0. (5 point deduction for failure to complete this problem)

- Write in all of the indicated information in the boxes of your response form.
- Darken the appropriate circles to encode the corresponding information.
- Write your name on this exam and sign the Honor Statement.

Notes:
- If your last name is too long, just write the first 10 letters.
- "F.I." and "M.I." are your first and middle initials, respectively.
- Your "Username" is the first part of your LA Tech email address.
- For "Section" use the guide provided to the right.
- Your "Exam Form" is printed on the upper right corner of this page.
- Indicate "ENGR" as the "Program".

1. (3 points) When using the PING distance sensor as described in the notes, the distance of an object is computed based on:

\[
\text{\textbf{Choices}} = \begin{cases} 
\text{A} & \text{Speed of light in vacuum} \\
\text{B} & \text{Speed of light in air} \\
\text{C} & \text{Speed of sound in vacuum} \\
\text{D} & \text{Speed of sound in water} \\
\text{E} & \text{Speed of sound in air} \\
\text{F} & \text{Speed of light in water} 
\end{cases}
\]

2. (3 points) To the right is a partial listing of specifications for a particular accelerometer. What is the maximum acceleration that can be measured along the x-axis if the x-axis is oriented horizontally?

\[
\text{\textbf{Choices}} = \begin{cases} 
\text{A} & 0 \\
\text{B} & 35.3 \text{m/s}^2 \\
\text{C} & 2.72 \text{m/s}^2 \\
\text{D} & 19.6 \text{m/s}^2 \\
\text{E} & 9.81 \text{m/s}^2 \\
\text{F} & 39.2 \text{m/s}^2 
\end{cases}
\]
3. (3 points) The object detection sensor pictured is like the one you implemented for a homework assignment. What type of electromagnetic radiation does this sensor detect? Hint: you used a special LED to emit the appropriate radiation.

Choices:
- A. Visible
- B. X-rays
- C. Gamma rays
- D. Infrared
- E. Ultraviolet
- F. Radio waves
- G. Microwaves

4. (3 points) Which of the following is NOT one of the 10 personas or “faces of innovation”?

Choices:
- A. Director
- B. Experimenter
- C. Hurdler
- D. Cross-pollinator
- E. Caregiver
- F. Philanthropist
- G. Set designer
- H. Anthropologist
- I. Storyteller
- J. Collaborator

5. (3 points) When working with sheet metal, a brake would be used to make which type of feature?

Choices:
- A. Connection between two sheets
- B. Focused bend (rounded corner)
- C. Impressed lettering
- D. Jagged cut
- E. Smooth cut
- F. Sweeping, curved bend
- G. Round hole

6. (3 points) Which is NOT true of a mind map?

Choices:
- A. Helps with brainstorming
- B. Can include doodles
- C. Can be colorful
- D. Uses linking phrases
7. (3 points) Two spur gears transmit torque between parallel shafts with 100% efficiency. Gear 2 spins twice as fast as Gear 1. Input torque $T_1$ is applied to the shaft of gear 1 clockwise as shown. For the system to operate at constant speed, the resisting torque $T_2$ must be equal to:

Choices = 
- "A" = "twice $T_1$ (CW)"
- "B" = "Not enough information"
- "C" = "zero"
- "D" = "half of $T_1$ (CW)"
- "E" = "twice $T_2$ (CCW)"
- "F" = "half of $T_1$ (CCW)"

Note: CW = clockwise, CCW = counterclockwise

8. (3 points) You and a friend are planning a trip from Ruston, LA, to Washington, DC. You want to use a decision matrix to help select your mode of transportation. Your baseline option is driving your own small car. You have identified four criteria to help in your selection and have assigned the weights and relative improvements given in the table. Based on the matrix, which mode of transportation should you choose?

<table>
<thead>
<tr>
<th>MODES OF TRANSPORTATION</th>
<th>Driving your small car</th>
<th>Renting large SUV</th>
<th>Flying</th>
<th>Riding bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>Weight</td>
<td>relative improvement</td>
<td>score</td>
<td>relative improvement</td>
</tr>
<tr>
<td>cost</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>comfort</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>cargo capacity</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>combined time for making arrangements and traveling</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
</tbody>
</table>

9. (3 points) Which type of program element gives priority to a specified function so that under certain conditions the Arduino suspends its current task, runs the prioritized function, then resumes the suspended task where it left off?

Choices = 
- "A" = "Suspend loop"
- "B" = "Rabbit trail"
- "C" = "Pause"
- "D" = "Interrupt"
- "E" = "Suspend function"
- "F" = "For loop"

10. (3 points) The five steps in the IDEO design process are listed below in random order. Select the proper order.

5. Implement the new concept for commercialization.
3. Evaluate and refine the prototypes in a series of quick iterations.
1. Understand the market, the client, the technology, and the perceived constraints.
2. Observe real people in real-life situations.

Choices = 
- "A" = "5, 4, 2, 1, 3"
- "B" = "4, 5, 2, 3, 1"
- "C" = "2, 5, 3, 4, 1"
- "D" = "5, 4, 2, 3, 1"
- "E" = "4, 5, 2, 1, 3"
- "F" = "2, 4, 1, 5, 3"
11. (5 points) The y-component of the force depicted below is closest to:

\[
\begin{align*}
\text{Choices} & = \\
\text{A} & = -115.9 \\
\text{B} & = -228.7 \\
\text{C} & = -250.0 \\
\text{D} & = 433.0 \\
\text{E} & = -586.7 \\
\text{F} & = 115.9 \\
\text{G} & = 228.7 \\
\text{H} & = 250.0 \\
\text{I} & = 433.0 \\
\text{J} & = 586.7
\end{align*}
\]

\[ F = 500 \text{ N} \]
\[ \theta = 30 \text{ deg} \]

12. (5 points) The resultant magnitude of the two forces depicted below is closest to:

\[
\begin{align*}
\text{Choices} & = \\
\text{A} & = -0.9 \\
\text{B} & = -11.8 \\
\text{C} & = -42.2 \\
\text{D} & = -134.2 \\
\text{E} & = -206.0 \\
\text{F} & = 0.9 \\
\text{G} & = 11.8 \\
\text{H} & = 42.2 \\
\text{I} & = 134.2 \\
\text{J} & = 206.0
\end{align*}
\]

\[
\begin{align*}
R_x &= -130 \text{ lb} \cdot \cos(25^\circ) \\
&\quad + 100 \text{ lb} \cdot \cos(45^\circ) \\
&= -47.1 \text{ lb} \\
R_y &= 130 \text{ lb} \cdot \sin(25^\circ) \\
&\quad + 100 \text{ lb} \cdot \sin(45^\circ) \\
&= 125.65 \text{ lb} \\
R &= \sqrt{(-47.1 \text{ lb})^2 + (125.65 \text{ lb})^2} \\
&= 134.19 \text{ lb}
\end{align*}
\]
13. (5 points) The resultant of the two forces depicted below creates an angle with the x-axis that is closest to...

\[
\begin{align*}
R_x &= 318 \text{ lbf} \\
R_y &= 268 \text{ lbf}
\end{align*}
\]

\[
\theta = \tan^{-1}\left(\frac{268 \text{ lbf}}{318 \text{ lbf}}\right) = 40.12^\circ
\]

Choices: 

- A: 28.7 deg
- B: 31.6 deg
- C: 34.5 deg
- D: 35.8 deg
- E: 37.3 deg
- F: 39.3 deg
- G: 40.1 deg
- H: 42.8 deg
- I: 46.4 deg
- J: 49.9 deg

14. (5 points) The three forces shown are applied to an object which remains in equilibrium at the origin. Using the information given, \( F_2 \) is found to be closest to:

\[
\begin{align*}
\vec{F}_1 &= 350 \text{ N} \\
\theta_1 &= 30^\circ \\
\vec{F}_2 &= \text{?} \\
\theta_2 &= 52^\circ \\
\vec{F}_3 &= \text{?} \\
\theta_3 &= 15^\circ
\end{align*}
\]

\[
\begin{align*}
\sum F_x &= -F_2 \sin(52^\circ) + F_3 \cos(15^\circ) - 350 \text{ N} \sin(30^\circ) = 0 \quad \text{USE CALCULATOR} \\
\sum F_y &= -F_2 \cos(52^\circ) - F_3 \sin(15^\circ) + 350 \text{ N} \cos(30^\circ) = 0
\end{align*}
\]

\[
F_2 = 309.9 \text{ N} \quad F_3 = 434 \text{ N}
\]
15. (5 points) A daredevil weighing \( W = 175 \text{ lb} \) walks across a rope between B and C. Given the dimensions shown, the tension in the rope is closest to:

\[
egin{align*}
T_{AB} &= \frac{12}{d} \text{ lb}, \\
T_{AC} &= \frac{175}{2.7} \text{ lb}
\end{align*}
\]

\[ \Rightarrow T_{AB} = T_{AC} \]

\[ \Rightarrow \sum F_x = T_{AB} \frac{2.7}{2.7} + T_{AC} \frac{2.7}{2.7} - 175 \hat{A} = 0 \]

\[ 2T_{AB} \frac{2.7}{2.7} = 175 \hat{A} \]

\[ T_{AB} = 213.2 \text{ lb} \]

16. (5 points) With a helping hand from a friendly passerby, Alex the Seal is able to support the ball. If the ball weighs \( W \) pounds, the force Alex’s nose is applying to the ball is closest to:

\[
\begin{align*}
W &= 3.5 \text{ lb} \\
\theta_1 &= 34 \text{ deg} \\
\theta_2 &= 16 \text{ deg}
\end{align*}
\]

\[
\begin{align*}
\sum \mathbf{F}_x &= F_{\text{hand}} \cos(16^\circ) - F_{\text{Alex}} \cos(14^\circ) = 0 \\
\sum \mathbf{F}_y &= F_{\text{hand}} \sin(16^\circ) + F_{\text{Alex}} \sin(14^\circ) - 3.5 \hat{y} = 0
\end{align*}
\]

\[ F_{\text{hand}} = 3.79 \text{ lb} \quad F_{\text{Alex}} = 4.39 \text{ lb} \]
17. (5 points) Considering only the weight of the lamp (center of gravity at point C), the moment generated about point D is closest to:

\[
\text{mass} \times \text{light} = 35 \text{ kg} \times (9.81 \text{ m/s}^2) \times (1.15 \text{ m}) = 394.9 \text{ N m}
\]

Choices:
- "A" 395 N m
- "B" 580 N m
- "C" 1357 N m
- "D" 2420 N m
- "E" 3090 N m

**NOTE:**
- neglect the weight of the pole/support
- consider clockwise rotation as positive and counter-clockwise rotation as negative

---

18. (5 points) Considering only the two forces shown, the moment generated about point A would be:

\[
M_A = 25 \text{ N}(8 \text{ m}) - 20 \text{ N} \cos(30^\circ)(8 \text{ m} + 6 \text{ m}) - 20 \text{ N} \sin(30^\circ)(5 \text{ m} + 3 \text{ m}) + 14 \text{ N}(5 \text{ m})
\]

\[
= -52.487 \text{ N m}
\]

Choices:
- "A" -52.487 N m
- "B" -55.157 N m
- "C" -57.835 N m
- "D" -60.500 N m
- "E" -63.092 N m
- "F" 52.487 N m
- "G" 55.161 N m
- "H" 57.810 N m
- "I" 60.510 N m
- "J" 63.180 N m

**Note:**
- consider clockwise rotation as positive and counter-clockwise rotation as negative
19. (5 points) While the Captain has been very active, Mr. Scrub has just been standing around not doing his job. Therefore, the Captain holding the knife is forcing Mr. Scrub to walk the plank. Given the weights of the pirates and the distances in the information below, the reaction at A is closest to:

```
Choices
- A* 0.002960 N
- B* 0.003172 N
- C* 0.003396 N
- D* 0.003608 N
- E* 0.003825 N
- F* 0.004041 N
- G* 0.004250 N
- H* 0.004472 N
```

Note:
- A is a pinned joint.
- Consider the men's weights to act at the vertical lines in the dimensions.
- Gravity acts in the downward direction.
- Mr. Scrub did not deserve this punishment.

\[
G \sum M_B = (0.0123 N)(12 cm) - (0.0159 N)(5 cm) - R_A(5 cm + 11 cm) = 0
\]

\[
R_A = \frac{(0.0123 N)(12 cm) - (0.0159 N)(5 cm)}{5 cm + 11 cm} = 0.004256 N
\]

20. (5 points) The crane's cable is pulling on the beam with a tension \( T_c = 300 \) N at the angle \( \theta \), measured from the vertical. The mass - 50 kg is suspended from the beam in the position shown. Dimensions are given below the image. If the beam is in static equilibrium, the reaction at D is closest to:

```
Choices
- A 159.1
- B 169.3
- C 179.6
- D 189.7
- E 199.0
- F 210.0
- G 220.0
- H 230.2
- T 240.3
- J 250.5
```

\[
\phi = \tan^{-1} \left( \frac{60}{80} \right) = 36.87^\circ
\]

\[
G \sum M_A = 300 \cos (51.87^\circ)(100 \text{ cm}) - 490.5 \cos (36.87^\circ)(200 \text{ cm}) + R_D(300 \text{ cm}) = 0
\]

\[
R_D = \frac{490.5 \cos (36.87^\circ)(200 \text{ cm}) - 300 \cos (51.87^\circ)(100 \text{ cm})}{300 \text{ cm}} = 199.85 \text{ N}
\]
21. (5 points) The x component of reaction at A is closest to:

Note that $\theta_1 + \theta_2 = 90^\circ$

\[ F = \frac{4000 \cdot 34 \text{ cm} \cdot \sin(54^\circ)}{34 \text{ cm}} = 323.6 \text{ N} \]

\[ R_c = 323.6 \text{ N} \cdot \sin(36^\circ) \]

\[ R_{ax} = 190.2 \text{ N} \]

Choices:

- A 123.0
- B 132.4
- C 142.2
- D 151.7
- E 161.3
- F 171.0
- G 180.5
- H 190.2
- I 199.8
- J 209.5

22. (5 points) A DC motor operates at a voltage of $V_m = 12 \text{ V}$ and consumes a current of $I_m = 0.5 \text{ A}$. The motor turns a gear train to lift a mass of mass $= 12 \text{ kg}$. If the system operates for time $t = 2 \text{ min}$ with an efficiency of $\eta = 80\%$, then the change in height of the mass is closest to:

\[ P_m = (12 \text{ V})(0.5 \text{ A}) = 6 \text{ W} \]

\[ \text{Energy In} = 6 \text{ W} \cdot 2 \text{ min} \left( \frac{60 \text{ sec}}{1 \text{ min}} \right) = 720 \text{ J} \]

\[ \text{Energy Out} = \eta \cdot \text{Energy In} \]

\[ \Delta h = \frac{\text{Energy out}}{W_t} = \frac{576.3}{117.72 \text{ N}} = 4.89 \text{ m} \]

Choices:

- A 4.615
- B 4.893
- C 5.140
- D 5.391
- E 5.640
- F 5.891
- G 6.130
- H 6.384
- I 6.624
- J 6.875
23. (5 points) Four spur gears mesh together as shown below. If the largest gear spins at 200 RPM, and transmits $T_4 = 23$ ft lb of torque, the Torque transmitted by the smallest gear is closest to:

$$T_4 = \left(2\pi \rho_4 \rho_5 \right) \frac{B}{2M} = \left(7.67 \pi \rho_4 \rho_5 \right) \frac{B}{2M} \approx 7.67 \text{ ft lb}$$

Choices:
- \(G\) 7.67
- \(H\) 8.05
- \(I\) 8.43
- \(J\) 8.83

24. (5 points) Four spur gears mesh together as shown below. Gear A has 24 teeth and meshes with Gear B. Gear B has 12 teeth and is stacked with Gear C. Gear C has 24 teeth and meshes with Gear D. Gear D has 12 teeth. If Gear A spins at $\text{RPM}_A = 220$ rpm, then Gear D spins closest to:

$$\omega_D = \left(220 \text{ rpm}\right) \frac{24}{12} \cdot \frac{24}{12} = 880 \text{ rpm}$$

Choices:
- \(A\) 791
- \(B\) 836
- \(C\) 880
- \(D\) 924
- \(E\) 969
- \(F\) 1014
- \(G\) 1058
- \(H\) 1104
- \(I\) 1148
- \(J\) 1193
25. (5 points) The electric motor shown is supplied with a voltage of \( V_{\text{in}} = 115 \text{ V} \) and a current of \( I_{\text{in}} = 5 \text{ A} \) while lifting a weight. The overall system efficiency is \( \eta = 60 \% \). Gear A has \( N_A = 15 \) teeth and Gear B has \( N_B = 194 \) teeth. The speed that Gear A is turning is closest to:

\[
\begin{align*}
\text{Options} & & \text{\begin{array}{ccc}
\text{A} & 116 & \text{B} & 124.9 \\
\text{C} & 133.1 & \text{D} & 141.8 \\
\text{E} & 150.1 & \text{F} & 158.6 \\
\text{G} & 167.1 & \text{H} & 175.6 \\
\text{I} & 184.1 & \text{J} & 192.6 \\
\end{array}}
\end{align*}
\]

\[
\begin{align*}
& P_{\text{in}} = \frac{115 \text{ V} \times 5 \text{ A}}{1000} = 0.575 \text{ W} \\
& P_{\text{out}} = \frac{60 \times 0.575 \text{ W}}{1000} = 0.0345 \text{ W} \\
& P_{\text{out}} = \text{Weight} \times \text{Velocity} \\
& \text{Weight} = \frac{3 \text{ kN} \times 1000}{1000} = 3 \text{ kN} \\
& d = 17 \text{ cm} \\
& \omega_{\text{pulley}} = \frac{\text{Velocity}}{d/2} = \frac{0.115 \text{ rad/s}}{17 \text{ cm}/2} \\
& \omega_{\text{pulley}} = 1.3529 \text{ rad/s} \\
& \omega_A = \omega_{\text{pulley}} \times \frac{N_B}{N_A} = 1.3529 \text{ rad/s} \times \frac{194}{15} \\
& \omega_A = 17.5 \text{ rad/s} \\
& \omega_A = 167.09 \text{ rpm} \\
\end{align*}
\]

\[
\begin{align*}
\text{Hint: Power may be broken down:} \\
\text{Power} = \frac{\text{Energy}}{\text{Time}} = \frac{\text{Force} \times \text{Length}}{\text{Time}} = \frac{\text{Force} \times \text{Distance}}{\text{Time}} \\
\text{Remember the definition of efficiency:} \\
\eta = \frac{\text{useful power out of system}}{\text{required power into system}}
\end{align*}
\]

26. (5 points) The set of alligator jaws shown have powerful muscles that connect between points B and C. These muscles contract, causing the jaw to hinge about point D and close on alligator snacks. The way the snapper becomes oriented in the alligator jaws leads to a force of \( F_A = 130 \text{ lb} \) being applied to the snack at A along a line that is perpendicular to a line between A and D. The force that the jaw muscles must exert to achieve this force at A is closest to:

\[
\begin{align*}
\text{Options} & & \text{\begin{array}{ccc}
\text{A} & 578 & \text{B} & 615 \\
\text{C} & 651 & \text{D} & 688 \\
\text{E} & 725 & \text{F} & 782 \\
\text{G} & 799 & \text{H} & 836 \\
\text{I} & 872 & \text{J} & 909 \\
\end{array}}
\end{align*}
\]

\[
\begin{align*}
\text{Lengths:} \\
\overline{AB} &= \sqrt{(2.7 \text{ in})^2 + (7.1 \text{ in})^2} = 7.77 \text{ in} \\
\overline{AD} &= 22.452 \text{ in} \\
\overline{CD} &= 2.7 \text{ in} - 1.8 \text{ in} = 0.9 \text{ in} \\
\overline{CB} &= 7.1 \text{ in} - 4.7 \text{ in} = 2.4 \text{ in} \\
\text{Slope of CB:} \\
\text{rise} &= 8.5 \text{ in} - 4.7 \text{ in} = 3.8 \text{ in} \\
\text{run} &= 18 \text{ in} - 16 \text{ in} = 2 \text{ in} \\
\text{hypotenuse} &= \sqrt{3.8^2 + 1.9^2} = 4.24 \text{ in} \\
\end{align*}
\]

\[
\begin{align*}
\sum \! F_D &= (130 \text{ lb}) (22.452 \text{ in}) - T_{\text{BC}} \left( \begin{array}{c} 1.8 \text{ in} \\ 4.7 \text{ in} \end{array} \right) - T_{\text{BC}} \left( \begin{array}{c} 1.9 \text{ in} \\ 4.7 \text{ in} \end{array} \right) (2.4 \text{ in}) = 0 \\
T_{\text{BC}} &= 725.17 \text{ lb}
\end{align*}
\]