University of Toronto
Faculty of Applied Science and Engineering
APS112 and APS113 Engineering Strategies and Practice
Quiz #1 February 14, 2017

This is a 50-minute quiz. The quiz is closed book and closed notes. The quiz has a total of 23 questions, worth 41 marks. The questions are divided between two booklets.

Question Booklet #2 – Short-Answer Question Booklet

First Name:																										
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There are 3 short-answer questions, worth 21 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 with the multiple-choice answer sheet slipped inside. 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 short sentences or bullet points.

All short-answer questions refer to the following client statement.

Client Statement #2 – Photovoltaic Cells
Performance of photovoltaic systems greatly degrade as dust and dirt adhere to the panels. As a result, water based washing systems have been developed to clean photovoltaic systems. Unfortunately, many locations which are suitable to photovoltaic systems have limited water availability (sunny skies means no rain). Design a water efficient method for keeping large photovoltaic power systems clean.

Figure 1: Cleaning of 200 W Photovoltaic Panels by Brian Kusler (https://www.flickr.com/photos/briankusler/2447511232/in/photostream/)

1. (7 MARKS) Give ONE primary function, TWO important objectives, and ONE important constraint for Client Statement #2 – Photovoltaic Cells. Metrics are required for the objectives and constraint, but you do not need to include goals or limits.

PRIMARY FUNCTION:
- Remove dirt and dust from panel
- Clean solar panel

NOT:
- Transport Mass (we want primary function, not the functional basis)
- Minimize water (Though this is a critical aspect of the project, it is an objective not a function)
- Increase solar cell efficiency (this is a result and not a function)
- Store water (this is a secondary function)
- Detect dirt/dust (this is a secondary function)

OBJECTIVES:
- Should minimize water usage
    - Litres per unit of time; Litres per panel; Litres
- Should minimize electricity usage
    - Watts
- Should be easy to operate
    - Number of daily human interactions required for operation
- Should be inexpensive
    - Dollars
- Should be durable
    - Number of moving parts; % of constructions materials that are non-oxidizing
- Should be easy to maintain
    - Number of standardized parts; number of locally accessible parts

NOT:
- Should clean efficiently (too vague…unless they give enough details using the metric)
- Should be environmentally friendly (too vague…unless they give enough details using the metric)
- Should be user friendly (too vague…unless they give enough details using the metric)

CONSTRAINT:
Must not use toxic cleaner
    - EPA toxicity guidelines; litres
- Must not require water service line

    - Yes / no
- Must collect runoff water
    - Litres
- Must not contain oxidizing materials.
    - % by volume, % by mass, mass

2. (7 MARKS) While designing a solution for Client Statement #2 – Photovoltaic Cells, you need to know the amount of water consumed washing panels at the 550 Megawatt (MW) Desert Sunlight Solar Farm in the Mojave Desert. If the panels are washed twice a week in the traditional way, estimate the annual water consumption for this task in Litres. Use reasonable assumptions based on your personal knowledge and the information provided here. You don't have to get an exact answer, but you do have to compute a number and **demonstrate structured thinking**.

Area of a Panel
From picture, one panel is about:

$$1m * 0.5m = 0.5\ m^2\ (per\ 200W)$$

Number of panels:

$$\frac{600x10^6W}{200\ W/panel} = 3x10^6\ panels$$

Total area to clean:

$$3x10^6 * 0.5m^2 = 1.5x10^6m^2$$

Estimate water usage:

Method # 1: a typical tap or hose has a flow rate of about 10L per minute.
Each panel might need to be sprayed for 1 minute.

$$\frac{10\ L}{minute} = 10\ L\ per\ panel$$

Total volume per wash

$$\frac{10\ L}{panel} * 3x10^6 panels = 30\ M\ L\ per\ wash$$

Total per year:

$$\frac{30x10^6 L}{wash} * \frac{2\ wash}{week} * \frac{52\ weeks}{year} = \mathbf{3x10^9\ L\ /year}$$

Method # 2: using area of panel

How much water per panel?
Assume vol of water=area time thickness of water
Assume need layer 1 mm thick
$1\ m^3 = 1000\ L$

$$\frac{Volume\ Water}{panel\ wash} = \frac{0.5m^2 * 10^{-3}m}{panel\ wash} = \frac{0.5x10^{-3}m^3}{panel\ wash} = 0.5\ l/panel\ wash$$

To remove dirt properly, perhaps need to flush 10 times

So Vol water per panel would be 5 L per panel (similar to Method #1 that gave 10L per panel per wash)

$$Total\ Volume\ per\ wash = \frac{5\ L}{panel} * 3x10^6\ panels = 15x10^6 L$$

Total per year in this case would be:

$$\frac{15x10^6 L}{wash} * \frac{2\ wash}{week} * \frac{52\ weeks}{year} = \mathbf{1.5x10^9\ L\ /year}$$

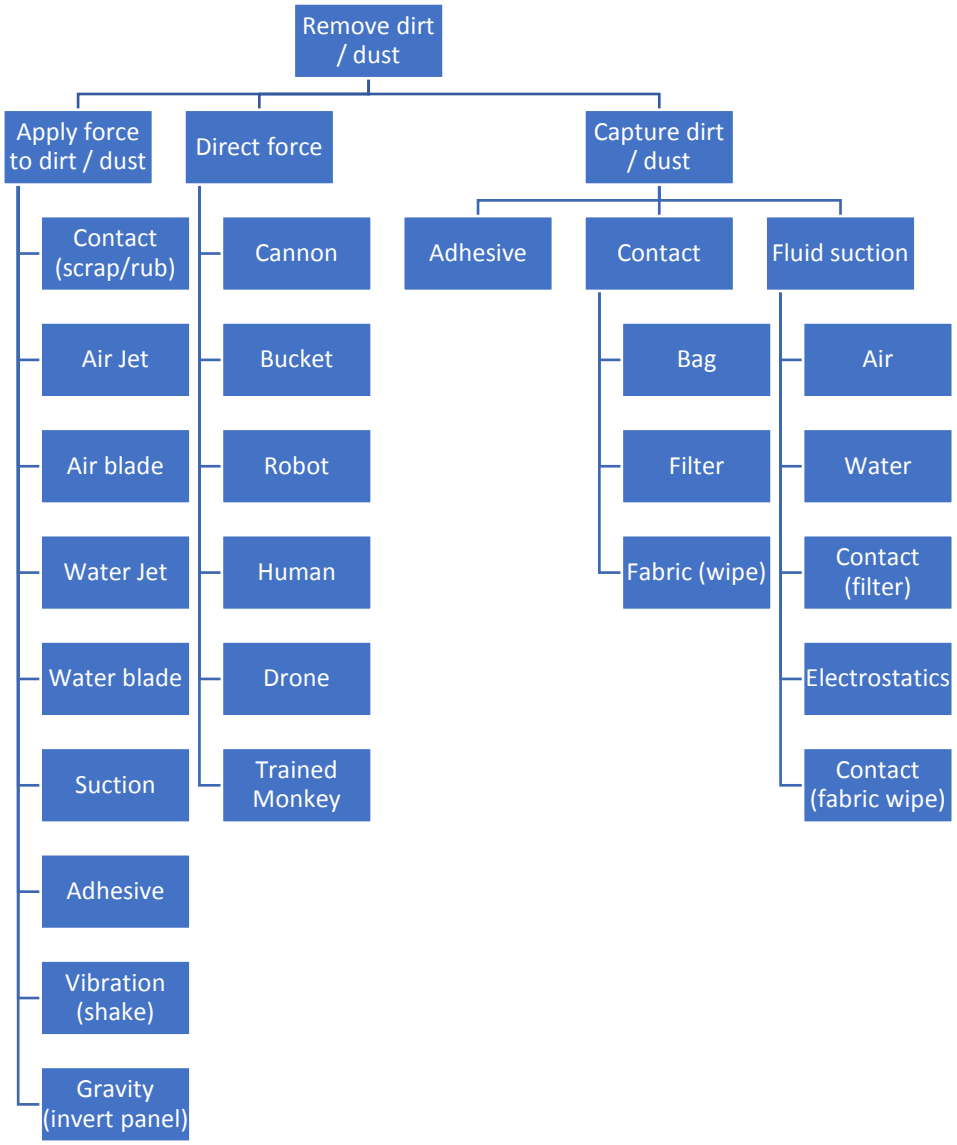
NOTE:
Note that on the web, I found they clean only 2 x per year. The number I got was ~60,000L per MW
For 550 MW this would come to 33 M liters. If they only wash 2 times per year, this means each wash would be about 15 M liters/wash

This is close to the estimates of 14-28 M liters per wash

3. (7 MARKS) Given Client Statement #2 – Photovoltaic Cells, provide a Functional Decomposition of the cleaning device.

   a. In your Functional Decomposition identify the Primary Function, three subfunctions, and at least one viable solution for each subfunction.

   b. Use these viable solutions to propose an overall solution.



Solution: Contact (Squeegy) & Water blade – Robot – Contact (Fabric)

Water blade & Squeegee mounted on a drone with drainage channels in panel bezel to wick away dirty water.