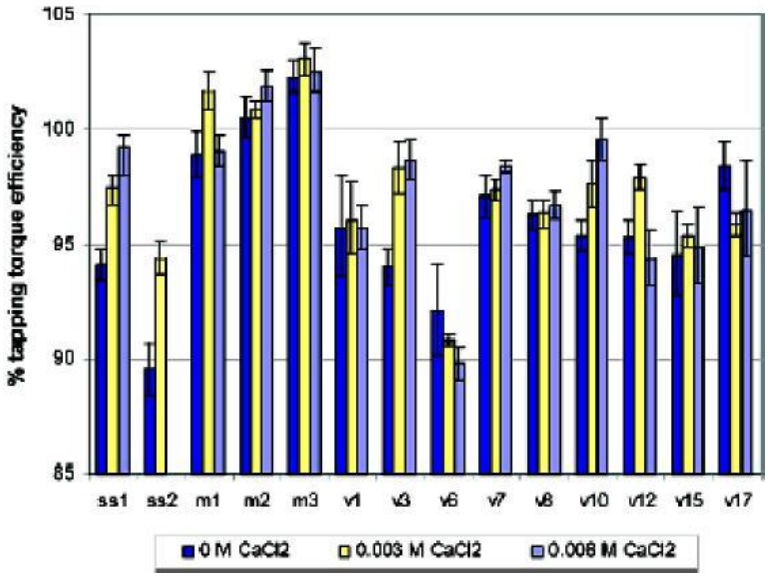


Figure 2-Tapping torque efficiency for SS1, SS2, and representative mineral oil- and vegetable oil-based formulations at 0, 0.003, and 0.008 M calcium chloride. Tapping torque data was not reported for SS2 at 0.008 M calcium chloride due to oil-water emulsion separation. Error bars represent 95% confidence intervals.

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♦ REGULATIONS FOR PRIVATE CANDIDATES

Private candidates will be required to write Papers 01, 02 and 032.

Paper 032 is an Alternative Paper to the School-Based Assessment. *This paper is worth 30 per cent of the total mark for the Unit.*

UNIT 1 - Paper 032 is a written paper consisting of a report based on a case study.

UNIT 2 - Paper 032 is a written paper consisting of a design based on a case study.

Candidates are required to answer questions based on the case study. The questions are designed to test the skills developed by students in the School-Based Assessment. The questions will test various stages of the research process. Candidates are advised to conduct the relevant research in sustainable tourism in preparation for writing paper 032.

Paper 032 (1 hour 30 minutes – 30 per cent of Total Assessment)

1. **Composition of Paper**
   The paper comprises a report.

2. **Syllabus Coverage**
   This paper is intended to test the knowledge and skills contained in Module 3 as outlined on Pages 15–16 (Unit 1) and 26 (Unit 2) of the syllabus.

3. **Question type**
   Question will be a structured case consisting of several parts.

4. **Mark Allocation**
   The question is divided into sub-parts and is worth 40 marks.

♦ REGULATIONS FOR RESIT CANDIDATES

Resit candidates must complete Papers 01 and 02 and Paper 03 of the examination for the year for which they re-register. A candidate who rewrites the examination within two years may reuse the moderated School-Based Assessment score earned in the previous sitting within the preceding two years.

Candidates are no longer required to earn a moderated score that is at least 50 per cent of the maximum possible score; any moderated score may be reused.

Candidates reusing SBA scores in this way must register as 'Resit candidates' and provide the previous candidate number. (In order to assist candidates in making decisions about whether or not to reuse a moderated SBA score, the Council will continue to indicate on the pre-slip if a candidate's moderated SBA score is less than 50 per cent).

Resit candidates must be registered through a school, a recognised educational institution, or the Local Registrar's Office.

♦ ASSESSMENT GRID

The Assessment Grid for the Unit showing marks assigned to papers and to Modules, and percentage contributions of each paper to the total scores.

Papers	Module 1	Module 2	Module 3	Total	(%)
External Assessment Paper 01 Structured (Short Answer)	15 (raw) 30 (wtd)	15 (raw) 30 (wtd)	15 (raw) 30 (wtd)	45 (raw) 90 (wtd)	(30)
Paper 02 Essay	40	40	40	120	(40)
School-Based Assessment Paper 031 and Paper 032	40 (raw) 30 (wtd)	40 (raw) 30 (wtd)	40 (raw) 30 (wtd)	120 (raw) 90 (wtd)	(30)
TOTAL	100	100	100	300	(100)

APPENDIX I

♦ GLOSSARY OF BEHAVIOURAL VERBS USED IN THE EXAMINATION

WORD	DEFINITION/MEANING	NOTES
Analyse	Examine in detail.	
Annotate	Add a brief note to a label.	Simple phrase or a few words only.
Apply	Use knowledge/principles to solve problems.	Make inferences/conclusions.
Assess	Present reasons for the importance of particular structures, relationships or processes.	Compare the advantages and disadvantages or the merits and demerits of a particular structure, relationship or process.
Calculate	Arrive at the solution to a numerical problem.	Steps should be shown; units must be included.
Classify	Divide into groups according to observable characteristics.	
Comment	State opinion or view with supporting reasons.	
Compare	State similarities and differences.	An explanation of the significance of each similarity and difference stated may be required for comparisons which are other than structural.
Construct	Use a specific format to make and/or draw a graph, histogram, pie chart or other representation using data or material provided or drawn from practical investigations, build (for example, a model), draw scale diagram.	Such representations should normally bear a title, appropriate headings and legend.
Deduce	Make a logical connection between two or more pieces of information; use data to arrive at a conclusion.	
Define	State concisely the meaning of a word or term.	This should include the defining equation/formula where relevant.
Demonstrate	Show; direct attention to.	
Derive	To deduce, determine or extract from data by a set of logical steps some relationship, formula or result.	This relationship etc. may be general or specific.

WORD	DEFINITION/MEANING	NOTES
Describe	Provide detailed factual information of the appearance or arrangement of a specific structure or a sequence of a specific process.	Description may be in words, drawings or diagrams or any appropriate combination. Drawings or diagrams should be annotated to show appropriate detail where necessary.
Determine	Find the value of a physical quantity.	
Design	Plan and present with appropriate practical detail.	Where hypotheses are stated or when tests are to be conducted, possible outcomes should be clearly stated and/or the way in which data will be analysed and presented.
Develop	Expand or elaborate an idea or argument with supporting reasons.	
Diagram	Simplified representation showing the relationship between components.	
Differentiate/ distinguish (between/ among)	State or explain briefly those differences between or among items which can be used to define the items or place them into separate categories.	
Discuss	Present reasoned argument; consider points both for and against; explain the relative merits of a case.	
Draw	Make a line representation from specimens or apparatus which shows an accurate relation between the parts.	In the case of drawings from specimens, the magnification must always be stated.
Estimate	Make an approximate quantitative judgement.	
Evaluate	Weigh evidence and make judgements based on given criteria.	The use of logical supporting reasons for a particular point of view is more important than the view held; usually both sides of an argument should be considered.
Explain	Give reasons based on recall; account for.	
Find	Locate a feature or obtain as from a graph.	
Formulate	Devise a hypothesis.	
Identify	Name or point out specific components or	

WORD	DEFINITION/MEANING	NOTES
	features.	
Illustrate	Show clearly by using appropriate examples or diagrams, sketches.	
Interpret	Explain the meaning of.	
Justify	Explain the correctness of.	
Investigate	Use simple systematic procedures to observe, record data and draw logical conclusions.	
Label	Add names to identify structures or parts indicated by pointers.	
List	Itemise without detail.	
Measure	Take accurate quantitative readings using appropriate instruments.	
Name	Give only the name of.	No additional information is required.
Note	Write down observations.	
Observe	Pay attention to details which characterise a specimen, reaction or change taking place; to examine and note scientifically.	Observations may involve all the senses and/or extensions of them but would normally exclude the sense of taste.
Outline	Give basic steps only.	
Plan	Prepare to conduct an investigation.	
Predict	Use information provided to arrive at a likely conclusion or suggest a possible outcome.	
Record	Write an accurate description of the full range of observations made during a given procedure.	This includes the values for any variable being investigated; where appropriate, recorded data may be depicted in graphs, histograms or tables.
Relate	Show connections between; explain how one set of facts or data depend on others or are determined by them.	
Sketch	Make a simple freehand diagram showing relevant proportions and any important details.	

WORD	DEFINITION/MEANING	NOTES
State	Provide factual information in concise terms outlining explanations.	
Suggest	Offer an explanation deduced from information provided or previous knowledge (... a hypothesis; provide a generalisation which offers a likely explanation for a set of data or observations).	No correct or incorrect solution is presumed but suggestions must be acceptable within the limits of scientific knowledge.
Test	to find out, following set procedures	

Western Zone Office
30 March 2016

CARIBBEAN EXAMINATIONS COUNCIL

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GREEN ENGINEERING

Specimen Papers and Mark Schemes/Keys

Specimen Papers:

Unit 1 Paper 01
Unit 1 Paper 02
Unit 1 Paper 03
Unit 2 Paper 01
Unit 2 Paper 02
Unit 2 Paper 03

Mark Schemes and Keys:

Unit 1 Paper 01
Unit 1 Paper 02
Unit 1 Paper 03
Unit 2 Paper 01
Unit 2 Paper 02
Unit 2 Paper 03

TEST CODE **02165010**

SPEC 2015/ **02165010**

C A R I B B E A N E X A M I N A T I O N S C O U N C I L

CARRIBEAN ADVANCED PROFICIENCY EXAMINATION®

GREEN ENGINEERING

SPECIMEN PAPER

Unit 1 – Paper 01

1 hour 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This test consists of 45 items. You will have 1 hour and 30 minutes to answer them.
2. Each item in this test has four suggested answers lettered (A), (B), (C), (D). Read each item you are about to answer and decide which choice is best.
3. Look at the sample item below.

   Sample Item

   The MOST serious environmental effect posed by hazardous waste is

   (A) air pollution
   (B) destruction of habitat
   (C) contamination of groundwater
   (D) increased use of land for landfills

   Sample Answer

   

   The best answer to this item is "contamination of groundwater " so (C) has been shaded.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

1. Which two of the following are widely regarded as being important aspects of sustainable development?

I. Intra-generational equity
II. Intra-generational inequity
III. Inter-generational inequity
IV. Inter-generational equity

(A) I and II only
(B) I and IV only
(C) II and III only
(D) II and IV only

2. Which of the following is NOT a characteristic of sustainable development?

(A) Social economic development which optimizes benefits available in the present without spoiling the likely potential for similar benefits in the future

(B) Reasonable and equitably distributed level of economic wellbeing that can be perpetuated continually

(C) Development that meets the needs of the present without compromising the ability of future generations to meet their own needs

(D) Maximizing the present-day benefits through increased resource consumption

3. The persistent trend of increasing temperatures over three decades is an indication that global warming is really happening. What was the warmest decade since temperatures have been recorded?

(A) 1990s
(B) 1980s
(C) 1970s
(D) 1960s

4. The three pillars of sustainability may be identified as

(A) plants, people and productivity
(B) planet, preservation and profit
(C) planet, people and profit
(D) people, planet and productivity

5. Which of the following is NOT a renewable energy resource?

(A) The sun
(B) The wind
(C) Natural gas
(D) Biomass

6. Which of the following is a non-renewable energy resource?

(A) Solar
(B) Methane
(C) Hydroelectric
(D) Coal

7. Examples of renewable resources include

(A) iron ore, forests and fish
(B) fresh water, forests and fish
(C) forests, fish and oil
(D) forests, gold and fish

GO ON TO THE NEXT PAGE

8. Which of the following is TRUE about risks?

(A) Risks have three components: a source/root cause, a probability and the consequence.
(B) Risks can be associated with specific stages of a project life cycle.
(C) Risks are commonly used to express certainty that undesired events will occur.
(D) Risks are hazards.

9. In which phase of the life cycle analysis process (LCA) is the life cycle interpretation done?

(A) First
(B) Second
(C) Third
(D) Fourth

10. Which of these causes the greenhouse effect?

I. Excess of nitrogen in the atmosphere
II. Excess of carbon dioxide in the atmosphere
III. Heat from cooking fires of an ever-increasing population

(A) I only
(B) II only
(C) I and III only
(D) I, II and III

11. Energy resources derived from organic materials are called

I. geothermal energy sources
II. fossil fuels
III. biomass

(A) II only
(B) III only
(C) I and III only
(D) II and III only

12. A risk response which involves the minimization of a threat is called

(A) mitigation
(B) deflection
(C) avoidance
(D) transfer

13. Which of the following are phases of life cycle analysis?

I. Extraction
II. Manufacturing
III. Use

(A) I and II only
(B) I and III only
(C) II and III only
(D) I, II and III

14. Which of the following is the largest consumer of water in the developing World?

(A) Manufacturing
(B) Electricity and gas
(C) Households
(D) Agriculture

GO ON TO THE NEXT PAGE

15. The industrial approach to assess the environmental performance of products is termed

(A) life cycle analysis
(B) industrial ecology
(C) corporate social responsibility
(D) product analysis/assessment

16. Which of the following are key objectives of green engineering?

I. Use raw materials more efficiently
II. Minimize the use of energy during production
III. Use of renewable materials

(A) I and II
(B) I and III
(C) II and III
(D) I, II and III

17. The recycling of plastic waste to produce containers is an example of the principle of

(A) maximizing efficiency in products and processes
(B) designing for separation and purification processes
(C) conserving complexity
(D) waste prevention instead of treatment

18. A tin can sealing process was redesigned to use two instead of three drops of solder. This is an example of the principle of

(A) output-pulled versus input-pushed
(B) maximizing efficiency in products and processes
(C) preventing waste instead of treating it
(D) durability rather than immortality

19. Manufacturers who encourage their customers to return their old equipment for recycling are following the principle

(A) that materials and energy must be inherently non-hazardous, rather than circumstantial
(B) of output-pulled versus input-pushed
(C) of maximizing efficiency in products and processes
(D) of conserving complexity

20. The principle based on durability rather than immortality implies that products should

I. be constructed to be durable during their useful commercial life
II. not be persistent and result in environmental problems
III. be easily repaired and maintained with minimum input

(A) I and II only
(B) I and III only
(C) II and III only
(D) I, II and III

GO ON TO THE NEXT PAGE

21. Industrial ecology can best be described as an effort to apply to the manufacturing process the principles

(A) utilized by the ISO quality management system
(B) of the carbon cycle
(C) of the interaction of organisms and their environment
(D) utilized by the total quality management system

22. The main objective of industrial ecology is to

(A) reduce greenhouse gases
(B) create a carbon sink
(C) create sustainable livelihoods for humanity
(D) improve the manufacturing process

23. Industrial ecology is expected to make its greatest impact on the

(A) atmosphere
(B) lithosphere
(C) anthroposphere
(D) biosphere

24. Industrial ecology relies on the

(A) integration of various production processes
(B) structured integration of similar production processes
(C) structured integration of complementary production processes
(D) ad hoc integration of various production processes

25. Green engineering complements industrial ecology because

(A) its principles support sustainability
(B) industrial ecology encourages symbiosis
(C) green engineering uses renewable energy
(D) green engineering encourages the use of renewable raw materials

26. For the construction of buildings, the use of clay blocks is more sustainable than concrete blocks because

I. less greenhouse gas is produced
II. the clay block process is more complex than cement manufacturing
III. the manufacturing of clay blocks is more energy efficient

(A) I and II only
(B) II and III only
(C) I and III only
(D) I, II and III

27. Product lifecycle management is now made much more efficient by the use of

(A) specially designed software
(B) new testing equipment
(C) renewable energy sources
(D) more efficient temperature controllers

28. One of the key tools utilized by industrial ecology is

(A) a quality management system
(B) the reuse of materials
(C) the use of lifecycle analysis
(D) the use of renewable raw materials

29. Which of the following are common to both green engineering and industrial ecology

I. The use of renewable energy
II. Lifecycle Analysis
III. Greenhouse gas reduction
IV. Green products

(A) I and IV only
(B) I, II and IV only
(C) II and III only
(D) I, II and III only

30. Hydropower is usually favoured as a source of energy for manufacturing because

(A) it is easily installed
(B) it is a renewable source of power
(C) large power plants would stabilize the grid
(D) it is usually cheap

31. Which of the following would be the MAIN environmental issue for an alcohol distillery?

(A) Excess production of carbon dioxide released into the environment
(B) The high amount of water used in the distillery
(C) The improper disposal of the vinasse into waterways
(D) The high levels of energy consumption for fermentation and distillation

32. During the distillation process, vinasse is produced. Which of the following forms of energy would NOT be obtained from this by-product?

(A) Biofuel
(B) Chemical energy
(C) Fossil fuel
(D) Electrical energy

33. Which purification technique is used in an alcohol distillery?

(A) Centrifugation
(B) Fractional distillation
(C) Flocculation
(D) Decantation

34. Which one of the following is NOT an advantage of the new metal working fluids (MWFs)?

(A) MWFs are more hard water stable and could be used again.
(B) MWFS are produced from bio-based resources.
(C) MWFs do not require ehtylenediaminetetraacetic acid (EDTA) that can lead to heavy metal mobility.
(D) MWFs produce butyl carbitol that can be reused in the production stage.

GO ON TO THE NEXT PAGE

35. A small amount of the carbon dioxide captured during the distillation process can be used in

I. the manufacture of dry ice for cooling purposes
II. the welding business as metal inert gas
III. fire extinguishers

(A) II only
(B) I and II only
(C) I, II, and III only
(D) III only

36. Which of the following is NOT a property of ethylenediaminetetraacetic acid?

(A) It is a chelating agent.
(B) It is a component of the bio-based metal working fluids.
(C) It can mobilize heavy metal.
(D) It does not biodegrade.

37. When manufacturers design products based on inherently benign, renewable materials and energy, which principles from green engineering are they applying?

(A) Principles 2 and 4
(B) Principles 2 and 5
(C) Principles 3 and 8
(D) Principles 1 and 12

38. The prevention of waste such as the discontinuous disposal of metal working fluid demonstrates which of the following principles of green engineering?

(A) Principle 1
(B) Principle 3
(C) Principle 5
(D) Principle 7

39. Which of the following is NOT a factor that influences decision-making in investing in renewable energy projects within the hotel industry?

(A) The acceptance of the public and hotel clientele
(B) The price of oil and electricity
(C) The country's environmental legislation
(D) The condition of the national and international economy

40. Which of the following is a requirement for hotels to receive Platinum Earth Check certification?

(A) The hotels must pay their annual environmental tax to the government.
(B) The hotels must be considered a five-star.
(C) The hotels must be involved in sponsoring environmental movements.
(D) The hotels must care for the planet while providing the best service to their clients.

41. Which of the following does NOT fall under energy efficiency projects used in hotels?

(A) Automatic key card that turns all lights and appliances on/off
(B) Replacing plastic shower caps with biodegradable ones
(C) Replacing compact fluorescent lights (CFLs) with light emitting diodes (LEDs)
(D) Solar water heating

GO ON TO THE NEXT PAGE

42. Which of the following is NOT a challenge for renewable energy adoption?

I. Lack of environmental sensitivity and interest
II. High initial capital cost
III. Absence of legislation, regulatory institutions and instruments

(A) I only
(B) II and III only
(C) I, II and III
(D) III only

43. Which of the following is an example of green engineering in the manufacturing and benefits of cement replacement?

(A) Greater durability and longevity
(B) Reduced risk of thermal cracking
(C) Reduced carbon footprint
(D) Decreased permeability

44. A manufacturing entity implemented an environmental management system and was certified in compliance to ISO 14000 standards. Which of the following are potential benefits of this system?

(A) Improvement in the overall environmental performance and compliance
(B) Increased efficiency and potential cost savings when managing environmental obligations
(C) Promotion of predictability and consistency in the company's environmental obligation
(D) Improved customer satisfaction and staff motivation

45. The improper disposal of large amounts of organic material in the distillation industry results in significant negative consequences to

I. the environment
II. society
III. a country's economy

(A) I, II and III
(B) I and II only
(C) I only
(D) II only

Item	Specific Objective	Key	Item	Specific Objective	Key
1	1.1.1	B	26	1.2.4	C
2	1.1.1	D	27	1.2.4	A
3	1.1.4	A	28	1.2.8	C
4	1.1.13	C	29	1.2.8	D
5	1.1.4	C	30	1.2.5	B
6	1.1.4	D	31	1.3.1	C
7	1.1.2	B	32	1.3.4	C
8	1.1.6	A	33	1.3.2	B
9	1.1.12	D	34	1.3.2	D
10	1.1.4	B	35	1.3.1	C
11	1.1.4	D	36	1.3.2	B
12	1.1.6	A	37	1.3.6	D
13	1.1.12	D	38	1.3.6	B
14	1.1.3	D	39	1.3.7	A
15	1.1.11	A	40	1.3.6	D
16	1.2.1	D	41	1.3.1	B
17	1.2.1	C	42	1.3.7	A
18	1.2.1	B	43	1.3.3	C
19	1.2.1	D	44	1.3.6	D
20	1.2.1	D	45	1.3.1	A
21	1.2.2	C			
22	1.2.2	C			
23	1.2.2	C			
24	1.2.2	C			
25	1.2.3	A			

TEST CODE **02165020**

SPEC 2015/ 02165020

C A R I B B E A N E X A M I N A T I O N S C O U N C I L

CARRIBEAN ADVANCED PROFICIENCY EXAMINATION®

GREEN ENGINEERING

SPECIMEN PAPER

Unit 1 – Paper 02

2 hours 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of SIX questions in THREE sections.
2. Answer ALL questions.
3. Write your answers in the spaces provided in this booklet.
4. DO NOT write in the margins.
5. If you need to rewrite any answer and there is not enough space to do so on the original page, you must use the extra lined page(s) provided at the back of this booklet. **Remember to draw a line through your original answer.**
6. **If you use the extra page(s) you MUST write the question number clearly in the box provided at the top of the extra page(s) and, where relevant, include the question part beside the answer.**

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

SECTION A

MODULE 1

CONCEPTS AND ISSUES

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

1. Caribbean countries are pushed to address global climate change.

(a) Define the term 'climate change'.

_____

_____

[2 marks]

(b) Name TWO greenhouse gases.

_____

_____

[2 marks]

(c) Outline the human activities which contribute the most greenhouse gases to the atmosphere.

_____

_____

_____

_____

[4 marks]

(d) Outline FOUR ways in which climate change can impact small island and low-lying states in the Caribbean.

_____

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_____

_____

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_____

[8 marks]

(e) Outline FOUR ways sustainable lifestyles can address climate change.

_____

_____

_____

_____

[4 marks]

Total 20 marks

2. In recent years, life cycle thinking has taken a more prominent role in environmental policy making.

(a) Define the term ‘life cycle analysis’.

_____

_____

[2 marks]

(b) Outline TWO reasons why the application of life cycle analysis is important.

_____

_____

_____

_____

[4 marks]

(c) Describe TWO stages of a life cycle assessment and explain why each stage is important.

_____

_____

_____

_____

_____

_____

_____

_____

[8 marks]

(d) Name TWO non-renewable resources/materials used in the manufacturing process.

_____

_____

[2 marks]

(e) Name FOUR categories of renewable resources/materials used in the manufacturing process.

_____

_____

_____

_____

[4 marks]

Total 20 marks

SECTION B

MODULE 2

THEORETICAL FRAMEWORK OF GREEN ENGINEERING

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

Green engineering and industrial ecology are two approaches that have been adopted to address the limits of natural resources, or impact on the environment and community and the need to promote sustainability.

3. (a) Explain the concept of green engineering.

_____

_____

_____

[3 marks]

(b) Identify TWO of the principles of green engineering and briefly explain EACH of them.

_____

_____

_____

_____

_____

_____

_____

_____

[8 marks]

(c) Explain the concept of industrial ecology.

_____

_____

_____

_____

_____

[5 marks]

(d) Explain TWO benefits accrued from the application of industrial ecology.

_____

_____

_____

_____

[4 marks]

Total 20 marks

4. (a) Briefly discuss TWO quality management systems used to support green engineering.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

[10 marks]

(b) Explain the following principles of ecology:

(i) Balance industrial inputs and outputs to natural levels and capacity.

_____

_____

_____

_____

[3 marks]

(ii) Efficient energy use.

_____

_____

_____

_____

[3 marks]

(c) Explain, using TWO examples, how opportunities for the integration of processes and material flows can be identified during the product design phase.

_____

_____

_____

_____

_____

[4 marks]

Total 20 marks

SECTION C

MODULE 3

GREEN ENGINEERING IN PRACTICE

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

One of the largest cost headings for the hotel industry is electricity. Hotels are now introducing new approaches to encourage electricity reduction.

5. (a) (i) If a hotel has 500 rooms and the power consumed per room is approximately 3000 W per hour, what would be the electrical energy consumed per hour? Express the answer in kWh.

_____

_____

_____

[2 marks]

(ii) If a barrel of oil is approximately equal to 1699.4 kWh, what would be the amount of barrels of oil used per hour?

_____

_____

[1 mark]

(iii) How many barrel(s) of oil would be used by the hotel per day?

_____

_____

[1 mark]

(iv) How many barrels of oil would be used per year?

_____

_____

[1 mark]

(v) If one barrel of oil costs US$100, what would be the total cost to the hotel per year?

_____

_____

[1 mark]

(b) (i) List TWO ways in which hotels improve their energy efficiency.

_____

_____

_____

[2 marks]

(ii) Explain economies of scale as it relates to the use of renewable energy.

_____

_____

_____

_____

[4 marks]

(iii) List TWO reasons why small hotels in the Caribbean choose not to use renewable energy in their operations.

_____

_____

_____

[2 marks]

(c) (i) Explain TWO advantages of having an environmental officer in a hotel?

_____

_____

_____

[4 marks]

(ii) List TWO incentives that governments can provide to organizations that try to invest in renewable energy.

_____

_____

_____

_____

[2 marks]

Total 20 marks

Metal working fluids (MWFs) are used to reduce heat and friction and to remove metal particles in industrial machining and grinding operations.

6. (a) State TWO principles of green engineering which can be applied to the manufacture of metal working fluids (MWFs) and explain how EACH is applied?

_____

_____

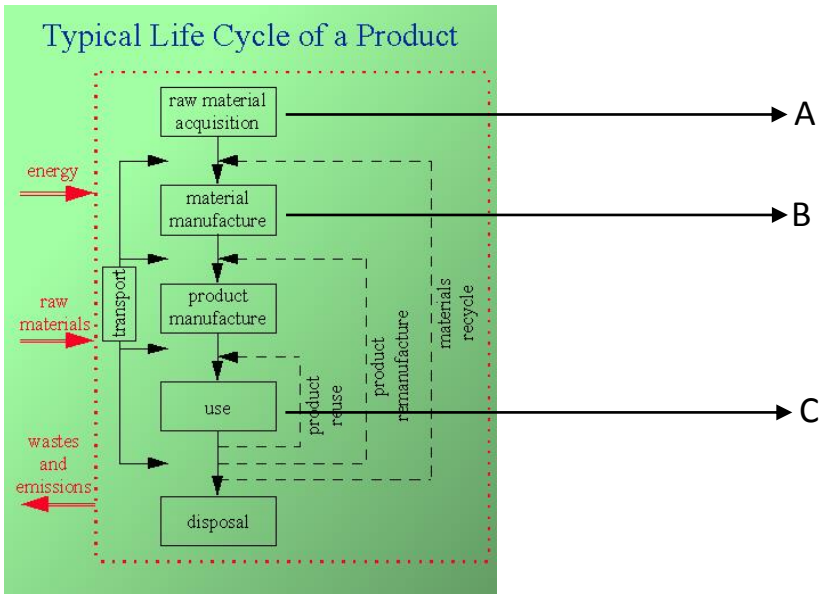
_____

_____

_____

[6 marks]

(b) Figure 1 shows the typical life cycle of a product.



(i) Identify ONE principle of green engineering that can be applied to EACH stage represented by A, B and C.

_____

_____

_____

[3 marks]

(ii) Justify the application of any ONE principle identified in (b) (i).

_____

_____

[2 marks]

(c) List THREE types of metal working fluids (MWFs) that are used in machining operations.

_____

_____

_____

[3 marks]

(d) The new MWFs are based on oil and anionic surfactants. The latter can be destabilized by a simple salt. What advantages does the salt have on MWFs?

_____

_____

_____

_____

[2 marks]

(e) The hard water stability provided by the MWFs can improve emulsion stability even though two components are removed. Name each of these components.

_____

_____

_____

_____

[4 marks]

Total 20 marks

C A R I B B E A N E X A M I N A T I O N S C O U N C I L

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEYS AND MARK SCHEME

MAY/JUNE 2015

SPECIMEN PAPER

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 1.

S.O		Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
1:1:4	(a)	Climate change is a long-term shift in weather conditions measured by changes in temperature, precipitation, wind, snow cover, and other indicators. It can be caused by natural processes **(1)**, such as changes in the output of the sun and in the amount of volcanic dust in the atmosphere. It can also be affected by human activities **(1)**.	2	2		
1:1:4	(b)	Carbon dioxide Methane Nitrous oxide Water vapour CFCs	Any TWO	2		
1:1:4	(c)	The burning of fossil fuels - primarily coal, oil, and natural gas - used for transportation, manufacturing, heating, electricity generation, and other applications and which currently accounts for human emissions of carbon dioxide - a major greenhouse gas. The remainder of the carbon dioxide emissions comes from human land use activities such as agricultural activities especially animal husbandry, poorly designed and managed landfill sites and the clearing and degradation of forests.	4	4		
1:1:4	(d)	1. Coral bleaching (corals will expel algae living in their tissues due to warm temperatures; corals die and become white/loss of algal pigmentation). 2. Floods, storm surge, erosion and other coastal hazards, exacerbated by sea-level rise that threaten vital infrastructure, settlements and facilities that support the livelihood of coastal communities.	8		8	

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 1. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
	(d) 3. Reduction in freshwater resources, to the point where they cannot meet demand during low rainfall periods. 4. Increased invasion by non-native species as a result of higher temperatures is also expected, particularly on middle and high-latitude islands. 5. Economic losses from reduced agricultural yields due to drought. 6. Loss of mangrove forests and coral reefs due to sea level rise. 7. Reduction in freshwater and general water resource availability due to decreased rainfall and saltwater intrusion. 8. Reduction in tourism due to increased frequency and severity of extreme weather.				
1:1:5	(e) 1. Green consumerism (demand less packaging). 2. Apply the 3 Rs (reduce waste generation). 3. Walk more and car pool. 4. Reduce carbon footprint (for example, low impact materials, energy efficient household appliances.	1 mark each for 4 correct		4	
		TOTAL 20 MARKS	**8**	**12**	**0**

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 2.

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:1:11	(a) LCA is a tool used to determine the raw materials, energy use, wastes, and emissions associated with the product's life cycle.	2	2		
1:1:11	(b) • To minimize the magnitude of pollution. • To identify processes, ingredients, and systems that are major. contributors to environmental impacts • To compare different options within a particular process with the objective of minimizing environmental impacts. • To provide guidance in long-term strategic planning concerning trends in product design and materials. • To optimize recycling of materials and waste. • To apply the most appropriate pollution prevention and/or abatement techniques.	2 marks each for any 2		4	
1:1:11	(c) • Life cycle inventory **(1)**: Determine the emissions that occur and the raw materials and energy that are used during the life-cycle of a product. **(3)** • Life cycle impact assessment: Assess what the impacts of these emissions and raw material depletions are. • Improvement analysis or interpretation: Interpret the results of the impact assessment in order to suggest improvements. When LCA is conducted to compare products this step may consist of recommending the most environmentally desirable product.	8	2	6	

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 2. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:1:2	(d) Fossil fuels (list) Minerals (list)	2		2	
1:1:2	(e) Wind Solar energy Hydro Biomass	1 mark for each		4	
		TOTAL 20 MARKS	**4**	**16**	**0**

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 3.

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:2:1	(a) Green engineering is the design and production of products or infrastructure with the aim of conserving natural resources leading to sustainability goals.	1	2		
	As such green engineering focuses on achieving sustainability through the application of science, technology and innovation.	1			
1:2:1	(b) Any two of the twelve principles, for example,	2 (1 for each principle)	2		
	Materials and energy must be inherently non-hazardous, rather than circumstantial.	1			
	This principle means that when choosing energy sources or materials to be used in the design of any product or infrastructure, care should be taken to ensure that these are safe as is.	1	6		
	Also, there should be minimum input to reduce any inherent danger these may cause the process, finished product or infrastructure to possess.	1 (3 for each explanation)			
1:2:5	(c) Industrial ecology is based on the need for humanity to mirror as much as possible the manner in which organisms optimize the resources within their environment.	1 1	4		
	Industrial ecology is an integration of various processes with the objective to optimize the use of inputs (energy and material) for the production of any man made item.	1 1			

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 3. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:2:7	(d) Cost savings.	1	6		
	Due to the integration of the processes, energy and material can be recovered from one process and utilized in another process thereby leading to savings.	2			
	Improve environmental protections.	1			
	Reduction in energy and material utilization in the overall processes will help the environment since there will be reduced demands of the larger environment.	2			
	TOTAL 20 MARKS		**20**	**0**	**0**

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 4.

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:2:3	(a) The ISO 14000 family of standards play an important role in supporting GE.	1	10		
	These standards guide corporate entities in key areas of their operations so they meet the requirements so as to be environmentally responsible.	2			
	These standards allow similar processes in different organizations to be compared with each other.	1			
	This in turn allows for easy integration of processes or utilization of material.	1			
	The ASTM standards play an important role in ensuring that materials, equipment and testing procedures are to the required technical specifications of the process.	1 2			
	These test standards ensure that all testing procedures are done in the identical manner regardless of which organization the testing is done at.	1			
	This allows the empirical comparison of materials and makes their use in different processes more acceptable.	1			
1:2:5	(b) (i) Balance industrial inputs and outputs to natural levels and capacity means that there should not be any output which demands more than any of the complementing input processes.	2	6		
	Also, these inputs should not demand more than can be supplied by the natural environment.	1			
	This supply should not have any negative impact on the health of the environment.	1			

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 4. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
	(b) (ii) Efficient energy use means: • Energy should be used efficiently • Renewable sources of energy should be used when it is a sustainable option.	1 1			
	(c) Energy is usually one of the first areas which provide opportunities for improving the process during the design stage since most processes are energy intensive. The other major opportunity for design modification is in the use of material input. By studying the final purpose of the product it is possible to modify the design to use the most appropriate material.	2 with a valid example 2 with a valid example	4		
	TOTAL 20 MARKS		**20**	**0**	**0**

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 5.

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:3:1	(a) (i) No. of rooms = 500 Energy consumed per room = 3000 W 500 * 3000 = 1500000 W 1 KW= 1000 W 1500000 W/1000 = 15000 KWH	2		6	
1:3:1	(ii) 1699.4 kWh = 1 barrel of oil 1500 kWh = x barrels of oil X = (1500 * 1)/ 1699.4 = 0.88 of a barrel of oil per hour	1			
1:3:1	(iii) 0.88 * 24 = 21.1 barrels per day	1			
1:3:1	(iv) 21.1 * 365 = 7701.5 barrels per year	1			
1:3:1	(v) 1 barrel = US $100 7701.5 = $xUS X = 100 * 7701.5 = $770150 US	1			
1:3:1	(b) (i) 1. By replacing all incandescent lights with light-emitting diodes (LEDs)	1	2		
	2. By installing automatic key cards that shut off all appliances and lights when guests exit the room	1			
	3. By using linen reuse cards to encourage guests to conserve on laundry use				
	4. Through housekeeping practices (such as keeping the windows closed when the heating system is on)				
	Any two				

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 5. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:3:1	(b) (ii) Economies of scale refers to the decrease in unit cost of a product or service resulting from large-scale operations, as in mass production. By purchasing larger quantities, the average costs will be lowered (this is because of lower transport cost). The transition from the use of non-renewable to renewable energy requires a high initial cost, but that cost can be lowered if the units (for example photovoltaic) are bought in bulk.	2 2		4	
1:3:4	(iii) 1. High initial cost for installation. 2. Lack of incentives from government. 3. High duties of renewable energy in some countries in the Caribbean. 4. Renewable energy projects are most of the time private driven without the influence of national policy. **Any two**	1 1		2	

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 5. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:3:1	(c) (i) 1. An environmental officer can formulate plans and identify areas where changes can be made, for example, in energy efficiency	2 2		4	
	2. Foster culture of environmental sensitivity and sustainability				
1:3:7		1		2	
	(ii) 1. Lower duty on renewable energy equipment and material.	1			
	2. Advertisement of the organization in media houses				
	3. Provide financial assistance for starting the renewable energy project				
	Any two				
	TOTAL 20 MARKS		**2**	**18**	**0**

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 6.

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:3:6	(a) 1. The substitution of metal working fluids (MWFs) components with alternatives that are more inherently benign than traditional MWF ingredients. Principle 1 relates to this innovation since the product designers need to ensure that material and energy inputs and outputs are inherently non-hazardous as possible. 2. The newly formulated MWFs prevent environmental impacts since it can be reused again and not disposed. This illustrates Principle 2 which places emphasis on the prevention of waste rather than treatment or cleaning of such. 3. The new MWF formulations are based on oil and non-ionic surfactants that can be produced from renewable, bio-based resources. This demonstrates Principle 12 because the designs should be based on renewable and readily available inputs throughout the life cycle. 4. The new MWF formulations can allow oil separation by the addition of a simple salt. Principle 3 makes mention that separation and purification operations should be a component of the design framework. 5. The new MWFs can allow oil recovery and reuse (Principle 6 and 10). **(2 marks for stating correctly)** **(4 marks for explaining)**	3 3		6	

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 6. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:3:	(b) (i) A. Principles 1 and 10 B. Principles 3 and 4 C. Principle 6	1 1 1		3	
1:3:6	(ii) Principles 1 and 10. Materials and energy inputs and outputs should be as non-hazardous as possible. Design of processes and systems must include integration and interconnectivity with available energy and material flows. Principles 3 and 4, separation and purification operations should be a component of the design framework and system components should be designed to maximize mass, energy and temporal efficiency. Principle 6, the product should be recycled, reused or should not cause damage when disposed. **Any one**	2		2	
1:3:2	(c) Types of MWFs are: 1. Straight oils 2. Oil-in-water emulsions – soluble oils 3. Oil – in- water emulsions – semi-synthetics 4. True solutions - synthetics **Any three**	 1 1 1		3	

GREEN ENGINEERING

UNIT 1 - PAPER 02

KEY AND MARK SCHEME

Question 6. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PS
1:3:3	(d) The addition of a simple salt allows oil separation	1	2		
	It also allows oil recovery and reuse.	1			
1:3:3	(e) The two components are:				
	1. Ethylenediaminetetraacetic acid (EDTA) $C_{10}H_{16}N_2O_8$	2	4		
	2. Butyl carbitol $C_4H_9(OCH_2CH_2)_2OH$	2			
		TOTAL 20 MARKS	**6**	**14**	**0**

TEST CODE **02165032**

SPEC 2015/ 02165032

C A R I B B E A N E X A M I N A T I O N S C O U N C I L

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GREEN ENGINEERING

SPECIMEN PAPER

Unit 1 – Paper 032

2 hours 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of a case study.
2. Read the case and use the information to complete a report.
3. All answers must be written in this booklet.
4. You are advised to take some time to read through the paper and plan your answers.
5. You may use silent, electronic, non-programmable calculators to answer questions.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

CASE STUDY

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

In a Caribbean island state, there is a recently constructed building situated along the Windward seacoast. The building is dark grey and has a flat, tarred concrete roof. The structure is tightly sealed with heavy window shades. The outer wall of the main lobby of this building is predominantly glass. However, artificial lighting is utilized during the day. All rooms within the building are air-conditioned at the coolest temperature level. The hot water in the building is supplied by an electrical water heating system.

1. Discuss FIVE issues related to energy inefficiency.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

[10 marks]

2. Choose any THREE of the issues identified in Question 1 and justify their inefficiency.

[9 marks]

3. Recommend a solution for EACH inefficiency in response to issues identified in Question 2 and, in EACH case, cite green engineering principles as the basis for your recommendation.

[9 marks]

4. Define EACH of the following terms.

Renewable energy _____

_____

_____

_____

_____

Energy efficiency _____

_____

_____

_____

_____

Carbon footprint _____ _____

_____

_____

_____

_____

Passive cooling _____

_____

_____

_____

_____

Insulation _____

_____

_____

_____

_____

[5 marks]

5. Identify TWO possible renewable energy solutions that may be employed at the building.

_____

_____

_____

_____

[2 marks]

6. List THREE factors that would influence the choice of renewable energy solutions.

_____

_____

_____

_____

[3 marks]

7. Explain how ONE of the recommendations identified in Question 3 can reduce the carbon footprint of the building.

_____

_____

_____

_____

[2 marks]

Total 40 marks

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GREEN ENGINEERING

UNIT 1 PAPER 032

MARK SCHEME

SPECIMEN PAPER

GREEN ENGINEERING

UNIT 1 - Paper 032

MARK SCHEME

SPECIMEN PAPER

Question	Syllabus Objective	Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
1. Issues related to energy inefficiency.	Unit 1, Module 1 Specific Obj. 1, 5 and 13	i. **Resource consumption** is a critical component of energy inefficiency. All materials are made using some form of energy consequently these resources have a carbon footprint which must be considered and properly managed when utilizing materials any project or process. ii. **Energy consumption** is also a critical component of energy inefficiency. While similar to resource consumption, energy consumption refers to the way in which energy is consumed. This must be taken into consideration and equally used in considerate proportion to avoid over utilization or energy wastage which will result to energy inefficiency. iii. **Pollution** – is the introduction of contaminants into the natural environment that may cause adverse change. Pollution can take the form of chemical substances or energy such as noise, heat or light. iv. **Carbon footprint** refers to the holistic consideration of all material and energy inputs in making a process or project successful. Carbon footprint in the context of energy inefficiency considers the lifecycle	Any five, 2 marks EACH		10	

GREEN ENGINEERING

UNIT 1 - Paper 032

MARK SCHEME

SPECIMEN PAPER

Question	Syllabus Objective	Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
		from production to how each resource is broken down in the environment after practical usage. v. **Efficient use of materials** is an essential component of energy inefficiency while a material or energy source may be abundant, accessible and have a low carbon footprint over usage of the commodity may result in wastage or pollution consequently efficient use of materials must be considered to avoid misuse or over usage. vi. **Passive Cooling** This is a cooling design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or no energy consumption				
2. Justification of inefficiencies.	1 and 5	**Efficient use of materials** i. The first issue related to the case study is painting a building in dark grey. Dark colours traps and store heat, this will result in significantly higher utilization of air conditioning to cool the facility consequent of the colour chosen to paint the building. Light colours repel light energy and consequently trap less heat **Passive cooling**	Any THREE, 3 marks EACH		9	

GREEN ENGINEERING

UNIT 1 - Paper 032

MARK SCHEME

SPECIMEN PAPER

Question	Syllabus Objective	Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
		ii. A flat roof is not aerodynamic and consequently not conducive to passive cooling of the facility as a result more air conditioning or artificial air circulation will be required to circulate fresh air in the building. **Resource consumption** iii. A flat concrete roof restricts the natural flow of water and tends to collect water which might result in leakage. This may have been the justification for using tar on the roof to seal potential leakage space. A slant roof would more easily facilitate water flow and reduces the risk of water being absorbed through the concrete. A slant roof might also eliminate the need for applying tar to the surface. **Energy consumption** iv. The glass windows at the main lobby should be utilized to allow natural lighting in the building. Blinds or window curtains should be opened and artificial light usage discontinued. Usage of artificial lights drives up the cost for electricity for the facility. Also natural lighting is better for human eyes and long term vision.				

GREEN ENGINEERING

UNIT 1 - Paper 032

MARK SCHEME

SPECIMEN PAPER

Question	Syllabus Objective	Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
		Pollution v. The rooms in the building should not be cooled to the coolest temperature; it should be moderated using proximity and/or occupancy sensors where the AC unit is only used when the room is occupied. **Carbon footprint** vi. The facility should utilize a solar water heater for instead of an electrical water heating system. This will reduce the energy consumption for the facility and capitalize on the tropical climate and relatively warm Caribbean days.				
3. Solutions for inefficiencies based on green engineering principles.	Unit 1, Module 2 Spec Objective 1	i. Use lighter colours to ensure that less energy is used in the building for cooling the facility. Green engineering principle is Prevention instead of treatment. Prevent or minimize the need for cooling the facility. ii. Blinds or window curtains should be opened and artificial light usage discontinued. Usage of artificial lights drives up the cost for electricity for the facility. This will allow the building to capitalize on the green engineering principle of maximizing efficiency iii. The rooms in the building should not be cooled to	Any THREE, 3 marks EACH		9	

GREEN ENGINEERING

UNIT 1 - Paper 032

MARK SCHEME

SPECIMEN PAPER

Question	Syllabus Objective	Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
		the coolest temperature; it should be moderated using proximity and/or occupancy sensors where the AC unit is only used when the room is occupied. This will ensure that energy is supplied as demanded or green engineering principle of Output – Pulled versus Input – Pushed where the AC dictates the temperature and the time it operates. Integrate material and energy flows. iv. A slant roof is more environmentally friendly and facilitates a cooler space versus a flat roof. Integrating this design will facilitate greater energy flow rather than. This speaks to the green engineering principle of integrating material and energy flow. v. A slant roof would more easily facilitate water flow and reduces the risk of water being absorbed through the concrete. A slant roof would also eliminate the need for applying tar to the surface the green engineering principle of preventing the possibility of the roof absorbing water rather than the having a flat roof and applying tar to prevent the roof from absorbing water. vi. The facility should utilize a solar water				

GREEN ENGINEERING

UNIT 1 - Paper 032

MARK SCHEME

SPECIMEN PAPER

Question	Syllabus Objective	Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
		heater instead of an electrical water heating system. This will reduce the energy consumption for the facility and capitalize on the tropical climate and relatively warm Caribbean days. This speaks to the green engineering principle of renewable rather than depleting.				
4. Definition of terms i. Renewable energy	Unit 2, Module 2, SO 3a	Energy that is collected from resources which are naturally replenished on a human timescale. These resources include sunlight, wind, rain, tides and geothermal heat	1 mark EACH	5		
ii. Energy efficiency	Unit 2, Module 2, SO 3a	Energy efficiency refers to utilizing less energy to provide the same service or product.				
iii. Carbon footprint	Unit 1, Module 1, SO 12a	The total set of greenhouse gas emissions caused by an individual, event, organization, product expressed at CO2 e				
iv. Passive cooling	Unit 2, Module 3, SO 1	This is a building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or nil energy consumption.				
v. Insulation	Unit 2, Module 2, SO 8	Insulation is added to buildings for comfort and energy efficiency. It helps in maintaining the indoor temperature by keeping cool/warm air out and keep cool/warm air in as needed by the proprietor.				
5. Energy solutions	Unit 1, Mod 3, SO 2 and 4	i. Solar thermal water heating ii. Wind technology to	Any TWO, 1 mark		2	

GREEN ENGINEERING

UNIT 1 - Paper 032

MARK SCHEME

SPECIMEN PAPER

Question	Syllabus Objective	Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
		provide electricity for the facility iii. Solar panels to provide electricity for the facility	EACH			
6. Factors that influence the choice of renewable energy solution.	Unit 1, Mod 3, SO 4 and 7	i. Ensure there is adequate space on roof to facilitate solar thermal water heaters ii. Ensure adequate wind energy assessments are executed using an anemometer to measure wind speed to ensure facility has sufficient wind to sustain wind energy production. iii. Analyze site to ensure minimal solar exposure criteria is met of at least 4 hours sunlight per day for 85% of the year.	Any THREE, 1 mark EACH		3	
7. Explanation of recommendations for reducing the carbon footprint.	Unit 1, Module 1, SO 12a	Using a solar water heater versus an electrical water heater will ensure that the facility utilize less energy to provide warm water for outlets on the property. This electrical energy used to warm the water is provided by a utility company. 90% of the utility companies in the Caribbean generate energy by burning fossil fuel which affects our environment. This is a critical factor to the carbon footprint of each drop of hot water produced by the solar	2		2	

GREEN ENGINEERING

UNIT 1 - Paper 032

MARK SCHEME

SPECIMEN PAPER

Question	Syllabus Objective	Suggested Response	Mark Allocation	Marks		
				KC	AK	PS
		water heater at the facility.				
			TOTAL 40 MARKS	**5**	**35**	

TEST CODE **02265010**

SPEC 2015/ 02265010

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SPECIMEN PAPER

Unit 2 – Paper 01

1 hour 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This test consists of 45 items. You will have 1 hour and 30 minutes to answer them.
2. Each item in this test has four suggested answers lettered (A), (B), (C), (D). Read each item you are about to answer and decide which choice is best.
3. Look at the sample item below.

Sample Item

Which of the following is an approach to solving human challenges by using patterns and strategies from nature?

(A) Robotics
(B) Symbiosis
(C) Biodiversity
(D) Biomimicry

Sample Answer

The best answer to this item is "biomimicry" so (D) has been shaded.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

1. Which of the following origins distinguishes natural polymers from other materials?

(A) Plants, animals or minerals only
(B) Organic materials only
(C) Plants and animals only
(D) Organic and some inorganic materials only

2. The utilization of natural organic fibres can be justified as more sustainable engineering materials than traditional synthetic organic materials because

(A) natural polymers are naturally growing
(B) natural polymers biodegrade after their service life
(C) natural polymers can withstand the natural environment
(D) natural polymers do not pollute the natural environment

3. In which of the following states are both organic and inorganic engineering materials utilized?

(A) Solid, liquid and in composite form only
(B) Solid, gas and liquid form only
(C) Solid form only
(D) Composite form only

4. Which of the following statements BEST describes embodied energy?

(A) Energy used to acquire materials from extraction to disposal
(B) Energy used to acquire sustainable material from extraction to disposal
(C) Energy used to acquire inorganic materials from extraction to disposal
(D) Energy used to acquire organic materials from extraction to disposal

5. Which of the following characteristics MUST sustainable inorganic and organic materials exhibit?

I. Renewability
II. Durability
III. Ready availability

(A) I and II only
(B) I and III only
(C) II and III only
(D) I, II and III

6. Which of the following BEST describes the term 'renewable energy'?

(A) Low cost energy supply
(B) Low pollution
(C) Replenishable supply
(D) Unlimited supply

7. All organic and inorganic materials are made up of

(A) electrons and protons only
(B) elements only
(C) compounds and mixtures only
(D) molecules only

8. Why are natural bio-polymers used in engineering design less damaging to the environment?

(A) They are lower in toxicity than man-made materials.
(B) They do not require processing.
(C) They are less reactive.
(D) They do not degrade.

GO ON TO THE NEXT PAGE

9. Key factors affecting green energy applications for sustainability can be listed as a lack of

(A) public awareness, societal support and financing
(B) equipment, societal support and financing
(C) proper policy, technology and financing
(D) technology, societal support and financing

10. Which of the following is a natural source of renewable energy?

(A) Wind turbine
(B) Solar panel
(C) Hydro generator
(D) Earth's soil

11. Which of the following statements BEST describes solar energy?

(A) Abundant for a short time during the day only
(B) Stored over time in many different natural resources
(C) Is present in the form of chemical binding energy of organic substances
(D) Is present in the form of chemical binding energy of inorganic substances

12. What is the average efficiency of a domestic PV solar panel?

(A) Less than 10%
(B) 15%
(C) 20%
(D) More than 20%

13. Solar and geothermal energy are the sources of renewable energy captured from

(A) the stars and earth
(B) the moon and earth
(C) space and the stars
(D) space and the moon

14. Renewable sources of energy include biofuels. Which of the following are types of biofuels?

(A) Landfill gas, sewage gas, refuse and organic products
(B) Landfill gas, sewage gas, refuse and inorganic products
(C) Landfill gas, sewage gas, refuse and solid products
(D) Landfill gas, sewage gas, refuse, all natural products

15. The temperature of a given weight of material tells us how much energy that material contains. Which of the following statements defines temperature?

(A) The average energy of macroscopic motions of a single particle in the system per degree of freedom
(B) The unique physical property that determines the direction of heat flow between two objects placed in thermal contact
(C) The unique physical property that determines the heat flow between two objects placed in thermal contact
(D) The average energy of microscopic motions of a liquid, air and solid in the system

16. You are asked to design a mobile robot for the fire department capable of automatically identifying a fire and extinguishing the flames. Which of the following core sensors should the robot have?

I. Temperature sensor
II. Motion sensor
III. Obstacle sensor

(A) I and II only
(B) II and III only
(C) I and III only
(D) I, II and III

17. Which of the following water treatment processes is the MOST energy intensive?

(A) Distillation
(B) Reverse osmosis
(C) Filtration
(D) Desalination

18. Which of the following is the correct sequence of events in the product design process?

(A) Idea – Simulation – Prototype – Manufacturing – Testing – Commissioning – Commercialization
(B) Idea – Simulation – Prototype – Testing – Manufacturing – Commercialization – Commissioning
(C) Idea-Prototype – Simulation – Testing – Manufacturing – Commercialization – Commissioning
(D) Idea – Simulation – Prototype – Testing – Manufacturing – Commissioning – Commercialization

Items **19–21** refer to the following scenario.

Mr Brown is an elderly carpenter who was recently diagnosed with a back problem. In his small workshop he works around a 4 ft table where he cuts the wood, and a 2 ft table where he carves his design in the board. Mr Brown would like a chair designed to prevent him from standing for long periods around the 4 ft table and reduce the need to bend over the 2 ft table.

19. What are the three core principles of product design that should be considered when designing this chair?

(A) Flexibility in use, size and space utilisation, simple and intuitive
(B) Equitable in use, flexible in use, low physical effort
(C) Simple and intuitive, equitable in use, flexible in use
(D) Tolerance for error, low physical effort, simple and intuitive

20. What is the most critical feature the chair should possess to meet the needs of Mr Brown when he is working around the two tables?

(A) Adjustable height
(B) Back support
(C) Head rest
(D) Arm support

21. Which of the following materials would be MOST appropriate for use in designing the chair for Mr Brown?

(A) Plastic
(B) Wood
(C) Metal
(D) Aluminium

22. At which stage of product design would you assess different materials?

(A) Testing
(B) Prototyping
(C) Researching
(D) Final design

23. Apple recently completed its iPhone 6s. The company selected 1000 persons to use the product for five months and provide feedback on product features and user interface. At what stage of product design is Apple currently?

(A) Product commercialization
(B) Product testing
(C) Prototype development
(D) Product commissioning

24. Which of the following is the difference between pilot testing and product testing?

(A) Pilot testing refers to the first release of the product while product testing is done before manufacturing.
(B) Pilot testing refers to testing done after making the prototype while product testing is done after manufacturing.
(C) Pilot testing refers to testing the product with a selected batch of users after manufacturing while product testing is done when preparing for commercialization.
(D) Pilot testing is done after researching appropriate materials while product testing is done when customers provide their feedback.

25. Which of the following scenarios BEST describes bio-mimicry?

(A) A chameleon changing his colour to match that of a leaf on a tree
(B) A ninja dressed in white when fighting in the snow
(C) An army camouflage to match the forestry background when going on a mission
(D) A spider's web used to catch its prey

26. Mr Johnson rears cattle on the south of Canada where it snows from October to February. During this period, transportation to the farm is restricted by snow filled roadways. What bio-mimicry technique could he employ to safeguard against food shortage for the animals?

(A) Spider web technique to capture prey
(B) Ants food gathering technique
(C) Queen bee technique to find nectar
(D) Whale survival technique to feed on tiny preys

27. The Shinkansen Bullet Train in Japan produces a gunshot like sound when emerging from tunnels due to a change in pressure which negatively affects passengers. A redesign of the front of the train can be emulated from nature. Which of the following would BEST inform the redesign?

(A) Whale travelling at a high speed underwater
(B) An eagle descending from a high altitude to catch its prey
(C) Birds flying in unison and creating a V-shape during flight
(D) A fish-eating bird that quickly darts under water

GO ON TO THE NEXT PAGE

28. An intelligent electric power grid communicates with various parts to identify power outages and regulate power to support the system. What element of nature does this intelligent power grid mimic?

(A) An ant sending a signal when he finds food
(B) Bee sensing what the colony needs to get done and playing its part to support the hive
(C) Birds flying in unison and alternating who goes to the front
(D) Fish swimming in unison and avoiding predators

29. You would like to make a high-rise building, located in a Caribbean territory where hurricanes and storms are an annual occurrence. Which two elements of bio-mimicry can assist with the stability of your tower and restrict water from entering your building?

(A) Spider web design for a solid structure and fish fin overlay to prevent water from entering
(B) Bird wings aerodynamic design to maintain stability during high wind and spider web design for a solid structure and foundation
(C) Trees swaying in the wind to reduce stress on branches and fish fin overlay to prevent water from entering
(D) Trees swaying in the wind to reduce stress on branches and spider web design for a solid structure and foundation.

30. When searching for a lost plane in the middle of the Pacific Ocean which bio mimicry technique may be employed?

(A) Owl's exquisite night vision
(B) Bat's sonar sensing
(C) Eagle's sharp vision
(D) Whale-like high pressure submarine

31. Which of the following contributes to the highest reduction of the overall demand of electricity in the average office??

(A) Use of mechanical ventilation
(B) Replacing AC units with lower SEER ratings
(C) Use of LED lights rather than incandescent bulbs
(D) Use of solar water heaters

32. Which of the following is/are the MOST critical consideration(s) in calculating the carbon footprint of a motor vehicle?

I. Fuel type (diesel, ethanol or electric)
II. Quantity of carbon dioxide emitted
III. Miles per gallon

(A) I only
(B) II only
(C) I and II only
(D) II and III only

33. The Mid-Summer High School is located in the dusty desert, the classrooms are hot and the lights are constantly on due to the construction of the building. To make students more comfortable, which of the following sustainable energy solutions could be implemented?

(A) Air ventilated roof design
(B) Large, clear windows for natural lighting and passive cooling
(C) Reconstructing the classrooms using materials that will repel heat and stay cool
(D) Installing solar air conditioners and LED light bulbs

34. Which of the following can be used by an intelligent home energy system to aid the reduction of electrical energy consumed in the home?

I. Automatically open and close blinds to regulate sunlight in each room
II. Automatically detect location of occupants to optimize temperature control
III. Control appliances to reduce idle energy

(A) I and II only
(B) I and III only
(C) II and III only
(D) I, II and III

35. Which of the following represents a more efficient use of the energy of a laptop?

I. Unplug laptop charger from power outlet when not in use
II. Unplug charger from laptop when battery is fully charged
III. Remove battery from computer when charger is plugged in

(A) I and III only
(B) I and II only
(C) II and III only
(D) I, II and III

36. Which of the following packaging options is most environmentally friendly for a bottled drink?

(A) Glass
(B) Plastic
(C) Ceramic
(D) Cardboard box

37. Whether it is an office, educational institution or household, lighting consumes a major portion of electric power (about 20 to 50%) in the world. Thus, it is very important that lighting in a workplace should be proper, adequate and efficient.

Which of the following summarizes the important techniques to minimize energy use in a building?

(A) Analysis of lighting intensity,
(B) Proper design of buildings and lighting systems
(C) Use of incandescent lamps and fixtures
(D) Minimize the daylight to reduce artificial light consumption

38. An energy audit was conducted at an old office building and a number of faults which result in increased air conditioning (AC) usage were identified.

Which of the following are the three MOST practical recommendations that could be made to reduce AC consumption.

I. Redesign the building to utilize passive cooling.
II. Clean AC vents.
III. Install a solar system for the AC unit.
IV. Close windows and doors when the AC is ON.
V. Install sensors to ensure the AC only runs when the building is occupied.

(A) I , II and IV only
(B) II, III and V only
(C) II, IV and V only
(D) III, IV and V only

39. While auditing the office building, the property owner complains of high energy bills and ask for a single recommendation that can result in a reduced monthly energy bill.

Which of the following would be the MOST suitable recommendation?

(A) Install solar panels to produce energy
(B) Install a wind turbine to produce energy from the wind space
(C) Utilize energy efficient best practices
(D) Engage in rain water harvesting and recycling techniques

40. Riverland is a rural community with two large rivers but no electricity because of its remote location and distance from the electricity grid. Riverland's community leader writes to a consultancy company asking for ways in which the community could use the power from the river.

Which of the following is the BEST recommendation to meet the needs of the community?

(A) Install a hydroelectric generator in the river to produce energy.
(B) Install a pump to supply homes in the community with water from the river.
(C) Create a dam so the community can build a water park and earn from tourism.
(D) Install underground pipes from the rivers to supply farms in the community with water.

41. Which of the following is an advantage of the integration of artificial and natural daylight?

(A) Decreased power savings and reduced pollution

(B) Enhanced sustainability and the psychological benefits for occupants during both day and night
(C) Provision of sufficient light for the particular tasks at the particular time
(D) Retention of sustainability during the day and night especially for the Caribbean environment

42. Which of the following is the most effective measure to minimize energy use in buildings?

(A) Building size and orientation, passive solar design, and the use of natural lighting
(B) Building colour and orientation, passive solar design, and the use of natural lighting
(C) Building shape and orientation, passive solar design, and the use of natural lighting
(D) Building height and orientation, passive solar design, and the use of natural lighting

43. Heat energy can be transferred from the building envelope (walls, roof and floor) through the processes of conduction, convection, radiation and

(A) melting
(B) freezing
(C) boiling
(D) evaporation

44. Which of the following BEST represents the most sustainable design attributes that may be utilized to reduce energy consumption in a Caribbean office space?

I. Large windows to capitalize on natural lighting
II. Passive cooling for ventilation and temperature control
III. Solar panels or wind turbines to provide power for the facility

(A) I and II only
(B) II and III only
(C) I and III only
(D) I, II and III

45. Which of the following is NOT an energy efficient solution for commercial buildings?

(A) Using LED units
(B) Using single glazed windows
(C) Using motion sensors to control lighting
(D) Turning off equipment when the building is not occupied

Item	Specific Objective	Key	Item	Specific Objective	Key
1	2.1.6	A	26	2.2.8	B
2	2.1.2	B	27	2.2.8	C
3	2.1.1	B	28	2.2.8	B
4	2.1.12	A	29	2.2.8	C
5	2.1.7	D	30	2.2.8	B
6	2.1.4	C	31	2.3.3	C
7	2.1.6	B	32	2.3.3	D
8	2.1.7	A	33	2.3.1	A
9	2.1.4	C	34	2.3.1	D
10	2.1.3	D	35	2.3.1	B
11	2.1.3	B	36	2.3.4	D
12	2.1.3	B	37	2.3.1	B
13	2.1.3	A	38	2.3.1	C
14	2.1.3	A	39	2.3.1	C
15	2.1.2	B	40	2.3.1	A
16	2.2.4	C	41	2.3.1	B
17	2.2.2	D	42	2.3.1	C
18	2.2.5	D	43	2.3.1	D
19	2.2.1	A	44	2.3.1	C
20	2.2.3	A	45	2.3.4	B
21	2.2.5	D			
22	2.2.5	C			
23	2.2.5	D			
24	2.2.5	B			
25	2.2.7	C			

TEST CODE **02265020**

SPEC 2015/ 02265020

C A R I B B E A N E X A M I N A T I O N S C O U N C I L

CARRIBEAN ADVANCED PROFICIENCY EXAMINATION®

GREEN ENGINEERING

SPECIMEN PAPER

Unit 2 – Paper 02

2 hours 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of SIX questions in THREE sections.
2. Answer ALL questions.
3. Write your answers in the spaces provided in this booklet.
4. DO NOT write in the margins.
5. If you need to rewrite any answer and there is not enough space to do so on the original page, you must use the extra lined page(s) provided at the back of this booklet. **Remember to draw a line through your original answer.**
6. **If you use the extra page(s) you MUST write the question number clearly in the box provided at the top of the extra page(s) and, where relevant, include the question part beside the answer.**

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

SECTION A

MODULE 1

UTILIZATION OF SUSTAINABLE MATERIALS AND ENERGY

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

The utilisation of sustainable materials and energy is a key aspect of green engineering.

1. (a) List FOUR factors to be considered in selecting sustainable materials for the building envelope.

_____

_____

_____

_____

[4 marks]

(b) List TWO organic and THREE inorganic materials which are commonly used for the construction of the building envelope.

_____

_____

_____

_____

_____

[5 marks]

(c) Discuss the advantage of using natural bio-polymers over synthetic polymers as limited life material for ground engineering in the Caribbean environment.

_____

_____

_____

_____

[3 marks]

(d) An external wall of a building is composed of 105 mm brick (k = 0.84); 65 mm cavity (Rcav = 0.18); 105 mm lightweight concrete block (k = 0.20); 15 mm lightweight plaster (k = 0.16). Take (internal resistance) Rsi as 0.12 and (external resistance) Rse as 0.05.

(i) Calculate the thermal transmittance (U value) of the following construction:

L/K = R for lightweight concrete blocks and bricks

Total resistivity (R_{tot})

U = 1/(R_{tot})

_____

_____

_____

_____

[4 marks]

(e) Discuss the role of a cavity in a wall and its deficiencies in reducing heat transmittance.

_____

_____

_____

_____

[4 marks]

Total 20 marks

2. All forms of energy we use today are stored in different ways in the energy sources. These sources are divided into two groups: renewable and non-renewable

(a) List FOUR types of energy sources and indicate the origin of EACH.

_____

_____

_____

_____

_____

_____

_____

_____

[8 marks]

(b) For the types of energy sources listed in (a), identify TWO potential negative consequences on the environment for EACH.

_____

_____

_____

_____

_____

_____

_____

_____

[8 marks]

(c) Produce a graph that demonstrates the behaviour of organic solid building material under stress (strain vs tensile strength).

_____

_____

_____

_____

_____

_____

_____

_____

[4 marks]

Total 20 marks

SECTION B

MODULE 2

SUSTAINABLE DESIGNS

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

Sustainable design involves creating products and engineering infrastructure that aim to reduce human impact on ecological systems.

3. (a) Identify THREE of the principles related to product design and briefly explain EACH.

_____

_____

_____

_____

_____

_____

_____

_____

_____

[6 marks]

(b) Explain the concept of bio-mimicry.

_____

_____

_____

_____

[2 marks]

(c) A ship transporting cargo from the Caribbean to Europe sank in the Pacific Ocean 20 years ago. Using the product design process and the concept of bio-mimicry, design a product that will help to find the ship. Your design should:

(i) Highlight and briefly explain the element from nature your product will adopt.

_____

_____

_____

_____

[2 marks]

(ii) State how your product will matriculate through the first two stages of the product design process.

_____

_____

_____

_____

[2 marks]

(iii) At the prototype development stage of the product, outline an experiment that could be undertaken to understand the basic relationship between time and the possible distance of the lost ship.

_____

_____

_____

_____

_____

_____

_____

_____

[6 marks]

(iv) Show how your product can be used to find the ship.

_____

_____

_____

_____

[2 marks]

Total 20 marks

4. (a) The government of your country is interested in introducing electric vehicles.

(i) Highlight TWO benefits of this introduction other than the reduction of carbon dioxide in the environment.

_____

_____

[2 marks]

(ii) How can the implementation of electric vehicles reduce the quantity of carbon dioxide in the environment?

_____

_____

_____

_____

[4 marks]

(iii) Electric vehicles can indirectly contribute additional carbon dioxide to the atmosphere during their daily operation. Explain how this is possible.

_____

_____

_____

_____

_____

[4 marks]

(iv) State how the problem in (a) (iii) can be mitigated.

_____

_____

_____

_____

[2 marks]

(b) (i) Define the term ‘rainwater harvesting’.

_____

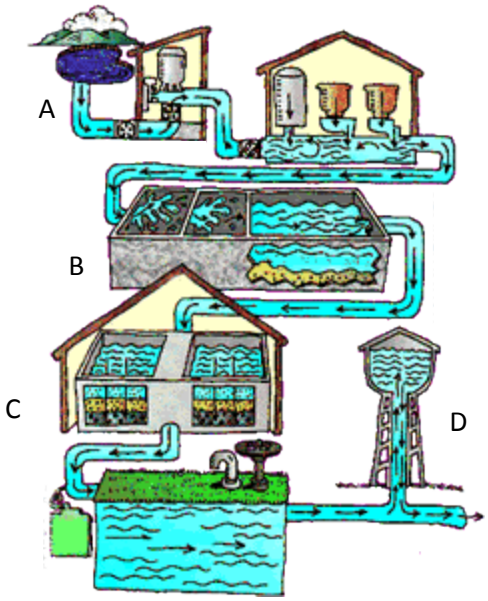
_____

_____

_____

[2 marks]

Figure 1 shows the process for the collection of rainwater.



(ii) Identify EACH of the stages of the process labelled A, B, C and D.

_____

_____

_____

_____

[4 marks]

(iii) Briefly explain any ONE of the stages identified in (b) (ii).

_____

_____

_____

_____

[2 marks]

Total 20 marks

SECTION C

MODULE 3

GREEN ENGINEERING SOLUTIONS

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

5. (a) Your community is embarking on a project to construct low-cost residential buildings. You are required to advise the community on appropriate guidelines for selecting materials and give advice on how to manufacture sustainable/green Portland cement concrete (PCC):

(i) List FIVE guidelines used to select sustainable materials for the building envelope.

_____

_____

_____

_____

_____

[5 marks]

(ii) State TWO reasons why Portland cement concrete is suitable for the construction of the building envelope.

_____

_____

[2 marks]

(iii) Using a labelled strain–strength sketch, explain the limitation of using Portland cement.

_____

_____

_____

_____

[2 marks]

(iv) Explain briefly, using specific examples, TWO measures to reduce energy consumption during the production of PCC.

_____

_____

_____

_____

[4 marks]

(v) Sketch a section of a simple suspended reinforced concrete beam. Clearly justify the role of reinforcement in the Portland cement concrete matrix

_____

_____

_____

_____

[4 marks]

5. (b) Identify the THREE methods used to reduce embodied energy during the manufacture of Portland cement.

_____

_____

_____

_____

[3 marks]

Total 20 marks

6. (a) The choice and location for an electric power station involves several technical and non-technical considerations. Identify SIX vital professional and non-professional judgements to be considered.

_____

_____

_____

_____

_____

_____

_____

[6 marks]

(b) Name FOUR features to be followed in order to maintain efficiency in using electricity

_____

_____

_____

_____

[4 marks]

(c) Combined lighting is the integration of artificial and natural daylight which has the advantage of saving fuel and power. At the same time, sufficient light is provided for tasks at all times. Draw a neat, labelled sketch of a room to show how the natural light and artificial lights are integrated. Show the combined lighting.

[10 marks]

Total 20 marks

C A R I B B E A N E X A M I N A T I O N S C O U N C I L

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEYS AND MARK SCHEME

MAY/JUNE 2015

SPECIMEN PAPER

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 1.

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
2:1:1	(a) • Cost • Availability • Durability • Toxicity • Embodied energy • Pollution (1 mark for any FOUR)	4	4		
2:1:2	(b) • Timber (processed and unprocessed) • Vegetable fibre (processed and unprocessed) • Tree sap • Animal skin • Animal hair • Plastics (PVC,Polyproplene, ABS, Polycarbonate,) (1 mark for any TWO) • Steel • Aluminium • Copper • Zinc • Lead • Glass • Brass (1 mark for any THREE)	5	5		
2:1:5	(c) • Natural bio-polymers biodegrade after service life • The materials are readily available in the Caribbean • Less fossil fuel used on manufacturing them • Material is renewable • Reduced pollution of the ground water • No disposal fees • Low manufacturing costs (1 mark each for any THREE)	3	3		

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 1. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
2:1:2	(d) • 1 mark each for calculating L/K = R for lightweight concrete blocks and brick • 1 mark for calculating total resistivity (R_{tot}) • 2 marks for calculating $U=1/(R_{tot})$	4		4	
2:1:3	(e) <u>Role</u> • Cavity is filled with air which acts as an insulator • Cavity as part of material reduces weight density ratio • Cavity can be used as communication channels (for example, cables for telecommunication) (2 marks for minimum 2) <u>Deficiencies</u> • Can transfer heat by convection • Can create air leakage • Can result in condensation if not properly sealed (2 marks for minimum 2)	4		4	
	TOTAL 20 MARKS		**12**	**8**	**0**

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 2.

<table>
<tr><th rowspan="2">S.O</th><th rowspan="2">Suggested Response</th><th rowspan="2">Mark Allocation</th><th colspan="3">Marks</th></tr>
<tr><th>KC</th><th>AK</th><th>PA</th></tr>
<tr><td>2:1:4</td><td>(a)

<table><tr><th>Energy Source</th><th>Origin</th></tr><tr><td>Fossil fuel</td><td>Organic matter</td></tr><tr><td>Hydrogen</td><td>Hydrogen atoms</td></tr><tr><td>Wind</td><td>Air/wind</td></tr><tr><td>Solar</td><td>Sun</td></tr><tr><td>Hydro</td><td>Water</td></tr><tr><td>Geothermal</td><td>Ground/hot water</td></tr><tr><td>Tidal/wave</td><td>Water,(sea, ocean lakes)</td></tr><tr><td>Biofuels</td><td>Organic matter</td></tr><tr><td>Nuclear</td><td>Atoms</td></tr></table>
(1 mark each for any FOUR types of energy sources)
(1 mark each for any FOUR origins)</td><td>8</td><td>8</td><td></td><td></td></tr>
<tr><td>2:1:5</td><td>(b)

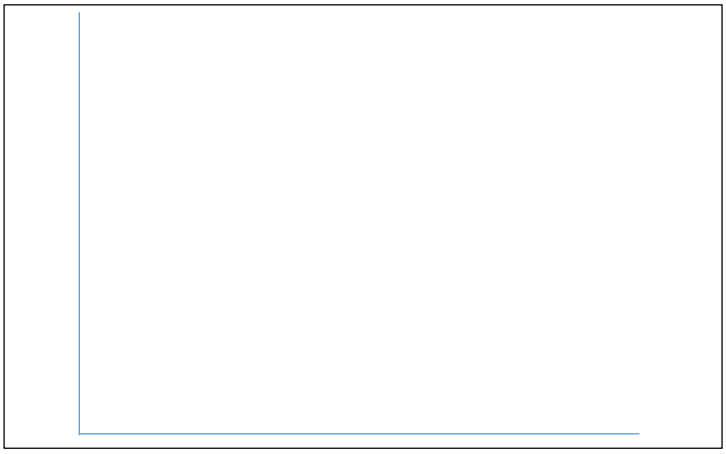
<table><tr><th>Type of Energy</th><th>Potential Negative consequences on Environment</th></tr><tr><td>Fossil fuel</td><td>Air pollution, acid rain, ozone depletion, global warming potential</td></tr><tr><td>Hydrogen</td><td>Thermal and chemical changes in atmosphere, influence on microorganisms in soils and water, accelerated corrosion of man-made structures</td></tr><tr><td>Wind</td><td>Landscape change, soil erosion, reduced air circulation and deterioration of local air quality</td></tr><tr><td>Solar</td><td>Landscape change, soil erosion, reduced solar irradiation for plants and vegetation</td></tr><tr><td>Hydro</td><td>Changes in local eco-systems and local weather conditions, social and cultural impact, induction of earthquake</td></tr></table></td><td>8</td><td>8</td><td></td><td></td></tr>
</table>

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 2. (continued)

<table>
<tr><th rowspan="2">S.O</th><th rowspan="2">Suggested Response</th><th rowspan="2">Mark Allocation</th><th colspan="3">Marks</th></tr>
<tr><th>KC</th><th>AK</th><th>PA</th></tr>
<tr><td>2:1:5</td><td>
<table>
<tr><th>Type of Energy</th><th>Potential Negative consequences on Environment</th></tr>
<tr><td>Geothermal</td><td>Landscape change, underground water resource, accelerated cooling of earth core</td></tr>
<tr><td>Tidal/wave</td><td>Landscape change, reduced water motion/circulation and deterioration of local water quality</td></tr>
<tr><td>Biofuels</td><td>May not be CO_2, neutral, may release global warming gases like methane during the production of biofuels, landscape change, deterioration of soil productivity</td></tr>
<tr><td>Nuclear</td><td>Radiation leakage and contamination; the disposal and safe storage of nuclear waste for hundreds of years up to a hundred thousand years in geological repositories</td></tr>
</table>
</td><td></td><td></td><td></td></tr>
<tr><td>2:1:3</td><td>(c)
 
2 marks for each labelled axis
2 marks for labelled graphs – quasi-brittle failure showing breaking point</td><td>4</td><td></td><td>4</td><td></td></tr>
<tr><td colspan="3">TOTAL 20 MARKS</td><td>16</td><td>4</td><td>0</td></tr>
</table>

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 3.

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
2:2:1	(a) • Equitable in use – the design is useful and marketable to people with diverse abilities. • Flexibility in use – the design accommodates a wide range of individual preferences and abilities. • Simple and intuitive – use of the design is easy to understand regardless of the user's experience, knowledge, language skills or current concentration level. • Perceptible information – the design communicates necessary information effectively to the user regardless of ambient conditions or the user's sensory abilities. • Tolerance for error – the design minimizes hazards and the adverse consequences of accidental or unintended action. • Low physical effort – the design can be used efficiently and comfortably and with a minimum of fatigue. • Size and space for approach and use – Appropriate size and space is provided for approach, reach, manipulation and use regardless of user's body size, posture or mobility. 1 mark for principle and 1 mark for definition	6	3	3	
	(b) The design and production of materials, structures and systems that are modelled on biological entities and processes.	2	2		

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 3. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
2:2:8	(c)(i) Animals utilize what is called echolocation or bio sonar. This is the biological sonar used by several kinds of animals. Echolocating animals emit calls to the environment and listen to the echoes of those calls that return from various objects near them. They use these echoes to locate and identify the objects.	2		2	
2:2:5	(c)(ii) Concept development – The idea is to model echolocation used by animals to locate an object in the sea. Product simulation – Utilize computer software (E.g. MATLAB) to observe how sound waves travel	2		2	
2:2:6	(c)(iii) Experiment to understand basic relationship between time and possible distance of the lost ship: Create a simple electrical prototype using a computer speaker and built-in microphone. Take computer to a large empty space such as an auditorium along with a stop watch. Open sound wave software on computer. Standing 100m from auditorium wall, play a loud sound on computer and look for a change in sound wave when echo is detected. Start stopwatch when audio sound (preferably a bang like sound) is played by computer and stop stopwatch when echo is detected by sound wave software. Repeat experiment at 150 m, 200 m and 250 m from wall and record the respective times. If a computer is inaccessible you can clap and listen for echo.	6			6

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 3. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
2:2:8	(c)(iv) Place the product under the bottom of a search boat **(1).** Navigate the search boat within the 2 mile radius the lost ship was last observed **(1).** Whenever the bio sonar detects the sunken ship the distance on the bio sonar will be less compared to the previous distance of the water depth. Divers or submarines can then be deployed to investigate the specific area.	2		2	
		TOTAL 20 MARKS	**5**	**9**	**6**

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 4.

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	(a)(i) Reduction of greenhouse gas Reduce importation of fuel for transportation Reduce carbon footprint of travel industry (1 mark each for any TWO)	2	2		
	(a)(ii) Motor vehicles utilize different forms of fuel to power the engine. These fuels are burnt by the engine to power the vehicle. During this process carbon dioxide is produced and emitted to the atmosphere. Electric vehicles would reduce the need for fuel and do not give off carbon emission during their operation. OR Motor vehicles utilize fuel which is imported. This imported fuel is transported by ships. While travelling to the Caribbean from their source country, these ships burn fuel to power themselves. During this process large quantities of carbon dioxide are released into the environment. Electric vehicles eliminate the need for fossil fuel hence no carbon emission during transportation of fuel to supply the vehicles.	4		4	
	(a) (iii) Electric vehicles utilize electrical energy to recharge batteries in order to operate. This electrical energy is generated by a power plant which normally utilizes fossil fuel in the energy generation process. To provide additional energy for electric vehicle these power plants use more fossil fuel and hence emit more carbon dioxide to the atmosphere.	4		4	

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 4. (continued)

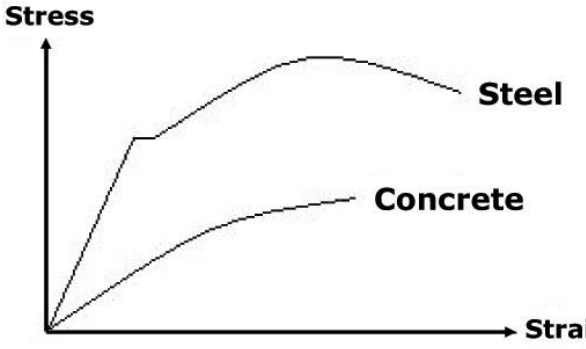
S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	(a) (iv) This can be mitigated by utilizing renewable energy to recharge the car batteries	2		2	
	(b)(i) Rainwater harvesting is the accumulation and deposition of rainwater for reuse on-site, rather than allowing the rainwater to run off.	2	2		
	(b) (ii) A - Coagulation B - Sedimentation C - Filtration D – Storage	4	4		
	b) (iii) Coagulation removes dirt and other particles suspended in water. Sedimentation – Using gravity to remove suspended solids from water. Solid particles entrained by the turbulence of moving water may be removed naturally. Filtration – The water passes through filters, some made of layers of sand, gravel and charcoal that help remove even smaller particles missed by sedimentation. Storage – Water is placed in a preferably closed tank or reservoir in order for disinfection to take place.	2	2		
	TOTAL 20 MARKS		**10**	**10**	**0**

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 5.

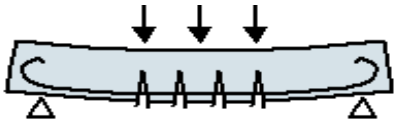
S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	(a)(i) • Analyse fully the product specifications and determine the minimum acceptable values for all relevant material properties. • Make first selection by eliminating all materials which do not possess all the minimum criteria • Assess the degree of relative importance of the various required properties from essential through desirable for each property • Place the potential materials in ranking order • Evaluate material and process costs for each material • Optimize to determine the materials which give the best overall combination of properties for the least cost	5	5		
	(a) (ii) • Availability of the materials for the manufacturing of PCC • Low cost materials	2	2		
	(a) (iii)  Concrete is brittle and cannot accommodate plastic deformation as steel does. Lower strains will cause concrete to fail.	2		2	

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 5. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	(a) (iv) Explanation of measures to reduce energy consumption during production of PCC should include: • Use recycled aggregates • Use cement replacement • Mix concrete at the construction site	4		4	
	(a) (v)  Suspended reinforced concrete beam • Labelled sketch of the suspended beam. **(2 marks)** • Reinforcement placed in the lower part of the beam as shown in the diagram. **(2 marks)**	4		4	
	(b) Methods that can be used to reduce the embodied energy during the manufacture of Portland cement are: • Use renewable energy • Use cement replacement materials to manufacture the cement • Use locally available materials to produce clinker • Use liquefied natural gas instead of diesel (1 mark each for any THREE)	3	3		
	TOTAL 20 MARKS		**10**	**10**	**0**

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 6.

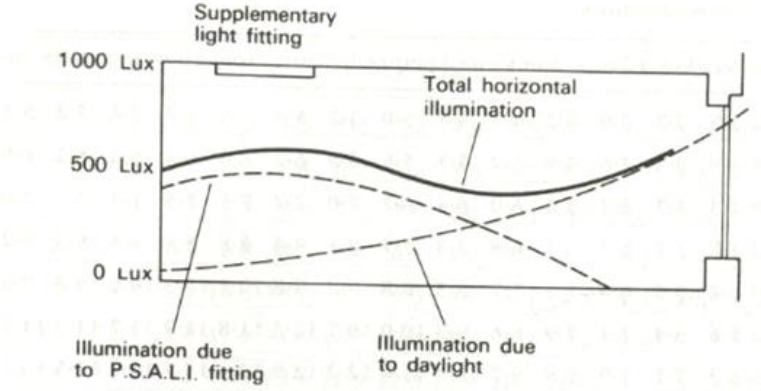
S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	(a) • Land elevation • Fuel supply • Water supply • Road and rail access • Height of the structure • Disposal of the waste products • Proximity to populated areas • Environmental implications (1 mark each, any SIX)	6	6		
	(b) • Maintenance of the equipment which are using electricity • Redesign to reduce energy costs • Avoid waste – switch off unwanted power • Monitor and control • Power factor correction (1 mark each, any FOUR)	4	4		

GREEN ENGINEERING

UNIT 2 - PAPER 02

KEY AND MARK SCHEME

Question 6. (continued)

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	(c)	10			
					
	Labelled Sketch			1	
	Curves showing natural lighting			3	
	Curves showing artificial lighting			3	
	Curves showing combined lighting			3	
		TOTAL 20 MARKS	**10**	**10**	**0**

TEST CODE **02265032**

SPEC 2015/ 02265032

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SPECIMEN PAPER

Unit 2 – Paper 032

2 hours 30 minutes

READ THE FOLLOWING IINSTRUCTIONS CAREFULLY.

1. This paper consists of a case study.
2. Read the case and use the information to complete the design concept.
3. All answers must be written in this booklet.
4. You are advised to take some time to read through the paper and plan your answers.
5. You may use silent, electronic, non-programmable calculators to answer questions.

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

CASE STUDY

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

The Bailey Bot Home Security robot is a mobile security robot that automatically navigates around the home to record video images. The robot can only traverse on surfaces of a uniform height. You have been employed by the company to redesign the robot to allow it to fly in order to traverse various heights and take protective action to affect or scare intruders.

The following information is required.

Project Title _____

_____

_____

_____

[1mark]

Background _____

_____

_____

_____

_____

[2marks]

Objective _____

_____

_____

_____

_____

[1mark]

Problem Statement _____

[2marks]

Benchmark _____

[2marks]

Relevance _____

[3 marks]

Creativity and Innovation

[8 marks]

Content and Knowledge of Project

[15 marks]

Project Plan and Design _____

[6 marks]

Total 40 marks

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UNIT 2 - PAPER 032

KEYS AND MARK SCHEME

MAY/JUNE 2015

SPECIMEN PAPER

GREEN ENGINEERING

UNIT 2 - PAPER 032

KEY AND MARK SCHEME

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	Title Home Security Flying Robot	1			
	Background of Project The Bailey Bot Home Security robot is a mobile security robot that automatically navigates around the home to record video images. The robot can only traverse on surfaces of a uniform height.	2			
	Objective Design a quadcopter robot capable of flying around the home and producing a high-frequency sound which scares an intruder away.	1			
	Problem Statement It is very expensive to have a camera in each room of the house. Camera systems only produce video images of an intruder.	2			
	Benchmarking The Bailey Bot Home Security robot is a mobile security robot that automatically navigates around the home to record video images. The robot can only traverse on surfaces of a uniform height and cannot defend itself or protect the home.	2			

GREEN ENGINEERING

UNIT 2 - PAPER 032

KEY AND MARK SCHEME

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	Relevance Crime and robbery is a major deterrent to economic growth across the Caribbean. An innovative flying robot capable of deterring thieves from entering a property or stealing items after entering will boost our economy. This robot will reduce crime related to robbery and encourage economic development. A mobile camera system will reduce the cost of having a camera in each room. This robot will fly around to locations in the house where motion is detected and record images. The very awareness of this innovation will deter potential thieves.	3			
	Creativity and Innovation The quadcopter security robot will be made from plastic and powered by a 9 volt battery and a mini solar panel. Plastic is a light material and hence would require less battery power during flight. Using mini solar panels on the flying robot will allow the harnessing of energy from ambient lighting entering the building. The robot will also be able to self charge by landing at a charging location to recharge the batteries.	8			
	Content and Knowledge of Project To reduce the embodied energy in the manufacturing of the robot, recycled plastic will be utilized for making the robot. This will reduce the environmental impact.	15			

GREEN ENGINEERING

UNIT 2 - PAPER 032

KEY AND MARK SCHEME

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	Discuss policy in manufacturing (incentive, tax, land admin, public safety, legislation) Policy and legislation will be an important component of accelerating sales of the robot. Incentives such as tariff removal for solar panels and batteries will reduce inputs and increase cost efficiency. Tax breaks during manufacturing will also incentivize the realization of the robot. Public safety policy will also benefit the industry by providing parameters under which quadcopters can fly in the presence of humans and not harm them. There are a number of principles of product design that the product will employ such as: Flexibility in use Simple and intuitive – No extensive experience will be needed to operate the robot. It will be designed to simply be placed in the home and start working autonomously, sending video images to a desired smartphone or website. Tolerance for error – The robot will be designed to operate under harsh conditions and around children. Low physical effort – The robot will require very little physical effort or concentration to commission by the customer. Size and space for approach – The robot will be small so it would be able to navigate small areas. How bio-mimicry aid the product design – The robot will use bio-sonar technology adopted from animals such as bats that use echolocating. This will be done by using a sensor that emits a sound at a specific frequency and listens for feedback. This will help to locate walls, fixtures and other elements in and around the home.				

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UNIT 2 - PAPER 032

KEY AND MARK SCHEME

S.O	Suggested Response	Mark Allocation	Marks		
			KC	AK	PA
	Project Plan and Design Sequence of product design (a) Product testing/evaluation – The product will be tested in the lab for two months to ensure that it works as designed. (b) Product commissioning – Fifty users from across the Caribbean will be selected to sample the robot and provide feedback on its operation.	6			
		TOTAL 40 MARKS			