2.007 Design and Manufacturing I, Spring 2013

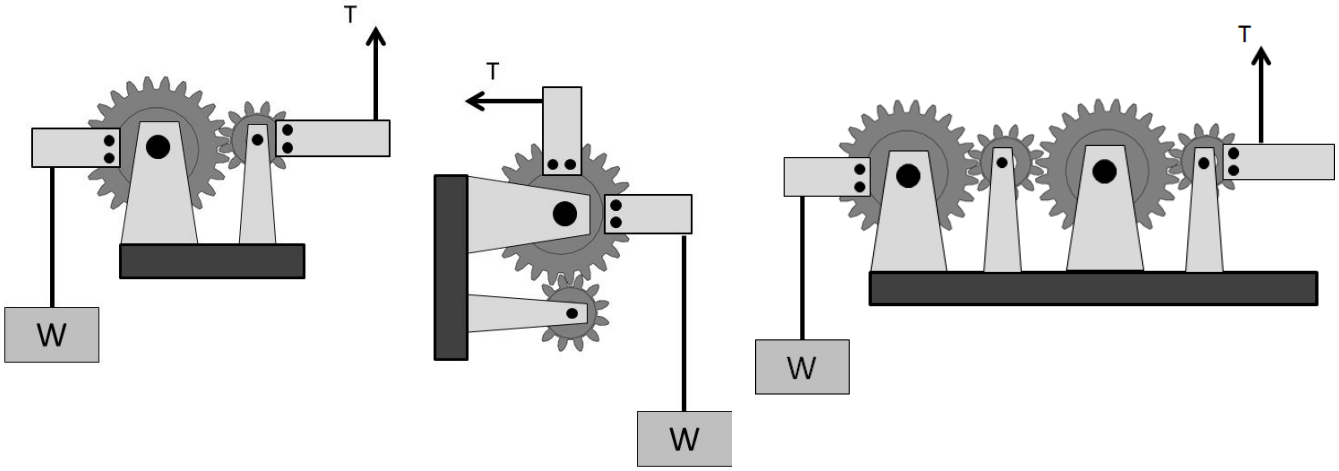
EXAM #2

NAME: _____

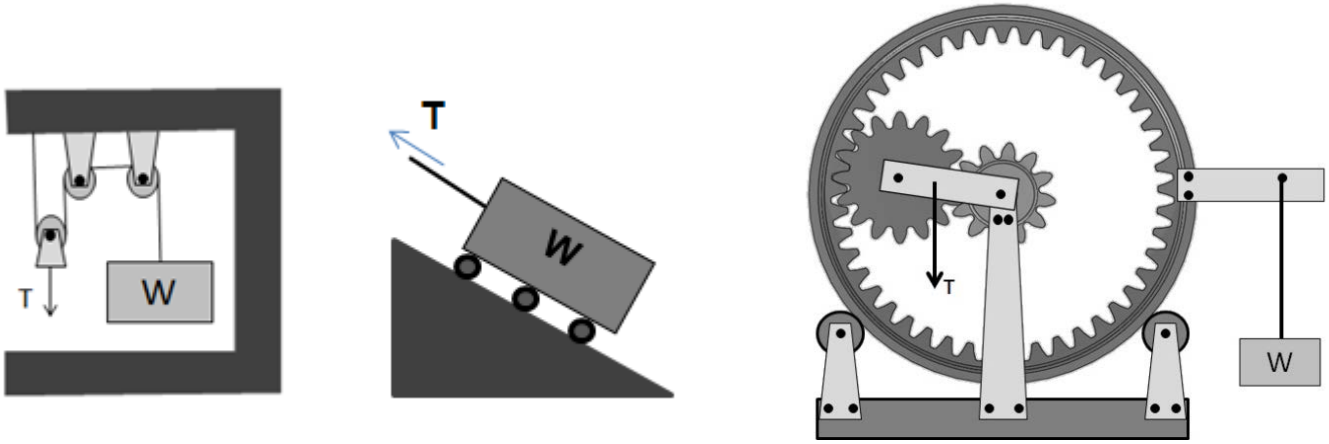
Date: Tuesday 30 April, 11AM

Please answer the following 9 questions showing your work to the extent possible within the allotted time. Point allocations are listed for each question. The points sum to 100. This exam counts as 15% of your total grade.

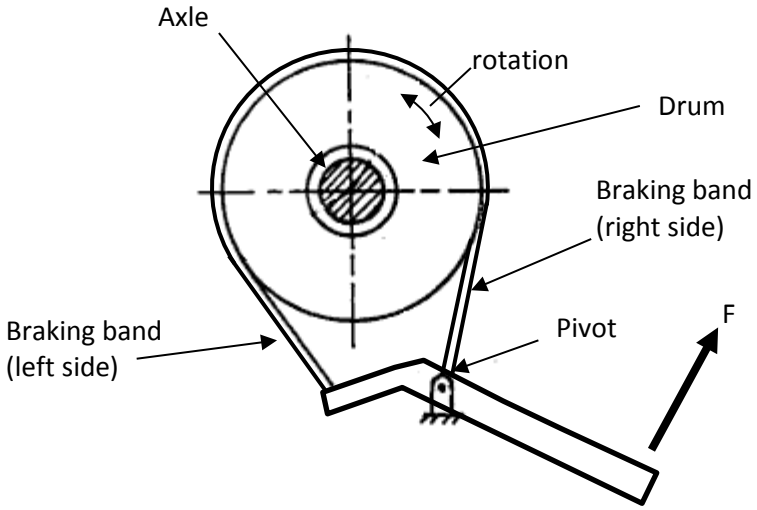
1. (10 points) Which one of these arrangements (in each row of three) can be raising the weight (W) slowly at a constant rate with the lowest applied force (T)? NOTE: Question applies to current configuration, not to new configurations after significant displacements.
    a. (5 points) Circle one machine in the row below -- lowest T for a given W.



    b. (5 points) Circle one machine in the row below -- lowest T for a given W.



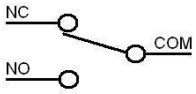
2. (5 points) Below is a graphical depiction of a band brake. When a force F is applied to a lever, the band will apply a braking torque to the drum via a braking band (a flexible strap). Circle <u>all</u> the true statements.



a) When the drum is rotating clockwise, the left side of the braking band is under higher tension than the right side of the braking band.
b) When the drum is rotating clockwise, the left side of the braking band cannot attain a tension greater than the actuation force F even if the friction coefficient is high.
c) When the drum is rotating clockwise, the right side of the braking band will be under some non-zero tension if there is a non-zero actuation force F.
d) When the drum is rotating counter-clockwise, the right side of the braking band is under higher tension than the left side of the braking band.

3. (5 points) Regarding common mechanical components, circle <u>all</u> the true statements.
a) A steel extension spring stores energy proportional to the square of its change in length.
b) A steel constant force spring, when extended, experiences a stress distribution similar to that of a beam in bending, with tension on one side, compression on the other side, and a linear distribution of stress through the thickness.
c) A rivet, during installation, experiences plastic deformation.
d) A bolt, when installed by applying torque to its head, will become slightly longer as it experiences elastic deformation in a portion of the bolt between the head and the nut.
e) Hydrostatic pressure will not cause deformation of objects unless they are hollow.

4. (10 points) A momentary tact switch, below, is to be used to detect the end-of-travel of a robotic arm. The state of the switch is to be read using a microcontroller. Draw a schematic diagram of a circuit that, using only passive components, produces the behavior: when <u>not</u> pressed, the microcontroller reads 5V (or digital HIGH), when pressed, the microcontroller reads 0V (or digital LOW).

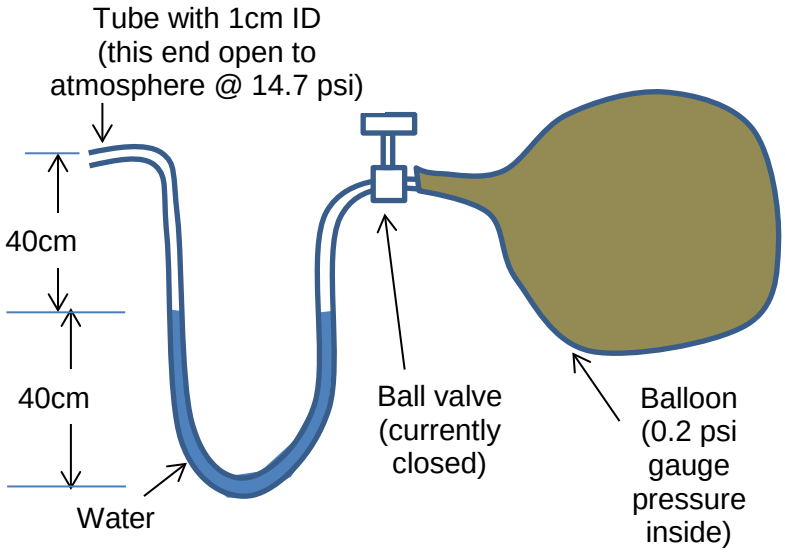


Draw your diagram here. NOTE: This icon represents the state of the switch when the switch is not pressed.

NOTE:
COM indicates ground,
NO indicates normally open,
NC indicates normally closed.

5. (5 points) A balloon is blown up to 4 liters enclosed volume which requires 0.2 psi of gauge pressure (1379 Pa). The balloon is subsequently placed on a tube that is filled with water with a closed ball valve preventing flow (for the moment) as depicted below. Which statement below most accurately describes what happens when the ball valve is opened?

a) No change is detectable by the human eye because 0.2 psi is such a low pressure.
b) The level of the water in the tube changes so that, after vibration damps out, the right side is about 14 cm higher than that on the left side.
c) The water shoots out of the tube and the balloon subsequently empties to the atmosphere (since Bernoulli's law shows that air leaving a balloon at 1379 Pa will exit with a velocity of more than 50 m/s).

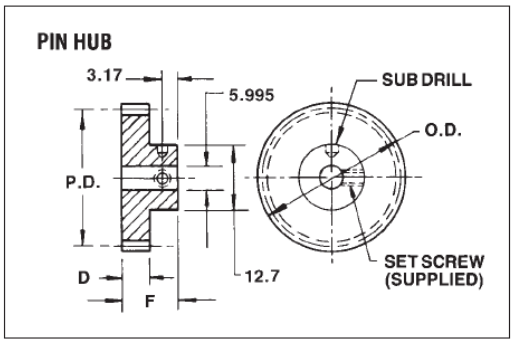


6. (15 points) The subproblems below refer to the page from a gear catalog provided here.

SPUR GEARS — 0.5 Module ■ 3.18 and 4.76mm Face Width ■ 20° Pressure Angle

Pin Hub — 6mm Bore

All Dimensions in Millimeters



Material: 303 Stainless Steel
2024-T4 Aluminum (Anodized Before Cutting)

Dim	Bore	
	4	6
D	3.18	4.76
F	9.52	11.10

Gear Data			Stainless Steel Part No.		Aluminum Part No.	
No. Teeth	Pitch Dia.	Outside Dia.	3.18 Face Width	4.76 Face Width	3.18 Face Width	4.76 Face Width
†20	10.0	11.0	MSG19-20	MSG21-20	MSG20-20	MSG22-20
†22	11.0	12.0	MSG19-22	MSG21-22	MSG20-22	MSG22-22
†24	12.0	13.0	MSG19-24	MSG21-24	MSG20-24	MSG22-24
†26	13.0	14.0	MSG19-26	MSG21-26	MSG20-26	MSG22-26
30	15.0	16.0	MSG19-30	MSG21-30	MSG20-30	MSG22-30
32	16.0	17.0	MSG19-32	MSG21-32	MSG20-32	MSG22-32
34	17.0	18.0	MSG19-34	MSG21-34	MSG20-34	MSG22-34
36	18.0	19.0	MSG19-36	MSG21-36	MSG20-36	MSG22-36
40	20.0	21.0	MSG19-40	MSG21-40	MSG20-40	MSG22-40
42	21.0	22.0	MSG19-42	MSG21-42	MSG20-42	MSG22-42
48	24.0	25.0	MSG19-48	MSG21-48	MSG20-48	MSG22-48
50	25.0	26.0	MSG19-50	MSG21-50	MSG20-50	MSG22-50
55	27.5	28.5	MSG19-55	MSG21-55	MSG20-55	MSG22-55
60	30.0	31.0	MSG19-60	MSG21-60	MSG20-60	MSG22-60
72	36.0	37.0	MSG19-72	MSG21-72	MSG20-72	MSG22-72
75	37.5	38.5	MSG19-75	MSG21-75	MSG20-75	MSG22-75
80	40.0	41.0	MSG19-80	MSG21-80	MSG20-80	MSG22-80
84	42.0	43.0	MSG19-84	MSG21-84	MSG20-84	MSG22-84
90	45.0	46.0	MSG19-90	MSG21-90	MSG20-90	MSG22-90
96	48.0	49.0	MSG19-96	MSG21-96	MSG20-96	MSG22-96
100	50.0	51.0	MSG19-100	MSG21-100	MSG20-100	MSG22-100
105	52.5	53.5	MSG19-105	MSG21-105	MSG20-105	MSG22-105
110	55.0	56.0	MSG19-110	MSG21-110	MSG20-110	MSG22-110
120	60.0	61.0	MSG19-120	MSG21-120	MSG20-120	MSG22-120
126	63.0	64.0	MSG19-126	MSG21-126	MSG20-126	MSG22-126
144	72.0	73.0	MSG19-144	MSG21-144	MSG20-144	MSG22-144
156	78.0	79.0	MSG19-156	MSG21-156	MSG20-156	MSG22-156
180	90.0	91.0	MSG19-180	MSG21-180	MSG20-180	MSG22-180

A) (5 points) If a 0.5 module gear with 20 teeth and another one with 80 teeth are mated together in a gear train, how far apart should the centers of their shafts be placed?

B) (10 points) If a 0.5 module gear with 20 teeth and another one with 80 teeth are mated together in a gear train and a torque of 0.3 N*m is applied to the 20 tooth gear and the gears are in equilibrium.

i. (5 points) What is the tangential force applied by one gear on the other?

ii. (5 points) What is the separation force applied by one gear on the other? (note the 20 degree pressure angle)

7. (15 points) Match the items below to the terms that describe them.

A. Torsion spring
B. Spider coupling
C. Constant force spring
D. E clip
E. Flanged bushing
F. Extension spring
G. Lead screw
H. Rolling element bearing
I. Universal or "U" joint
J. Cotter pin
K. Roll pin
L. Planetary gear
M. Worm gear
N. Splined shaft
O. Differential gears

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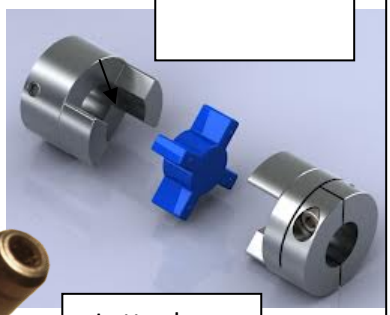

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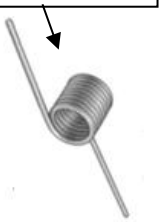

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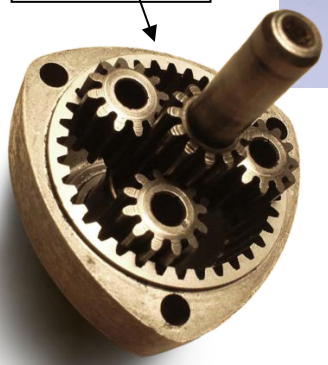

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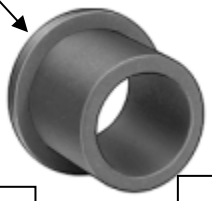

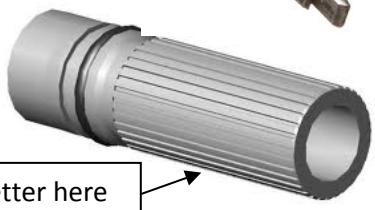

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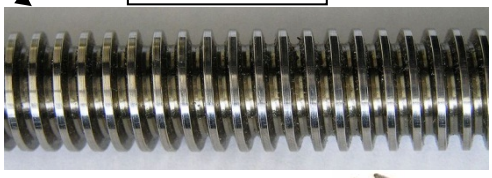

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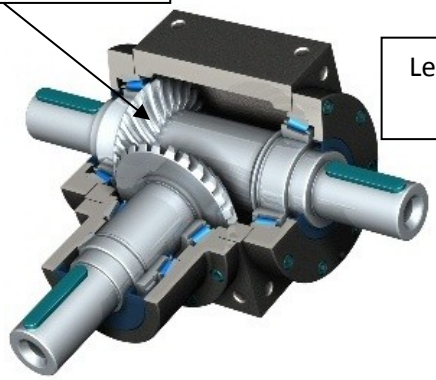

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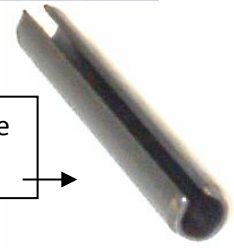

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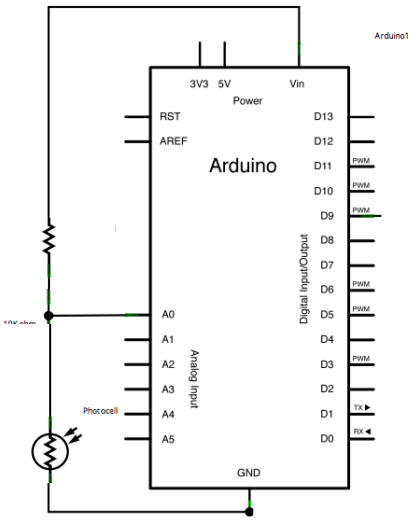
8. (15 points) An Arduino is wired with a photocell and a resistor and loaded with the code below. The goal is to detect when an LED (not shown) is illuminated.

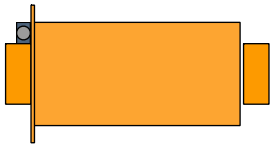



```
byte sensorValue = 0;
byte Aval = 1023;
byte Bval = 1;
long store=0;
int result;
word count=0;

void setup() {
  Serial.begin(9600);
  while (millis() < 5000) {
    sensorValue = analogRead(A0);
    store=store+sensorValue;
    count++;
    if (sensorValue > Bval) {
      Bval = sensorValue;}
    if (sensorValue < Aval) {
      Aval = sensorValue;}
  }
  result=store/count;
}


void loop() {
  sensorValue = analogRead(A0);
  if (abs(sensorValue-result)> abs(Bval-Aval)) Serial.println("extreme condition detected");
  else Serial.println("normal conditions preval");
  delay(1000);
}
```

a) (5 points) (T/F) When the light intensity on the photo-resistor increases, the voltage at pin A0 drops.

b) (10 points) During the first five seconds that the program is running, the photo-resistor is exposed to a range of ambient light conditions. Although the LED to be detected is off, the operator sometimes shades the photoresistor, sometimes exposes the photoresistor to the room's light, and sometimes exposes the photoresistor to a portable flashlight that is not as bright as the LED to be detected. Describe the behavior of the code. How would you describe the values in the variables `result`, `Aval`, and `Bval`?

9. (20 points) A winch (depicted graphically below) is a mechanical device that is used to pull on a rope or cable. It is composed of a drum to which the rope is attached and wound around, which is driven by an electric motor through a gearbox. The winch depicted here is manufactured by "Warn" and is rated as a 9000 lbs winch. The winch drum is powered by an electric motor (left side of picture) through a three-stage planetary gear drive (right side of the picture). Schematic shows the dimensions and bearing placement for the rope drum and the maximum operational load.



A) (15 pts) As the winch winds in and out, the cable winds on every axial location across the entire length of the drum. Because of this, the location of the 9000 lbs cable tension changes (although you may assume its direction remains nearly constant). Determine the maximum load that could be experienced by the bearings (either on the one on the left or right) and the maximum bending moment that could be experienced by the drum. Show your work.

B) (5 pts) The winch motor has an electrical load rating at maximum operational load of 3600 W (4.8 hp) at 12 V. The battery you plan to use is rated at 12 V and 50 Ah. How long could you run the winch on this battery?