# Engineering Innovation Final Exam 2016

**Engineering Innovation Final Exam Honor Code**

This exam must be worked on by you and you alone. You are welcome to search for any publicly available materials that might be useful to you. But, you must not ask anyone else for guidance, help, or information. This includes TA's, Teaching Fellows, family, friends, and fellow students. It also includes posting questions to ask.com,Yahoo.answers.com, and similar websites. You are permitted to ask your instructor to clarify a problem; but don't ask him or her for advice on how to proceed.

***Failure to comply with the Honor Code will result in a score of zero for the exam.***

**Please sign your name to indicate that you understand the rules and the consequences of not abiding by them.**

**Print your name: _____**

**Signature: _____**

***This page, including your signature must be returned with your final exam!!!***

Please write neatly or type your responses. If you use reference material you must provide a citation. To receive full credit, all work must be provided.

**This exam has 6 questions. You are to answer 5 of the 6 questions. Please indicate the problems that you wish for us to grade by circling Y. If you do not wish for us to grade the problem, circle N. If you do not circle anything below, the first 5 problems will be graded.**

| | | | |
|---|---|---|---|
| Problem 1: | Grade? Y / N | Score _____/20 | Grader's Initials _____ |
| Problem 2: | Grade? Y / N | Score _____/20 | Grader's Initials _____ |
| Problem 3: | Grade? Y / N | Score _____/20 | Grader's Initials _____ |
| Problem 4: | Grade? Y / N | Score _____/20 | Grader's Initials _____ |
| Problem 5: | Grade? Y / N | Score _____/20 | Grader's Initials _____ |
| Problem 6: | Grade? Y / N | Score _____/20 | Grader's Initials _____ |

**Problem 1 – 20 points.**

Civil engineers are involved with building more than bridges and roads. They may also be employed to design and build wastwater treatment systems. Use the table below to answer the following questions.

TABLE 18. APPROXIMATE ORDINARY MAXIMUM LOADS ON DRAIN TILE AND SEWER PIPE IN DITCHES FROM COMMON DITCH-FILLING MATERIALS, IN POUNDS PER LINEAR FOOT [1]

| $H$ = height of fill above top of pipe, ft | $B$ = breadth of ditch, at top of pipe | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 ft | 2 ft | 3 ft | 4 ft | 5 ft | 1 ft | 2 ft | 3 ft | 4 ft | 5 ft |
| | Partly compacted damp topsoil, 90 lb per cu ft | | | | | Saturated topsoil, 110 lb per cu ft | | | | |
| 2 | 130 | 310 | 490 | 670 | 830 | 170 | 380 | 600 | 820 | 1,020 |
| 4 | 200 | 530 | 880 | 1,230 | 1,580 | 260 | 670 | 1,090 | 1,510 | 1,950 |
| 6 | 230 | 690 | 1,190 | 1,700 | 2,230 | 310 | 870 | 1,500 | 2,140 | 2,780 |
| 8 | 250 | 800 | 1,430 | 2,120 | 2,790 | 340 | 1,030 | 1,830 | 2,660 | 3,510 |
| 10 | 260 | 880 | 1,640 | 2,450 | 3,290 | 350 | 1,150 | 2,100 | 3,120 | 4,150 |
| | Dry sand, 100 lb per cu ft | | | | | Saturated sand, 120 lb per cu ft | | | | |
| 2 | 150 | 340 | 550 | 740 | 930 | 180 | 410 | 650 | 890 | 1,110 |
| 4 | 220 | 590 | 970 | 1,360 | 1,750 | 270 | 710 | 1,170 | 1,640 | 2,100 |
| 6 | 260 | 760 | 1,320 | 1,890 | 2,480 | 310 | 910 | 1,590 | 2,270 | 2,970 |
| 8 | 280 | 890 | 1,590 | 2,350 | 3,100 | 340 | 1,070 | 1,910 | 2,820 | 3,720 |
| 10 | 290 | 980 | 1,820 | 2,720 | 3,650 | 350 | 1,180 | 2,180 | 3,260 | 4,380 |
| 12 | 300 | 1,040 | 2,000 | 3,050 | 4,150 | 360 | 1,250 | 2,400 | 3,650 | 4,980 |
| 14 | 300 | 1,090 | 2,140 | 3,320 | 4,580 | 360 | 1,310 | 2,570 | 3,990 | 5,490 |
| 16 | 300 | 1,130 | 2,260 | 3,550 | 4,950 | 360 | 1,350 | 2,710 | 4,260 | 5,940 |
| 18 | 300 | 1,150 | 2,350 | 3,740 | 5,280 | 360 | 1,380 | 2,820 | 4,490 | 6,330 |
| 20 | 300 | 1,170 | 2,420 | 3,920 | 5,550 | 360 | 1,400 | 2,910 | 4,700 | 6,660 |
| 22 | 300 | 1,180 | 2,480 | 4,060 | 5,800 | 360 | 1,420 | 2,980 | 4,880 | 6,960 |
| 24 | 300 | 1,190 | 2,540 | 4,180 | 6,030 | 360 | 1,430 | 3,050 | 5,010 | 7,230 |
| 26 | 300 | 1,200 | 2,570 | 4,290 | 6,210 | 360 | 1,440 | 3,090 | 5,150 | 7,460 |
| 28 | 300 | 1,200 | 2,600 | 4,370 | 6,390 | 360 | 1,440 | 3,120 | 5,240 | 7,670 |
| 30 | 300 | 1,200 | 2,630 | 4,450 | 6,530 | 360 | 1,440 | 3,150 | 5,340 | 7,830 |
| Infinity | 300 | 1,200 | 2,730 | 4,850 | 7,580 | 360 | 1,450 | 3,270 | 5,820 | 9,090 |

a) If your pipe is 7.5 feet below the ground and the breadth of the ditch at the top of the pipe is 2 feet, what is the maximum load on the pipe if the fill material is saturated topsoil?

b) You are preparing to bury a sewer line with dry sand and know that the pipe you have selected will fail if the maximum load is 4,310 pounds per linear foot and the breadth of the ditch must be 4 feet. You desire to bury the line as deep as possible. To the nearest inch, how deep can this pipe be buried?

c) What is the maximum breadth of ditch at top of the pipe that you can dig if you want to bury a sewer pipe that will support 1550 pounds per linear foot 84 inches deep in partially compacted damp topsoil?

d) If your pipe is 28 inches below the ground and the breadth of the ditch at the top of the pipe is 32 inches, what is the maximum load on the pipe if the fill material is saturated sand?

**Problem 2 – 20 points**

You are asked to join a research team as a summer assistant. The group is determining the power required to transmit a signal through various atmospheric conditions present on a newly discovered planet.

The student assistant last summer collected the following data, but did not have time to analyze it before she returned to college in the fall. The lab director has given you the data below and asked you to answer the following questions.

| Power [P] (Watts) | Signal Frequency [f] (GHz) | Atmospheric Pressure [p] (Pa) | Atmospheric Temperature [T] (K) |
|---|---|---|---|
| 0.01 | 2.1 | 0.013 | 200 |
| 0.22 | 4.2 | 0.079 | 200 |
| 0.36 | 10.9 | 0.147 | 200 |
| 0.5 | 7.6 | 0.147 | 200 |
| 0.57 | 2.1 | 0.079 | 200 |
| 0.88 | 4.2 | 0.147 | 200 |
| 0.95 | 3.8 | 0.147 | 200 |
| 1.56 | 2.1 | 0.147 | 200 |
| 1.91 | 2.1 | 0.147 | 200 |
| 1.79 | 4.2 | 0.079 | 400 |
| 7.12 | 4.2 | 0.079 | 600 |
| 31.51 | 4.2 | 0.079 | 1000 |
| 54.32 | 2.1 | 0.867 | 200 |
| 105.76 | 2.1 | 1.215 | 200 |

a) What is the relationship between Power and Temperature?
b) What is the relationship between Power and frequency?
c) What is the relationship between Power and pressure?
d) What power would be required to transmit a signal with a frequency of 8.3GHz in an atmosphere with a pressure of 0.444 Pa and a temperature of 350K?

**Problem 3 – 20 points**

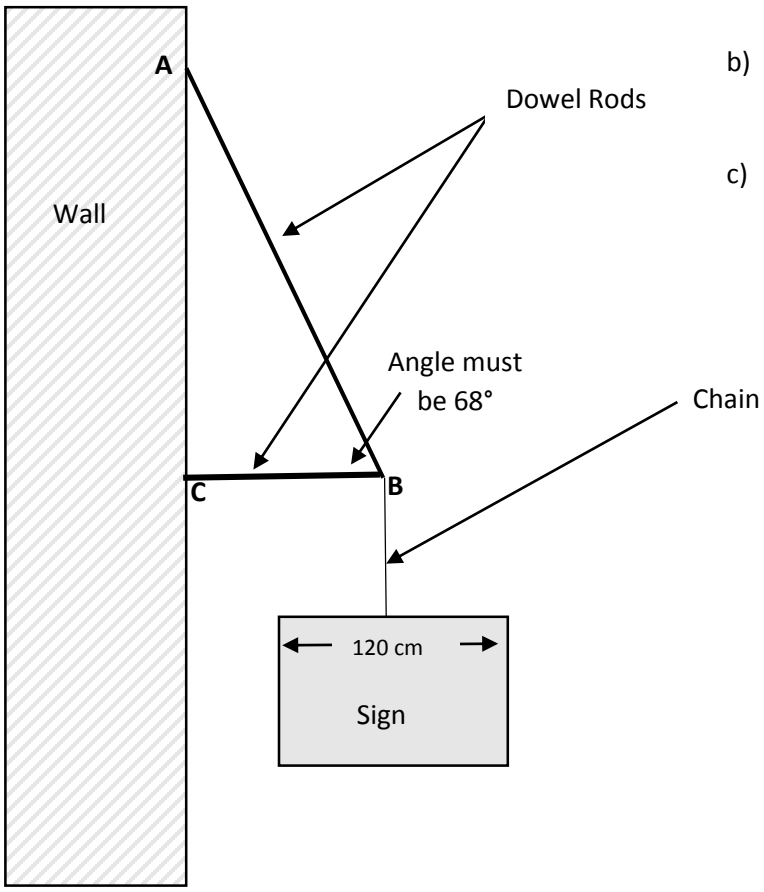
You have been hired to install the largest sign possible for a new business located inside a renovated warehouse. The owners of the warehouse have many requirements for the allowed signage.

**REQUIREMENTS:**

- The sign must be exactly 120cm wide and exactly 1 inch thick.
- The sign must be constructed of Western Red Cedar.
- The supports for the sign must be constructed of 1/2inch diameter Western Red Cedar dowel rods.
- The sign support must have the geometry provided in the figure below.
- The support chain has a mass of 500 grams and is sufficiently strong.
- The sign must be centered on the chain.

You conduct research and learn:

Tensile strength of cedar is 425 psi
Young's modulus of cedar is $1.0 \times 10^6$ psi
Density of cedar = 0.38 g/cm$^3$




**QUESTIONS:**

a) What is the maximum load that the rod AB is able to support?

b) What is the maximum load that the rod BC is able to support?

c) What is the height of the tallest sign you can construct?

**Problem 4 – 20 points**

If all hotels in the state of Maryland installed shampoo, conditioner, body wash and lotion dispensers in the hotel room rather than provide individual bottles of each, how many pounds of plastic would be kept out of the landfills and recycling centers each year? To earn full credit you must provide a list of all your assumptions, the justification for each assumption and the url for all websites you used to answer this question.

VS.


**Problem 5 – 20 points**

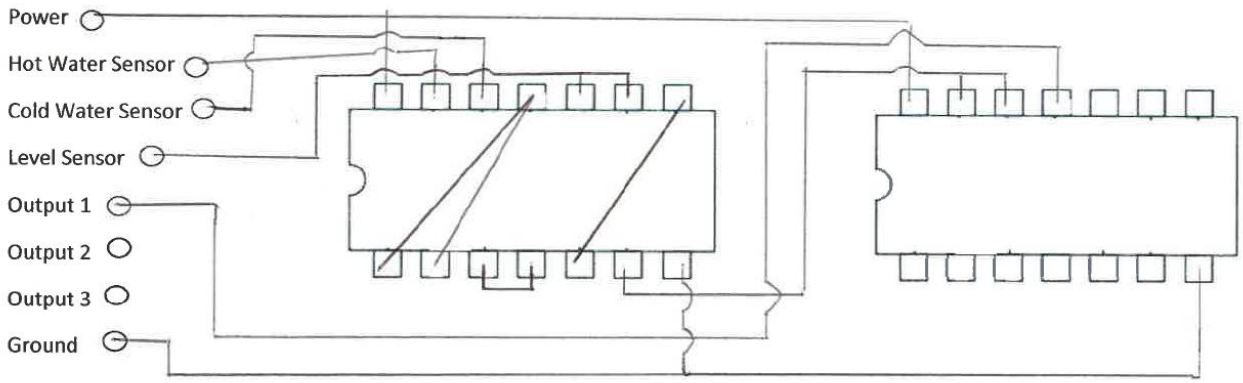
You are part of a design team that has been contracted to help a local nursing home operate more efficiently. Their staff spends a large portion of each day preparing to bathe the local residents. The nursing home would like you to develop a controller that will automatically fill the bathtubs to the correct level and temperature. The new system must also have a method for alerting the staff if there is a problem.

Your team decides to place three sensors in the bathtub – a hot sensor, a cold sensor and a water level sensor. The signals from these sensors are the inputs to the controller system. The hot sensor sends a signal to the controller when the water is too hot. The cold sensor sends a signal to the controller when the water is too cold. The level sensor sends a signal to the controller when the water level reaches the required depth.

There are three output signals from system, one to the hot water valve, one to the cold water valve and one to an alarm system.

One member of the team has started the design process and left you with the following chip wiring diagram before leaving on vacation. A note left with the wiring diagram indicates that the team member intended Output 1 to be the Alarm system.

Ribbon cable is needed to connect the circuit to the sensor inputs, outputs, the power and ground. The circuit includes two TI SN 7400N 14-pin CMOS chips containing four NAND gates each (the same chips that were used in the robotic car lab).




a) Reverse engineer the circuit and provide either a sketch of the NAND Gate system or a printout of the NAND gate system created using the Circuit Builder JavaApplet you used in the robotic car project.
b) Complete the output column in the truth table for this circuit.

| **INPUTS** | | | **OUTPUT 1** |
|---|---|---|---|
| $T_H$ – Hot Sensor | $L_W$ – Water level sensor | $T_C$ – Cold Sensor | |
| 0 | 0 | 0 | |
| 0 | 0 | 1 | |
| 0 | 1 | 0 | |
| 0 | 1 | 1 | |
| 1 | 0 | 0 | |
| 1 | 0 | 1 | |
| 1 | 1 | 0 | |
| 1 | 1 | 1 | |

c) Write a paragraph for the rest of the design team that explains how this circuit works. If it is a good design, explain why this is a good solution to the problem. If it is not a good design, explain why the design is not satisfactory for the problem.

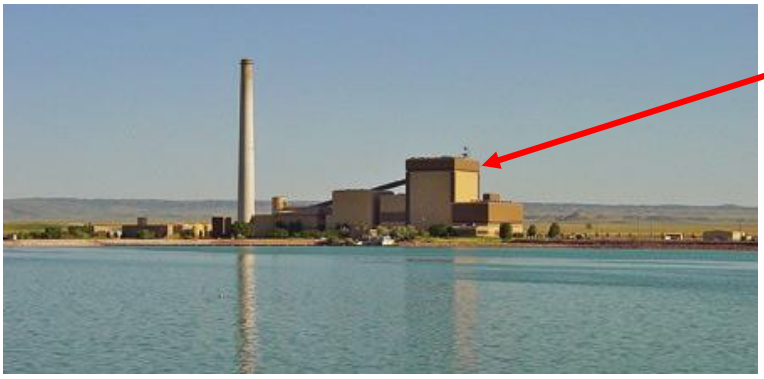
**Problem 6 – 20 points**

This problem is a series of four questions worth 5 points each.

**a – 5 points)** An investment costing $1000 promises to return $100 each year for the first five years and $200 each year for the following five years. What is the present value of this investment?

**b – 5 points)** Air pollution control engineers often need to design facilities to remove particulate matter. One type of control technology is a bag house. Below is a photo of a bag house designed to reduce the level of coal dust emissions from this coal-fired power plant.

Rawhide Energy Station – a coal-fired power plant in Colorado




http://www.baghouse.com/wp-content/uploads/2011/09/bag-house.jpg

You are working through a particulate control calculation and find this definition of a variable I which helps determine the efficiency of the bag house.

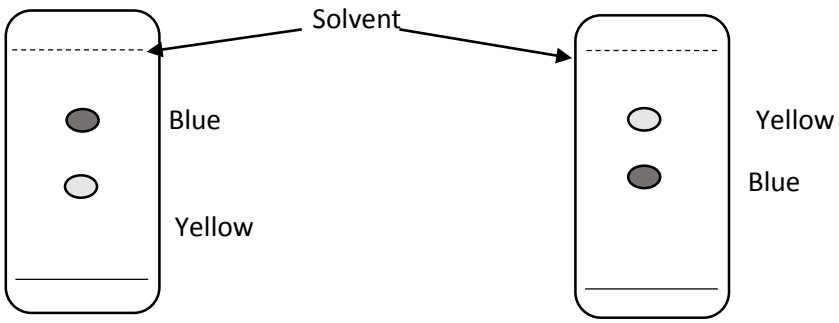
$$I = \frac{V_p d_p^2 \rho_p K_C}{18 \mu_g d_f}$$

The variables in this equation are:

| | | |
|---|---|---|
| $V_p$ | = | Velocity of the dust particle |
| $d_p$ | = | Diameter of the dust particle |
| $\rho_p$ | = | Particulate density |
| $\rho_g$ | = | Air density |
| $\mu_g$ | = | Dynamic viscosity of the air |
| $d_f$ | = | Diameter of the fiber that is used to construct the bag |
| $K_C$ | = | $1 + \frac{2\lambda}{d_p}\left[1.257 + 0.400 exp\left(\frac{-0.55 d_p}{\lambda}\right)\right]$ |
| $\lambda$ | = | $\frac{\mu_g}{0.499 \rho_g u_m}$ |
| $u_m$ | = | Velocity of the air molecules |

What are the dimensions on this new variable, I? To receive full credit, you must show all your work.

**c – 5 points)** You have the following chromatography results for the transport of dyes in a green marker. What would you predict the retention factor for the blue and yellow dyes to be in 100% acetone?




35% Water, 65% Acetone

100% Water

**d – 5 points)** Calculate z and Δz for the following equation:

$z = v(xy+w^2)$ where:

$v = 0.644m \pm 0.004m$

$x = 3.42m \pm 0.06m$

$y = 5.00m \pm 0.12m$

$w = 12.13m \pm 0.08m$