University of Toronto
Faculty of Applied Science and Engineering
Final Examination, December 11, 2015
Duration: 2.5 hours
APS111H1 F and APS113Y1 Y - Engineering Strategies & Practice 1

Calculator Type: 4 (No electronic or mechanical devices permitted)
Exam Type: A (Closed book, no aids permitted)
Course Coordinator: Micah Stickel
Communication Coordinator: Peter Weiss
Module B Coordinator: Jacinta O'Brien

Instructions:
This is a closed book exam; no calculators or aids are permitted, except for a translation-only non-electronic dictionary, i.e., direct word-to-word translations but no definitions.

To start: Fill out both the answer sheet (scan sheet) and the exam booklet (blank lined booklet) with:

- Your name
- Your student number
- Your course (APS111 or APS113)
- Today's date
- You do not need to fill out the course instructor or form code.

There are two parts to the exam: multiple-choice questions, and a writing component.

Multiple-Choice (60%):

- There are a total of 34 multiple-choice questions, each of which is worth about 1.7 marks, for a total of 60 marks worth 60% of the exam.
- Answer this part on the answer sheet (scan sheet).
- Read each question carefully and provide the **most correct answer** on the answer sheet: do not answer the multiple-choice questions on these exam question pages.
- **Only one answer is to be given for each question**.
- There is no penalty for incorrect answers.
- Be sure to fill out the answer sheet clearly with no overlaps, using a pencil.
- Erase any errors completely.

Writing Component (40%):

- The second part of the exam is a writing component worth 40% of the exam.
- Answer this part in the exam booklet: **do not** answer the written component questions on these exam question pages.
- Carefully follow the instructions.

When you are done the exam, insert the answer sheet (scan sheet) into the exam booklet and hand in both together. You may keep the question pages.

Part 1: Multiple-choice questions (60%)

1. Hydrogen has been proposed as a fuel for internal combustion engines, in part because the only emissions are heat and water. However, hydrogen is difficult to store, it takes up too much volume at room temperature, and is dangerous when compressed. To overcome these difficulties, nanotubes can be used. Nanotubes offer a very large surface area within a very small volume; however, they are very costly. Scientists have demonstrated that heating waste chicken feathers creates structures that are almost identical to nanotubes at a much lower cost, thereby offering an economically and technically feasible alternative to nanotubes. Using the waste chicken feathers to store hydrogen is an example of which one of the 3Rs?
   a. Reduce.
   b. Reuse.
   c. Recycle.
   d. Renew.

2. Professional engineering in Canada is a self-regulated profession. The philosophy underlying self-regulated professions is that the members of the profession are the most appropriate group of individuals to determine the standard of professional competence and ethics required to protect the public. Professional engineering is also a "closed" profession. This means that professional engineering in Canada is:
   a. Available to only a limited number of practitioners because there is an upper limit to the number of professional engineering licenses there are in Ontario.
   b. Restricted to only those individuals who are deemed qualified to be professional engineers.
   c. Open only to applicants who have graduated from an accredited engineering program.
   d. A very expensive career path.

3. Researchers at the Delft University of Technology have developed "bioconcrete" using a type of bacteria that is naturally found in highly alkaline lakes or inside certain rocks. When the bacteria are added as an ingredient to concrete, the bacteria induce the formation of calcite, which can stop the formation of cracks. Using bacteria to prevent the formation of cracks in concrete is an example of which of the following?
   a. Biomagnification.
   b. Pollution Control.
   c. Sustainability.
   d. Biomimicry.

4. A by-law is:
   a. A law made by a municipal government that applies within its own boundaries.
   b. A provincial law that applies to municipalities.
   c. A law that applies to retail stores.
   d. A federal regulation.

5. Which statement best describes bioaccumulation?
   a. The entry of persistent toxic substances into the environment.
   b. The build-up of persistent toxic substances in the fatty tissues of organisms.
   c. The concentration in the tissues of an organism of substances occurring in the environment.
   d. The increase in the concentration of a substance in the tissues of organisms at successively higher levels in a food chain.

6. In designing the Telehealth system, Intel Corporation considered a number of issues about the users of the system, including their age, their lack of technology awareness and limited computer skills, their isolation, and their lack of mobility. Which of the following statements best describes Intel Corporation's approach?
   a. Balancing economy, environment and social considerations.
   b. Accounting for social considerations in design.
   c. Stakeholder engagement.
   d. Changing cultural values.

7. Which of the following definitions for Adaptive Capacity is **TRUE**?
   a. An industrial system that emulates an efficient, sustainable natural system.
   b. The ability of a product or system to adjust to changing environmental conditions.
   c. Using a graphic decision chart and a weighted decision matrix to choose among alternatives.
   d. A rigorous method for analyzing the production, operating, and end-of-life environmental costs for a technology in terms of mass and energy.

8. In Ontario law, good character comprises three components, including the courage to do what is right, no matter the personal consequences. This component of the Ontario law is also referred to as which of the following?
   a. Due diligence.
   b. Code of Ethics.
   c. Whistle-blower clause.
   d. Professional Engineers Ontario.

9. Lead occurs naturally in the environment and is an important element used in paints, pipes, and car batteries. Lead is also released back into the environment during lead battery recycling. Exposure to moderate concentrations of lead can cause neurological damage, especially in children. A company is considering different locations for a new lead battery recycling facility. As part of the economic evaluation, the company's design engineer estimated the cost to provide health care to children who live near the lead battery recycling facility. What is this type of cost?
   a. Fixed Cost.
   b. Internal cost.
   c. External cost.
   d. Variable cost.

10. Sustainability is defined as the intersection of economic, environmental, and social considerations, as shown in **Figure 1**. It is also possible to define the intersection of each pair of considerations. Which one of the following describes the intersections of (A) environmental and social considerations, (B) economic and social considerations, and (C) economic and environmental considerations?
    a. "A"=Vulnerable; "B"=Feasible; "C"=Fair".
    b. "A"=Feasible; "B"=Viable; "C"=Equitable".
    c. "A"=Beneficial; "B"=Equitable; "C"=Viable".
    d. "A"=Beneficial; "B"=Exponential; "C"=Questionable".

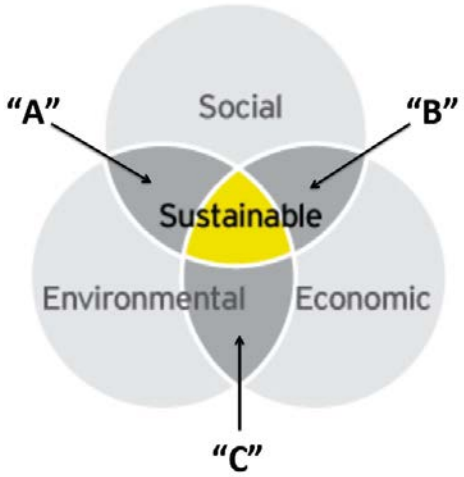

Figure 1. Chart for Question 10.

11. Which of the following statements about present worth is **TRUE**?
    a. Present worth relies on simple interest calculations and a fixed interest rate.
    b. Present worth is only used for private sector engineering design projects.
    c. Present worth cannot be applied to external costs and benefits.
    d. Present worth is calculated by discounting future cash flows.

12. Which of the following statements about laws is **TRUE**?
    a. It is mandatory for design engineers to comply with legislation and regulations, but there is no legal requirement for design engineers to comply with policies or guidelines.
    b. When there is a federal election and the political party that is elected changes, all federal laws must also change.
    c. The City of Toronto and the International Organization for Standardization (ISO) can create laws.
    d. Due diligence is not relevant to engineering designs.

13. Based on the Brundtland Commission definition of sustainable development, which of the following statements is **TRUE**?
    a. Sustainable development does not affect rare or endangered species.
    b. Sustainable development enables future generations to meet their needs.
    c. Sustainable development meets the needs of people in developing countries.
    d. Sustainable development will help the Lego Group to build the new sustainability centre.

14. **Figure 2** shows a graphical representation of costs as a function of output. Which of the following statements is **TRUE**?
    a. Line 0-X represents the fixed cost and Line X-X represents the variable cost.
    b. Line 0-Y represents the variable cost and Line X-Z represents the total cost.
    c. Line 0-X represents the indirect cost and Line X-X represents the total cost.
    d. Line X-Z represents the fixed cost and Line X-X represents the total cost.

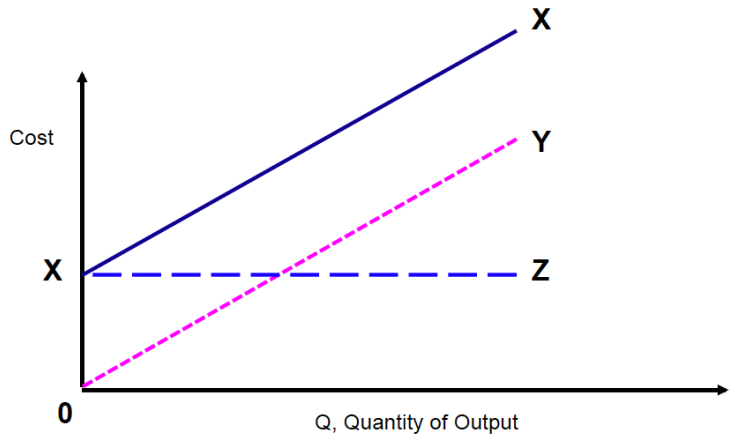

Figure 2. Chart for Question 14.

15. Which one of the following statements best describes compounds that are biodegradable?
    a. Compounds that are biological.
    b. Compounds that cause harm to humans.
    c. Compounds that remain in the environment.
    d. Compounds that break down via natural processes.

16. NGOs, such as Greenpeace and the Conference Board of Canada, are stakeholders that may have an interest that is affected by your design. NGO stands for:
    a. Next Generation Optimization.
    b. New Government Organization.
    c. Non-Governmental Organization.
    d. Nouveau Gouvernement de l'Ontario.

17. Life cycle assessment is different from industrial ecology because:
    a. Life cycle assessment ends with the final disposal of the product, whereas industrial ecology considers uses for the product after the end of the products service life.
    b. Life cycle assessment has been applied to many different products and systems, but industrial ecology has only been applied at Kalundborg, Denmark.
    c. Life cycle assessment applies to products and industrial ecology is restricted to large-scale industries.
    d. Life cycle assessment identifies waste emissions, whereas industrial ecology identifies waste emissions as inputs to other industrial processes.

18. The supply of and demand for labour, the cost of a barrel of crude oil, and the Bank of Canada interest rate are all examples of what type of factors?
    a. Microeconomic.
    b. Macroeconomic.
    c. Triple Bottom Line.
    d. Engineering Economic.

19. Which one of the following statements about stakeholders is **TRUE**?
    a. For private sector projects, the government has limited interest and little influence.
    b. Design engineers can ignore the public because they usually have little interest and no influence.
    c. The Ontario Environmental Assessment Act does not require stakeholder consultation.
    d. For public sector projects, where the government is the client, the government has high interest and high influence.

20. A group of designers has been given the task of improving the ticket vending machine for the Austrian Railway. They spend some time watching how passengers interact with the current design, considering the steps the passengers followed, the amount of time it took and the mistakes made. This process is:
    a. Task analysis.
    b. Snapshot.
    c. Participatory design.
    d. Organizational Human Factors.

<<More questions on next page>>

21. Team X is “storming” – their first assignment did not receive the grade they had hoped. Now they are trying to agree on a schedule and work breakdown, but one member, Lee, is getting angry at Jackie. The rest of the team does not understand why. Jackie is saying she can make it to any of the meetings, but she is sitting with her arms folded in front of her, not making eye contact and speaking without inflection. This shows that, in communication,
    a. Words often have more influence than body language and tone.
    b. Tone often has more influence than words and body language.
    c. Body language and tone often have more influence than words.
    d. Body language, tone and words all have equal influence.

Q22 - 34 pertain to Case Study #1: Lego Goes Sustainable located in Appendix A.

22. The Lego Group conducted two life cycle assessments (LCAs): one for the existing fossil fuel-based plastic and one for a new plastic that uses corn as the primary ingredient. The Lego Group limited the scope of each LCA to raw material extraction, raw material transport, formation of the plastic, and toy brick production. The LCAs followed procedures described in ISO 14040 and ISO 14044, and collected and assessed information about air and water emissions, solid waste generation, and energy requirements for each type of plastic. The results of the LCAs indicated that neither type of plastic was environmentally preferable. This means the LCAs:
    a. Should be redone at the Lego Group's sustainability centre.
    b. Provide information about current processes and can serve as baselines when the Lego Group conducts future LCAs.
    c. Must have a different scope to ensure the results identify which plastic is less environmentally harmful.
    d. Were a waste of time and money.

23. The Lego Group has factories in Denmark, Hungary, the Czech Republic, and Mexico. It will soon open a new factory in China. The Lego Group uses a cost index published by Thomson Reuters / Jefferies CRB to account for the wages paid to workers who make the toy bricks at the different factory locations. By using a cost index the Lego Group is able to account for which one of the following factors?
    a. Inflation.
    b. Present worth.
    c. Regional Variation.
    d. Time value of money.

<<More questions on next page>>

24. LEGO® toy bricks have a very high product safety rating, with zero product recalls every year for the last 5 years. To demonstrate this high level of safety to consumers in Canada who buy the toy bricks for their children, the Lego Group relies on:
    a. Demand-side legislation.
    b. Children who volunteer to test the toy bricks.
    c. Certification by the Canadian Standards Association.
    d. Plastic that is formed using fossil fuels extracted from the Alberta oil sands.

25. The Lego Group has hired you as the chief design engineer to locate and build the new sustainability centre. Instead of locating the new centre in Billund, the Lego Group has chosen a location on the island of Vadehavet, which is about 120 kilometres west of Billund off the west coast of Denmark. The site is remote with a local population of less than 100 residents, and is currently without road access. Your assignment is to identify and evaluate all the steps required to access the site, build the new sustainability centre, and establish transport routes for bringing workers and materials to the centre. As part of your assignment, which of the following should you do?
    a. Assume Canadian design practices and standards can be applied.
    b. Not worry about the local residents, since the new sustainability centre will take precedence and the Lego Group will pay for the residents to be relocated to the Danish mainland.
    c. Avoid developing a range of options because the shortest distance to the new centre will have the least cost and must be chosen as the preferred design.
    d. Consider the possible impacts of the new sustainability centre and its operations on local residents and the local environment.

26. LEGO® toy bricks are made in manufacturing facilities that incur a number of different types of costs. Which one of the following statements about the costs of the toy bricks is **TRUE**?
    a. The cost of the plastic used to the produce the toy bricks represents a fixed operating cost.
    b. Rent and taxes paid for the manufacturing facility are variable costs.
    c. The cost of advertising LEGO® toy bricks is a direct cost.
    d. Workers wages are an indirect cost.

<<More questions on next page>>

27. As a design engineer, you have been asked by the Lego Group to investigate the possibility of implementing an industrial symbiosis (industrial ecology) as one of the criteria for evaluating different locations for the new sustainability centre. You know that many global companies have manufacturing facilities located in Billund, including Bang & Olufsen, Ecco, and CCI Europe. You agree to use the criterion, but you want to ensure the Lego Group fully understands the principles, so you explain that one of the following statements about industrial ecology is **FALSE**:
    a. Most inputs should be obtained through recycling.
    b. Industries should minimize the use of materials and energy.
    c. Products should be designed so they have a finite service life.
    d. Products and processes can produce residuals, but not wastes.

28. During the production of LEGO® toy bricks, excess heat is released into the atmosphere as the heated plastic is injected into the moulds. The Lego Group estimates the annual amount of waste heat is sufficient to meet the energy needs of 500 households. The Lego Group has hired you as the design engineer to build a system to capture the excess heat and convert it to electricity. Which of the following terms best describes what you have been asked to do with the excess heat?
    a. Reuse.
    b. Reduce.
    c. Recover.
    d. Renewable.

29. The year is 2030, and you have been hired as a design engineer by the Lego Group to work at their sustainability centre. You have been experimenting with different materials that could be used instead of the fossil-fuel based plastic, and you have identified 3 potential substitutes: milk protein, polycaprolactone (PCL), and silica. The Lego Group has given you 3 objectives for the new sustainable material: (1) heat resistance up to 310°C, (2) compatibility with existing toy brick moulds, and (3) manufacturing costs using the new sustainable material not to exceed current costs. To compare how well the different materials satisfy the objectives, you propose to use a decision-making method. Which of the following statements best describes which method you will use and why?
    a. Multi-voting, because it is simple to use and provides a high degree of confidence.
    b. Graphic decision chart, because it can be used for more than 2 objectives.
    c. Pugh Method, because it is simple to use and works best with only a few alternatives.
    d. A risk-based model, because it is simple to use and captures the significant risks involved in changing the plastic used for the toy bricks.

30. As the design engineer hired by the Lego Group, you plan to use the scale shown in **Table 1** to evaluate the new sustainable materials against the 3 objectives of (1) heat resistance up to 310°C, (2) compatibility with existing toy brick moulds, and (3) manufacturing costs using the new sustainable material not to exceed current costs. The Lego Group has determined the weight for each objective, and this information is shown in **Table 2**, which also shows the value you have assigned to each alternative to indicate how well it meets each objective. Using a weighted matrix method, which of the following recommendations would you make to the Lego Group?
    a. Milk protein is the preferred new sustainable material because it was the alternative with the highest weighted score.
    b. PCL is the preferred new sustainable material because it satisfies all 3 objectives equally.
    c. Silica is the preferred new sustainable material because it was the alternative with the highest weighted score.
    d. None of the alternatives are preferred because the standard deviation of the results is less than 10%.

Table 1 for Question 28.

Scale	Value
Does not meet the objective	0
Somewhat meets the objective	2
Mostly satisfies the objective	5
Almost completely satisfies the objective	8
Fully satisfies the objective	10

Table 2 for Question 28.

Objective	Weight	Values for Each Alternative		
		Milk Protein	PCL	Silica
(1) Heat resistance up to 310°C	2	2	5	10
(2) Compatibility with existing toy brick moulds	6	8	5	5
(3) Manufacturing costs using the new sustainable material not to exceed current costs	3	2	5	2

31. What price should the Lego Group charge for the toy bricks so that the payback period is equal to the time between now and the opening of the new sustainability centre, assuming the number of toy bricks sold annually remains constant?
    a. 0.02¢ per toy brick.
    b. 0.03¢ per toy brick.
    c. 0.038¢ per toy brick.
    d. 0.0002¢ per toy brick.

32. The Lego Group has decided to build a manufacturing facility in Ontario. They are using the same production processes as all the other factories that build LEGO® toy bricks, including the same packaging. Recently, the Ontario government announced new legislation that will come into effect in 2030 that would make manufacturers legally responsible for the packaging they use for their products. Since LEGO® toy bricks come in cardboard boxes, this means the Lego Group:
    a. Must implement pollution prevention to control the production of the cardboard packaging.
    b. Can create a program to recycle the packaging.
    c. Will close their Ontario manufacturing facility because complying with the new law will be too costly.
    d. Does not have to do anything because the legislation is not mandatory.

33. After graduating in 2019, you relocated to Denmark and began working for the Lego Group, rising from an entry level position as a design engineer to the head of the research and development department. In your current role, you supervise a team of chemical, electrical, industrial and materials engineers working on new LEGO® products and you have responsibility for developing raw material specifications and negotiating raw material prices. A former U of T classmate works for a plastics manufacturer and has contacted you about becoming a supplier. The Lego Group has a policy that states all suppliers should be evaluated through a competitive process, except under special circumstances. Vendors must pay the Lego Group to participate in the process. Your classmate has offered you a cash payment (equal to half the cost of participating in the competitive process) if you allow your classmate's company to become a supplier to the Lego Group without going through the competitive process. What action should you take and why?
    a. Allow your classmate's company to bypass the competitive process, but do not accept the cash payment.
    b. Talk to your boss about the policy to find out if your classmate's company qualifies for the special circumstance exemption.
    c. Encourage the classmate to follow the competitive process and do not accept the cash payment because doing so would put you in a conflict of interest.
    d. It does not matter what you do because you are not a licensed professional engineer and a policy is not a legal requirement.

<<More questions on next page>>

34. A new LEGO® design engineer proposes an “out-of-the-box” idea for the sustainable toy bricks – they will be the same sizes and weights as the current bricks but look completely different. His supervisor challenges this idea on the basis of how humans interact with technology – her reasoning is:
    a. On a political level, the new shapes look like aircraft control mechanisms and therefore should not be used.
    b. On a psychological level, the new toys are more intuitive when they look like the existing toys.
    c. On a physical level, the shapes the designer is proposing will require new shapes of packaging.
    d. On a social level, the company is doing enough by introducing sustainability – it does not need more ideas.

End of questions pertaining to Case Study #1: Lego Goes Sustainable located in Appendix A.

End of multiple-choice questions.

<<Long-answer questions start on the next page>>

Part 2: Long Answer Questions (40%)

Questions 35 to 37 are based on Case Study #2: RFP for a Security System for Foldable Electric Cars, located in Appendix B.

INSTRUCTIONS: This section requires 3 written answers. Use an exam booklet, and write in your name, student number, course, and date of examination on the booklet's cover page. You may use as many pages as you need for your preliminary work, but the final answers must be no more than four (4) pages single-spaced or eight (8) pages double spaced. Clearly indicate the final copy to be graded by writing "Final Copy" at the start of it. Use full sentences and paragraphs and bullet lists where appropriate.

This section of the exam evaluates your ability to

- Communicate in clear, concise, well-organized sentences and paragraphs with minimal error
- Structure a logical argument, making clear claims and supporting them with the evidence currently available to you
- Recognize the kinds of information you would need, moving forward, to validate and better support your claims and generate specific questions to help you find that information
- Read, understand, and analyse engineering-related material under time pressure

35. Based on Case Study 2: RFP for a Security System for Foldable Electric Cars, located in Appendix B, in paragraph form (one or more paragraphs) write a concise Problem Statement in your own words. DO NOT COPY SENTENCES WORD-FOR-WORD FROM THE CASE STUDY IN YOUR PROBLEM STATEMENT. YOU WILL RECEIVE NO MARKS FOR MATERIAL COPIED WORD-FOR-WORD FROM THE CASE STUDY. (20 marks)

36. Based on Case Study 2: RFP for a Security System for Foldable Electric Cars located in Appendix B, generate Functions, Objectives and Constraints. Utilize course tools such as Functional Basis and Functional Decomposition. In total, you should have about 10 items, whether they are Primary Functions, Secondary Functions, Unintended Functions, Objectives or Constraints. Treat this like a section of a design document with a section introduction and sub-sections. Introduce each of the sub-sections (e.g. Functions, Objectives, Constraints) with a few sentences that help the reader understand their nature and significance. (15 marks)

37. Identify five key research questions you would want to answer in order to check the validity of your claims and to develop the three top objectives further. (Don't worry about whether the questions are open or closed.) (5 marks)

End of all questions for this exam.

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The appendices (case studies) start on the next page.

You may remove the appendix in order to use it when answering questions.

Appendix A: Case Study #1: LEGO® Goes Sustainable

The Lego Group first introduced its shiny, hollow-tubed plastic rectangular toy bricks in 1958.

Source: http://www.lego.com/en-us/aboutus/media-library#?filter&ids=7aa7836d702840bfb024e51c7b0b9d10

The plastic used by the Lego Group to make its toy bricks is fossil fuel-based. During the manufacturing process, the plastic is heated to between 230°C (degrees Celsius) and 310°C, and then injected into moulds. The force used to inject the heated plastic into the moulds can reach 29,000 psi (pounds per square inch). In comparison, the tire pressure for the average car does not usually exceed 43 psi. The moulds used to manufacture the toy bricks are accurate to within 0.0004 mm (millimetres). The Lego Group has factories in Denmark, Hungary, the Czech Republic, and Mexico. It will soon open a new factory in China. All LEGO® toy bricks are fully compatible with each other, regardless of when (from 1958 to today) or where they were made.

According to the Lego Group, the plastic "offers great quality, fulfills the highest safety standards, and lasts for a long time making it a very durable product". In 2014, Lego Group produced more than 60 Billion toy bricks.

In July, 2015, Lego Group announced that it will search for a new sustainable material to replace the fossil fuel-based plastic for its toy bricks. The Lego Group is investing $150 million to build a sustainability centre in Billund, a small town on Denmark's Jutland peninsula, to investigate alternative materials. The Lego Group wants to start production of its toy bricks using the new sustainable material by 2030.

Appendix B: Case Study #2: RFP for a Security System for Foldable Electric Cars

At the Toronto-based start-up, Vision 20/20 Inc., we are in the business of creating products for the future. As such, we are seeking proposals for a security device for electric folding cars. Three such automobile designs currently exist:

- The Hiroko developed by Massachusetts Institute of Technology (MIT) and a Spanish redevelopment agency, DENOKINN [1];
- The Armadillo-T developed by the Korean Advanced Institute of Science and Technology (KAIST) [2];
- The Casple Podadera developed by the Spanish business group Casple and the designer Francisco Podadera [3].

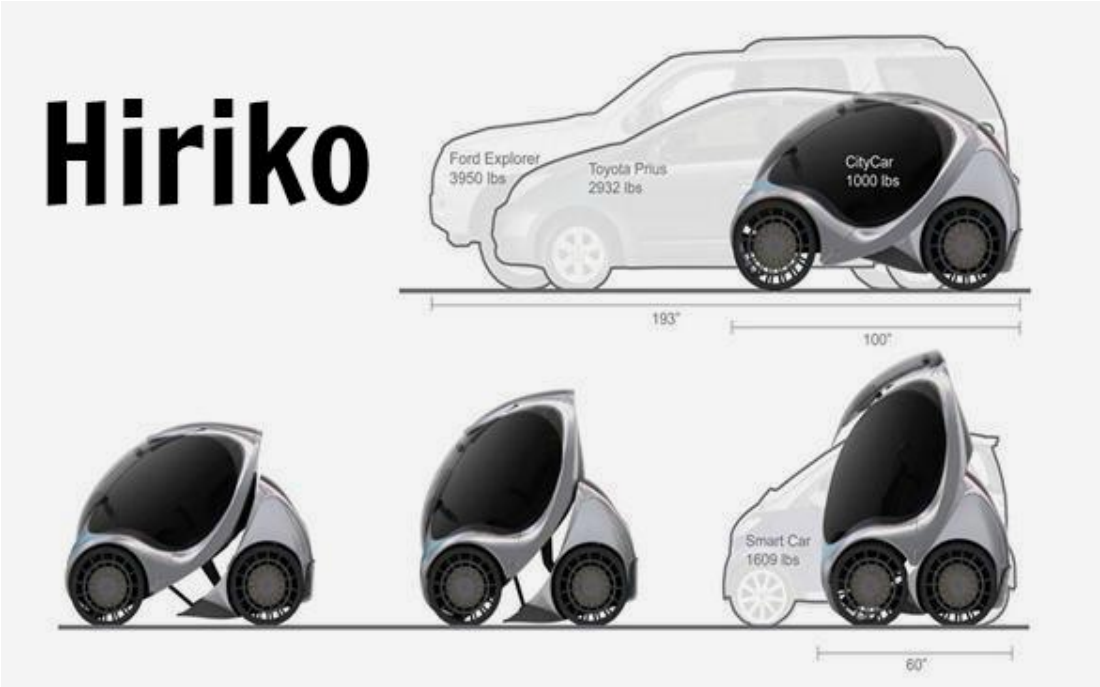

Figure 1: Diagram of Hiroko Folding car, from G. Munro [1]

Figure 2: Armadillo-T driving and folded configurations. From K. Munro [2]

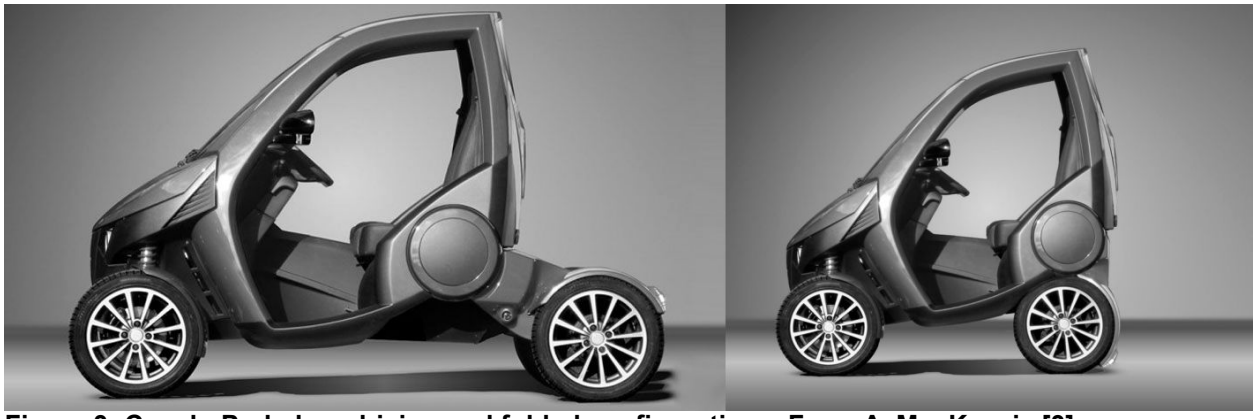

Figure 3: Casple-Podadera driving and folded configurations. From A. MacKenzie [3]

Measuring between 2.30 and 2.80 metres in use and between 1.65 and 1.90 metres when folded [1-3], these two person vehicles are the ultimate answer to the challenges of city driving and city parking! Up to three of these could fit in a conventional Toronto parking space (5.6*2.6 metres) [4]. So, how it works is, the driver finds a parking spot about a third of the size of a normal spot, gets out of the car, folds it and parks it through a smart phone app. However, at Vision 20/20, we foresee a major drawback for these cars. They are so light (the Hiroki is a mere 452Kg [1] and the Armadillo-T is 3 Kg [2] lighter than that), they could easily be lifted and carried away by a small number of strong people with a minimal amount of equipment.

So, we believe that as these new foldable electric cars start to come on the market, there will be a need for a security device that prevents unauthorized removal of the vehicle while allowing law enforcement to tow when necessary. It would also be desirable for the security system to warn the car owner in the case of the car being moved. However, any such alarm system cannot create a disturbance if the car is parked in a residential neighbourhood at night. Finally, if an electrical source or a source of energy transformable to electrical power is available, it would be an added benefit if the security system could also charge the car's battery while the car is parked. In the case of this add-on, electromagnetic systems would be preferred.

[1] G. Munro (2013 Jan 2) "New for 2013-The Hiroko-The Foldable Car!" [Online] *efergy* Available: http://efergy.com/blog/new_for_2013-the_hiroko_the_foldable_car/#

[2] K. Munro (2013 Aug 13) "Armadillo-T Foldable Electric Micro-car by KAIST" [Online] *de zeen magazine* Available: http://www.dezeen.com/2013/08/23/armadillo-t-foldable-electric-micro-car-by-kaist/

[3] A. MacKenzie (2013 Feb 18) "The Casple-Podadera City Car Knows When to Fold 'Em" [Online] *Gizmag* Available: http://www.gizmag.com/casple-podadera-folding-car/26268/

[4] City of Toronto (2014 Aug 19) *Chapter 200 Parking Space Regulations* [Online] Available: http://www.toronto.ca/zoning/bylaw_amendments/ZBL_NewProvision_Chapter200.htm

APS111&113 Fall 2015 Final Exam - Answer Key to Multiple-Choice Questions

Question	Correct Answer
MC1	C
MC2	B
MC3	D
MC4	A
MC5	B
MC6	B
MC7	B
MC8	C
MC9	C
MC10	C
MC11	D
MC12	A
MC13	B
MC14	D
MC15	D
MC16	C
MC17	A
MC18	B
MC19	D
MC20	A
MC21	C
MC22	B
MC23	C
MC24	C
MC25	D
MC26	C
MC27	C
MC28	C
MC29	C
MC30	A
MC31	A
MC32	B
MC33	C
MC34	B

After analyzing the results, the professors decided to make question #26 bonus. Students who answered it correctly received a bonus mark. Students who answered incorrectly were not penalized. The multiple-choice portion of the exam was marked out of 33 instead of 34. It's possible to score 34/33.

APS111 2015 FINAL EXAM: CIs' LONG ANSWER MARKING GUIDE

In general, what we are looking for in questions 35, 36, 37:

- Understands key course concepts well enough to write intelligently about them: functions, objectives, research questions
- Paragraph level: Communicates using cohesive, unified, well-organized paragraphs with some sentence to sentence relationship
- Sentence level: Sentences are clear, concise, and any errors do not impede comprehensibility or significantly impeded ease of reading

What we do NOT expect under exam–writing conditions:

- Research or research citations
- Metrics or goals
- Perfect grammar, super-polished writing

Question 35.

Based on Case Study 2: RFP for a Security System for Foldable Electric Cars, located in Appendix B, in paragraph form (one or more paragraphs) write a concise Problem Statement in your own words. DO NOT COPY SENTENCES WORD-FOR-WORD FROM THE CASE STUDY IN YOUR PROBLEM STATEMENT. YOU WILL RECEIVE NO MARKS FOR MATERIAL COPIED WORD-FOR-WORD FROM THE CASE STUDY. (20 marks)

Criteria	Fails (F) 9/20 and below	Below (C, D) 10-13/20	Meets (B) 14-15/20	Exceed (A) >16/20
Content	Does not recognize the actual problem. Misidentifies problem.	Recognizes some of actual problem, but does not transform it to engineering terms.	Recognizes problem, transforms it into solution-independent engineering terms.	Recognizes problem, identifies gap and transforms information entirely into solution independent engineering terms.
Organization & Presentation at sentence, paragraph & document level	Lack of organization or structure in paragraphs.	Some attempt at organization in paragraphs. Overreliance on "transition" words.	Demonstrates deliberate & consistent logical development of material	Excellent paragraph organization in paragraphs: thoughtful topic sentence skilfully developed through both sentence order and use of transition words and conjunctions

	Sentences unrelated to one another	or Inconsistent or inaccurate use of conjunctions/transition phrases	Satisfactory paragraph organization: clear relationship between topic sentences and organization of following sentences, careful choice of transition or linking strategies.	Guides the reader with appropriate use of structure, presentation, & word choices
	Overuse/dependence on language of question, case study, or definitions	Language of question and/or case study mixed with some personal language	Language of case study, questions used strategically and accurately with mostly personal language	Language of case study/questions integrated with student's language as part of the discipline discourse
	Ideas are lost as a result of poor word choice or poor sentence structure	Ideas are comprehensible with effort; everyday vocabulary dominates	Meaning is clear at paragraph, sentence, and word choice level with minimal error Sentences are simple, direct; mostly accurate use of course terms, some repetition	Meaning presented in clear, elegant, and concise prose Combination of simple and complex sentences; concise; precise and accurate use of course terms
	Major and/or frequent syntax, usage, vocabulary or language form errors	Somewhat free of syntax, usage, vocabulary or language form errors	Mostly free of syntax, usage, vocabulary or language form errors	Entirely free of syntax, usage, vocabulary or language form errors

Question 36.

Based on Case Study 2: RFP for a Security System for Foldable Electric Cars located in Appendix B, generate Functions, Objectives and Constraints. Utilize course tools such as Functional Basis and Functional Decomposition. In total, you should have about 10 items, whether they are Primary Functions, Secondary Functions, Unintended Functions, Objectives or Constraints. Treat this like a section of a design document with a section introduction and sub-sections. Introduce each of the sub-sections (e.g. Functions, Objectives, Constraints) with a few sentences that help the reader understand their nature and significance. (15 marks)

Component	Fails (F) 7/15 and below	Below (C, D) 7.5-10/20	Meets (B) 10.5-11.5/20	Exceed (A) >12/15
Introductory sentences	Does not introduce lists or introduces lists in way that is not meaningful	Uses textbook definitions	Adapts textbook definitions to specific situation	In addition to "meets" adds meaningful dimensions to introductory sentences
Functional basis	Does not provide Functional basis or provides incorrect functional basis	Provides partial functional basis – e.g. uses verb "control" rather than specific kind of control	Provides one functional basis according to form	Identifies two functional bases – one controlling mass, the other controlling information
Primary functions	Does not correctly identify primary function(s)	Identifies one primary function	Identifies two primary functions	Identifies primary functions, in language that moves beyond functional bases
Secondary functions	Does not provide relevant secondary functions	Provides some relevant secondary functions	Provides a fairly complete list of secondary functions	Provides a comprehensive list of secondary functions
Objectives	Objectives vague and/or meaningless	Some meaningful objectives given	All objectives are reasonable, not necessarily measurable	Objectives may have goals added and seem to be measurable
Constraints	Misses constraints in Client Statement	Some constraints given but may be in terms of client statement	All constraints indicated in client statement are translated into engineering language	Constraints from problem statement, in engineering language, are augmented by reasonable other constraints (laws, codes)

Question 37.

Identify five key research questions you would want to answer in order to check the validity of your claims and to develop the three top objectives further. (Don't worry about whether the questions are open or closed.) (5 marks)

- Like the PSQ assignment:
- Can students recognize what they don't know that they need to know
- I.e., Can they identify what additional information they need?
- Can they come up with some ideas on where/how to find it?
- Evaluate their ability to link questions with the claims they made in Q. 34
- To get full marks (5/5) only have to meet expectations, not exceed (exam)

FAIL 0/5	1-1.5	2-3	FULL MARKS 4-5/5
No answer Qs have no relationship to objectives discussed Questions already answered in case study	Provides 1 Q. useful for validating/developing chosen objectives	Provides 1 or 2 questions useful for validating/developing the chosen objectives	At least 3 questions All Qs. target info that would validate or develop the chosen objectives Each objective addressed by at least one question

Appendix B: Case Study #2: RFP for a Security System for Foldable Electric Cars

At the Toronto-based start-up, Vision 20/20 Inc., we are in the business of creating products for the future. As such, we are seeking proposals for a security device for electric folding cars. Three such automobile designs currently exist:

- The Hiroko developed by Massachusetts Institute of Technology (MIT) and a Spanish redevelopment agency, DENOKINN [1];
- The Armadillo-T developed by the Korean Advanced Institute of Science and Technology (KAIST) [2];
- The Casple Podadera developed by the Spanish business group Casple and the designer Francisco Podadera [3].

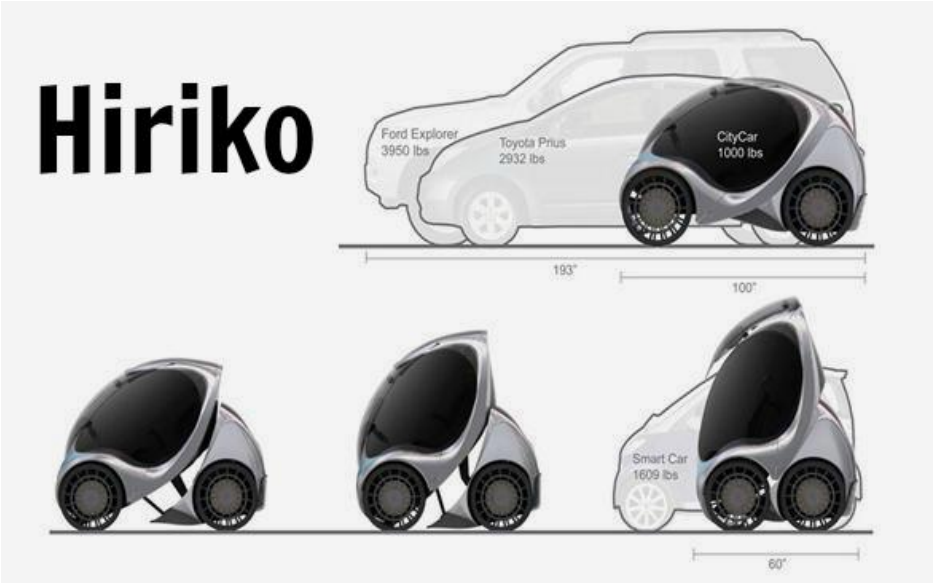

Figure 1: Diagram of Hiroko Folding car, from G. Munro [1]

Figure 2: Armadillo-T driving and folded configurations. From K. Munro [2]

Figure 3: Casple-Podadera driving and folded configurations. From A. MacKenzie [3]

Measuring between 2.30 and 2.80 metres in use and between 1.65 and 1.90 metres when folded [1-3], these two person vehicles are the ultimate answer to the challenges of city driving and city parking! Up to three of these could fit in a conventional Toronto parking space (5.6*2.6 metres) [4]. So, how it works is, the driver finds a parking spot about a third of the size of a normal spot, gets out of the car, folds it and parks it through a smart phone app.

However, at Vision 20/20, we foresee a major drawback for these cars. They are so light (the Hiroki is a mere 452Kg [1] and the Armadillo-T is 3 Kg [2] lighter than that), they could easily be lifted and carried away by a small number of strong people with a minimal amount of equipment.

So, we believe that as these new foldable electric cars start to come on the market, there will be a need for a security device that prevents unauthorized removal of the vehicle while allowing law enforcement to tow when necessary. It would also be desirable for the security system to warn the car owner in the case of the car being moved. However, any such alarm system cannot create a disturbance if the car is parked in a residential neighbourhood at night. Finally, if an electrical source or a source of energy transformable to electrical power is available, it would be an added benefit if the security system could also charge the car's battery while the car is parked. In the case of this add-on, electromagnetic systems would be preferred.

[1] G. Munro (2013 Jan 2) "New for 2013-The Hiroko-The Foldable Car!" [Online] *efergy* Available: http://efergy.com/blog/new_for_2013-the_hiroko_the_foldable_car/#

[2] K. Munro (2013 Aug 13) "Armadillo-T Foldable Electric Micro-car by KAIST" [Online] *de zeen magazine* Available: http://www.dezeen.com/2013/08/23/armadillo-t-foldable-electric-micro-car-by-kaist/

[3] A. MacKenzie (2013 Feb 18) "The Casple-Podadera City Car Knows When to Fold 'Em" [Online] *Gizmag* Available: http://www.gizmag.com/casple-podadera-folding-car/26268/

[4] City of Toronto (2014 Aug 19) *Chapter 200 Parking Space Regulations* [Online] Available: http://www.toronto.ca/zoning/bylaw_amendments/ZBL_NewProvision_Chapter200.htm

APS11113 Fall 2015 Final Exam – Explanation of Questions with which Students had Difficulty

Question	Rationale
5. Which statement best describes bioaccumulation?	
a. The entry of persistent toxic substances into the environment.	"Entry" does not describe accumulation
b. The build-up of persistent toxic substances in the fatty tissues of organisms.	"Build-up" = accumulation
c. The concentration in the tissues of an organism of substances occurring in the environment.	"Concentration" is a measure of the amount of contaminant at the time a sample is taken; it does not describe accumulation
d. The increase in the concentration of a substance in the tissues of organisms at successively higher levels in a food chain.	This is the definition of "bio-magnification" presented in the Economics 1 lecture; the key is the second part of the answer.
8. In Ontario law, good character comprises three components, including the courage to do what is right, no matter the personal consequences. This component of the Ontario law is also referred to as which of the following?	
a. Due diligence.	Due diligence is defined as "taking reasonable care to ensure all relevant standards, codes, and statues are adhered to..."; it applies more to an approach to engineering work, rather than a behavior.
b. Code of Ethics.	The Code of Ethics is a guide to appropriate behavior that is embedded in the Professional Engineers Act and Regulations.
c. Whistle-blower clause.	"Whistle-blower" clause is described as the "courage to do what is right, no matter the personal consequences", taken directly from the lecture (see Slide 18 in the November 27 lecture – I even use a large arrow to point it out).
d. Professional Engineers Ontario.	This is the organization that requires "good character".

Question	Rationale
11. Which of the following statements about present worth is **TRUE**?	
a. Present worth relies on simple interest calculations and a fixed interest rate.	Simple interest calculations and fixed interest rate can be used, but so can compound interest and variable interest rate. Furthermore, in Economics 2 lecture, I explained that most engineering (and real world) time value of money calculations are based on compound interest – see Slide 12.
b. Present worth is only used for private sector engineering design projects.	Private sector projects do not have a monopoly on present worth; it can be used for public sector, and not-for-profit sector, projects, too.
c. Present worth cannot be applied to external costs and benefits.	Present worth can be applied to any type of costs and benefits.
d. Present worth is calculated by discounting future cash flows.	This is the definition directly from Economics 2 (see Slide 14).
17. Life cycle assessment is different from industrial ecology because:	
a. Life cycle assessment ends with the final disposal of the product, whereas industrial ecology considers uses for the product after the end of the products service life.	This is a main difference between LCA and Industrial ecology: LCA ends with final disposal, but with industrial ecology, "disposal is not the end" (see lecture on Sustainability, Slide 24).
b. Life cycle assessment has been applied to many different products and systems, but industrial ecology has only been applied at Kalundborg, Denmark.	Incorrect because industrial ecology has been applied beyond Kalundborg.
c. Life cycle assessment applies to products and industrial ecology is restricted to large-scale industries.	Incorrect because LCA can be applied to systems (as well as products) and industrial ecology is not restricted to large-scale industries.
d. Life cycle assessment identifies waste emissions, whereas industrial ecology identifies waste emissions as inputs to other industrial processes.	Both LCA and industrial ecology identify waste emissions (so this is not a difference), and there is nothing to stop an LCA from concluding that waste emissions could be used as an input to another process.

Question	Rationale
26. LEGO® toy bricks are made in manufacturing facilities that incur a number of different types of costs. Which one of the following statements about the costs of the toy bricks is **TRUE**?	
a. The cost of the plastic used to the produce the toy bricks represents a fixed operating cost.	False because the amount of plastic depends on how many bricks are manufactured; the cost of plastic is a variable cost.
b. Rent and taxes paid for the manufacturing facility are variable costs.	False because rent and taxes must be paid on a regular basis (monthly, annually) no matter how many bricks are made or how many hours / days / months the manufacturing facility operates; these are fixed costs.
c. The cost of advertising LEGO® toy bricks is a direct cost.	The cost of advertising a product must be taken into consideration when determining the cost to the client.
d. Workers wages are an indirect cost.	False, because as with advertising, worker's wages are a direct cost of toy brick production.
27. As a design engineer, you have been asked by the Lego Group to investigate the possibility of implementing an industrial symbiosis (industrial ecology) as one of the criteria for evaluating different locations for the new sustainability centre. You know that many global companies have manufacturing facilities located in Billund, including Bang & Olufsen, Ecco, and CCI Europe. You agree to use the criterion, but you want to ensure the Lego Group fully understands the principles, so you explain that one of the following statements about industrial ecology is **FALSE**:	
a. Most inputs should be obtained through recycling.	This statement is TRUE: "most inputs should be obtained through recycling" (Sustainability, Slide 28, #5).
b. Industries should minimize the use of materials and energy.	This statement is TRUE: "minimize the use of materials and energy" (Sustainability, Slide 28, #3).
c. Products should be designed so they have a finite service life.	This statement is FALSE: a key principle is to design products to create other useful products at the end of the product's originally-intended service life (Sustainability, Slide 28, #6).

Question	Rationale
d. Products and processes can produce residuals, but not wastes.	This statement is TRUE (Sustainability, Slide 28, #1).
28. During the production of LEGO® toy bricks, excess heat is released into the atmosphere as the heated plastic is injected into the moulds. The Lego Group estimates the annual amount of waste heat is sufficient to meet the energy needs of 500 households. The Lego Group has hired you as the design engineer to build a system to capture the excess heat and convert it to electricity. Which of the following terms best describes what you have been asked to do with the excess heat?	
a. Reuse.	Reuse means there is "no essential change to the component in order for it to be utilized for a different purpose" (see Textbook definition, p. 594). The question specifies that the design engineer is to "build a system to capture the excess hear and convert it to electricity" – if anything, this is an example of "recycling".
b. Reduce.	Reduce means to use less – but the question is about using excess heat; there is no mention of reducing heat generation.
c. Recover.	The question specifies that the design engineer is to "build a system to capture the excess heat and convert it to electricity". This is an example of waste heat "recovery"; related to the energy from waste example described in Environment 1.
d. Renewable.	A manufacturing process is not considered a renewable energy source.

Question	Rationale
31. What price should the Lego Group charge for the toy bricks so that the payback period is equal to the time between now and the opening of the new sustainability centre, assuming the number of toy bricks sold annually remains constant?	
a. 0.02¢ per toy brick.	See calculation below.
b. 0.03¢ per toy brick.	Incorrect.
c. 0.038¢ per toy brick.	Incorrect.
d. 0.0002¢ per toy brick.	The answer is $0.0002; this amount must be multiplied by 100 to obtain the amount in cents.

Let P = price per toy brick in $

Payback period = the time between now and the opening of the new sustainability centre = assume 15 years

Number of toy bricks sold annually = assume to be # manufactured annually = 60 billion = 60 x 10^9/ year

Cost for the new sustainability centre = $150 million = $150 x 10^6

Payback period = 15 years = $\frac{Cost\ for\ the\ new\ sustainability\ centre}{Annual\ Revnue}$

Annual revenue = (Price per toy brick) x (Number of bricks sold annually)

= $\frac{\$P}{Brick}$ x $\frac{60{,}000{,}000{,}000\ Bricks}{Year}$ = $60P x 10^9/ year

Thus, payback period = 15 years = $\frac{Cost\ for\ the\ new\ sustainability\ centre}{Annual\ Revnue}$ = $\frac{\$150{,}000{,}000}{\$60{,}000{,}000{,}000P/year}$

= (15 years) x ($60,000,000,000P/year) = $150,000,000

= $900,000,000,000P = $150,000,000

= P = $\frac{150{,}000{,}000}{900{,}000{,}000{,}000}$ = $0.000167 ≈ $0.0002

There are 100¢ in $1, therefore multiply P x 100 to get the amount in cents = (100¢ / $) x $0.0002 = 0.02¢

29. The purpose of Q29 was to test the student's understanding of the different methods to choose among alternatives. The answer to Q29 is "c", and the choices come from the chart on p. 151 of the text book, which lists different decision-making models, along with the descriptions of the models on the pages thereafter.

The year is 2030, and you have been hired as a design engineer by the Lego Group to work at their sustainability centre. You have been experimenting with different materials that could be used instead of the fossil-fuel based plastic, and you have identified 3 potential substitutes: milk protein, polycaprolactone (PCL), and silica. The Lego Group has given you 3 objectives for the new sustainable material: (1) heat resistance up to 310°C, (2) compatibility with existing toy brick moulds, and (3) manufacturing costs using the new sustainable material not to exceed current costs. To compare how well the different materials satisfy the objectives, you propose to use a decision-making method. Which of the following statements best describes which method you will use and why?

a. Multi-voting, because it is simple to use and provides a high degree of confidence. ***Per the chart on p. 151 of the textbook, multi-voting is simple to use but provides a <u>low</u> level of confidence, so the statement that multi-voting provides a high degree of confidence is incorrect.***

b. Graphic decision chart, because it can be used for more than 2 objectives. ***Per the description on p. 152 and the diagram on p. 153 of the textbook, a graphic decision chart is used to compare against <u>2</u> criteria, not more than 2 as is the case here with 3 objectives identified, so the statement that the method can be used for more than 2 objectives is not correct.***

c. Pugh Method, because it is simple to use and works best with only a few alternatives. ***The Pugh method is listed under the "Simple Models" on p. 154 of the textbook, and the description in the chart on p. 151 actually states that the Pugh Method "works best with only a few alternatives", making this answer the best one of the 4 choices available.***

d. A risk-based model, because it is simple to use and captures the significant risks involved in changing the plastic used for the toy bricks. ***Per the chart on p. 151 of the textbook, risk-based models are identified as "very difficult" to use, and while this type of model will capture the risks, the first part of the answer is incorrect.***