University of Toronto
Faculty of Applied Science and Engineering
APS112 and APS113 Engineering Strategies and Practice

Quiz #1 February 12, 2016

This is a 50-minute quiz. The quiz is closed book and closed notes. The quiz has a total of 19 questions, worth 30 marks. The questions are divided between two booklets.

Question Booklet #2 – Short-Answer Question Booklet

First Name:	
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There are 4 short-answer questions, worth 15 marks in total. These must be answered in the spaces provided in this Short-Answer Question Booklet. This question booklet, with your name and UTOR Email filled in, must be returned along with the multiple-choice answer sheet. Do not separate any pages. Do not write on the QR code at the top of the pages.

We are not looking for long paragraph answers. Use the spaces provided on the question paper to write your answers in short sentences or bullet points for Questions 16-19. (Questions 1 to 15 are found in the multiple-choice question booklet.)

All short-answer questions refer to the following problem statement and figure:

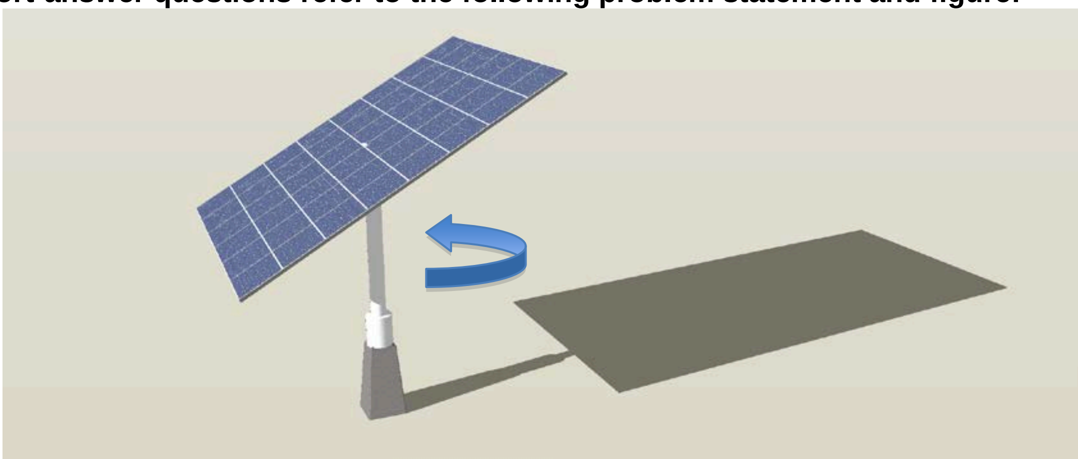

Figure 1: This is a solar panel on a vertical post. It can rotate around a vertical axis at the base of the post. There is very little friction, so it would be easy for a person to rotate the panel by hand.
(Figure based on a Sketchup model Solar Tree 1.0 uploaded by Simon V. on 12/13/13 to the 3d warehouse at 3dwarehouse.sketchup.com)

You are designing an ultra-low-cost **tracking system** to rotate a solar panel to follow the sun from morning to night. (You are not designing the panel or post. The solar panel already exists and is mounted on a post with a freely rotating base.)

A typical commercial tracking system has sensors and motors and is computer controlled. You need to design a mechanical system that can be set in motion by a human each morning, and will approximately follow the sun during the day with no further human assistance. The target market is remote and isolated communities in northern Bangladesh that have no access to power, and have a low level of technological development.

16. (4 MARKS) List ONE Function, TWO important objectives and ONE important constraint for the design.

FUNCTION:

1) Track the sun – sense position of the sun – actuate to move the panel

OBJECTIVES:

1) As X as possible X = inexpensive, durable, intuitive (easy to operate), reliable, easy to maintain, etc.
   Suitable metrics and goals could be added to each of these but are not required here.

CONSTRAINT:

Design must be X : Any concrete X will do the job. Safe, Less than $2, Maintainable with local materials, etc.

17. (2 MARKS) When designing the tracking device, you are asked to draw on **analogies** to provide ideas. Provide a useful analogy, and explain what type of analogy it is and how it is relevant to the current problem.

The design will have to include several subfunctions, and we could find suitable analogies for each. Subfunctinos include storing energy, a slow timing mechanism to calibrate release of energy, or a sunshine tracking device, an actuation device.

Sunshine tracker

Biological analogy:

- Sunflower or other plant that follows the sun?

Personal analogy:

- How does a person do it – sensing the position of the sun for sunbathing (with eyes closed perhaps)?

Technical analogy:

- How would we sense a light for a motion detector or some other camera?
- How does a sundial work?

Clock Mechanism

Technical analogy:

- How does a clock mechanism work?
- How does an hour glass work?

Energy Storage for gradual release

Technical Analogy

- How is energy stored in a grandfather clock? In a wind up watch?

Biological Analogy

- Energy lost from a melting icicle (storage and clock?)

1 mark for identifying a USEFUL i.e. relevant analogy and 1 mark for naming it.

18. (4 MARKS) One solar panel generates 100 W (1 Watt = 1 J/s) at noon during full sunshine. In the village, solar energy is stored in batteries and used after dark only to provide light for reading and other nighttime activities.

    In the space below, estimate how many solar panels are needed for a village of 1000 people in a remote and underdeveloped part of northern Bangladesh. You must compute an actual number, and show the steps used in making your estimate. Most of the marks will be assigned for showing that you know how to do such a calculation.
    Do all calculations using Watt-hours (Wh) as your unit of energy.

    Useful Information: A bright LED flashlight needs 4W of power.

    BASIS is 1 day:

Energy consumed

1000 people x 1 household/5 people = 200 households

200 households x 2 lights per household x 3 hours per day x 4 W/light ~ **5000 W hrs**

Energy generated

100W/panel x 12 hours of daylight x .7 average of noon power output during the day (assuming tracking) x .7 loss of efficiency going to the battery and back
= 600 W hrs/day per panel

5000W hrs / 600 W hrs/panel = **8 panels**

It is not necessary to have every factor. It is not necessary to use the same numbers. Reasonable estimates could result in

2000 W hrs <energy consumed < 20000 W hrs

The output of the panel should be estimated much tighter:

300 W hrs < energy generated < 1200 W hrs (hard maximum)

So the answer could vary quite widely as follows

(20,000 W hrs/300 W hrs per panel) 60 panels > answer > 2 panels (2000 W hrs/1200 W hrs)

1 mark for having the general method correct including not using too many significant figures in the calculations
1 mark for identifying the need to estimate consumption and generation
1 mark for capturing most of the basic assumptions
1 mark for an answer in range, assuming that the method has been followed.
0 marks for a guess

(5 MARKS) IN THE SPACE BELOW, provide a Functional Decomposition of the required tracking device, propose some viable solutions for the main subfunctions, and propose an overall solution.

Some hints are in the previous question: The main function is to rotate the panel in to keep it as perpendicular as possible to the sun. A human will “set” it in the morning, and then go off to work. By using such a device, an extra 30% efficiency can be gained over a stationary panel.

Subfunctions:

- Store energy
- Convert energy to movement of the panel.
- Timing mechanism OR Solar tracking mechanism

You can simply brainstorm solutions for the subfunctions, or you can use SCAMPER, Triz, Analogy or some other technique to help you generate more possible solutions.

Simple solutions for storing energy: Lift a weight. Start with a fresh candle or piece of wood (which has chemical energy) Compress air in a 2L pop bottle, wind up a spring, etc.

Simple solutions for converting energy to movement. Weight drops slowly and moves a rope attached to one side of the panel. Air expands and pushes a plunger. Spring (bungee cord) retracts and pulls on the panel. Heat from candle expands air in piston attached to the panel.

Simple timing mechanisms: water dripping from a tiny hole in a bottle. Sand pouring out of a hole in a bucket. Slow burn of candle. Pendulum and gear mechanism like a grand father clock. Movement through a very viscous medium.

Simple tracking mechanism: Wax that melts when shadow moves and exposes it to sunlight. Long tube or slot with solar cell in the end – generates power only when lined up with the sun. Anything that is painted black and heats in the sunshine so that it moves to put itself back in the shade – bimetal strip. Gas in a pipe. Etc.

Any combination would be ok.

1) Human pumps up an old car innertube that slowly leaks into a bicycle pump pushing it out over the day rotating the panel.
2) Human winds up a spring and puts in a square of black wax to hold it in place. When the sun moves and hits the wax it starts to melt and the panel rotates it so it is back in the shade.

1 mark for knowing what a functional decomposition is and making an effort.
1 mark for getting the key subfunctions
1 mark for generating at least two solutions for storing energy
1 mark for generating at least two solutions for timing AND/OR tracking
1 mark for putting it together in a final answer

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