Name: **Solution**

Seat Assignment: __________________________

Specify your EXAM ID on the right. Use 000 if you do not know your exam ID.

Circle your LAB SECTION

<table>
<thead>
<tr>
<th>Lab Start Time</th>
<th>Lab Location</th>
<th>Lab Location</th>
<th>Lab Location</th>
<th>Lab Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:10a</td>
<td>A0X3 Nathan</td>
<td>A1Y3 Luc</td>
<td>A7X3 Jeremiah</td>
<td>A8X1 Megan</td>
</tr>
<tr>
<td>9:45a</td>
<td>B0X3 Nathan</td>
<td>B1Z1 Saeed</td>
<td>B7Y1 Niantai</td>
<td>B8X1 Megan</td>
</tr>
<tr>
<td>11:20a</td>
<td>C0Y1 Nathan</td>
<td>C1Z1 Jeremiah</td>
<td>C7Y3 Niantai</td>
<td>C8X1 Tennessee</td>
</tr>
<tr>
<td>12:55p</td>
<td>D0Y1 Megan</td>
<td>D1Z1 Luc</td>
<td>D8X1 Tennessee</td>
<td></td>
</tr>
<tr>
<td>2:30p</td>
<td>E0Y1 Niantai</td>
<td>E1Z1 Luc</td>
<td>E8X3 Tennessee</td>
<td></td>
</tr>
</tbody>
</table>

**Instructions and Guidelines**

- Do not open the exam until instructed to do so.
- While taking this exam, you may use any calculator that does not have the ability to connect to the internet and four handwritten, 8.5-inch x 11-inch reference sheets (front and back).
- Use a No. 2 pencil; make sure your work is dark enough and clear enough to be read when scanned.
- For each multiple-choice question, completely bubble your selected answer. If you wish to eliminate an answer choice, cross out the words above that bubble, but do not place any marks in that bubble.
- For each free response / PROCESS question, document your work (no work, no credit) following the PROCESS format. Your response should include (i) a problem statement, (ii) a representation or picture, (iii) organized information, (iv) calculations with equations in variable form, and (v) a final answer with units.
- When time is called, stop writing immediately. Working after time is called is academic dishonesty.
- Turn in your reference sheet(s) with your exam.

**Known Values**

- Density of water: \( \rho_{\text{water}} = 1000 \text{ kg/m}^3 = 1 \text{ kg/L} \)
- Atmospheric Pressure: \( P = 101,300 \text{ Pa} = 1 \text{ atm} \approx 14.7 \text{ psi} \)
- Gravitational Constant: \( G = 6.6742 \times 10^{-11} \text{ N} \text{ m}^2/\text{kg}^2 \)
- Electrostatic Constant: \( k = 8.9875 \times 10^9 \text{ N m}^2/\text{C}^2 \)
- Universal Gas Constant: \( R = 8.314 \text{ (Pa m}^3)/\text{(mol K)} = 8.314 \text{ J/} \text{(mol K)} = 0.0821 \text{ (atm L)/} \text{(mol K)} \)
- Speed of Sound at 20°C: \( v = 343 \text{ m/s} \)
- Threshold of Hearing: \( l_0 = 1 \times 10^{-12} \text{ W/m}^2 \)
- Speed of Light in a Vacuum: \( c = 3 \times 10^8 \text{ m/s} \)

**Selected SI Prefixes and Conversion Factors**

- \( 10^{-2} = \text{centi} = c \)
- \( 10^{-6} = \text{micro} = \mu \)
- \( 1 \text{ m}^3 = 1000 \text{ L} \)
- \( 10^{-3} = \text{milli} = m \)
- \( 1 \text{ atm} = 101,300 \text{ Pa} \)
- \( 1 \text{ W} = 3.413 \text{ BTU/hr} \)
1. (1 pt) 600 J of heat is removed from a system while the system does 400 J of work. Determine the change in internal energy of the system. \[ \Delta U = Q - W = -600 \text{ J} - 400 \text{ J} = -1000 \text{ J} \]

2. (1 pt) 2 negatively charged balls are held 4.0 m apart from each other. At this distance, the force exerted by ball 1 on ball 2 is 20.0 N. What is the force exerted on ball 2 if the distance between the balls is decreased to 2.0 m?

\[ F = \frac{kq_1q_2}{r^2} \]

3. (1 pt) Luc adds a single ice cube at 0°F to a bowl of hot soup at 180°F. Which experiences a smaller change in temperature?

- Ice cube
- Soup
- Same for both

4. (1 pt) Cube M and Cube L are the same size, but Cube M is more dense than Cube L. Both cubes are submerged to the same depth in the same liquid. Which of the following relationships is true?

- Cube M < F_{buoyant}, Cube L
- F_{buoyant}, Cube M = F_{buoyant}, Cube L
- F_{buoyant}, Cube M > F_{buoyant}, Cube L

5. (1 pt) Make the statement true. When heat is added to a system, the temperature of the system ______ changes.

- never
- sometimes
- always

6. (1 pt) A steel cable has a yield strength of 800 lb. Using a factor of safety of 2, what is the maximum load the cable can safely support?

- 400 lb
- 800 lb
- 1600 lb
- 3200 lb

7. (1 pt) Make the statement true. In an electric circuit, when 2 resistors are in series, the _____ of each resistor is the same.

- voltage
- current
- charge

8. (1 pt) Make the statement true. The pressure exerted by a bear walking on its two hind legs is ______ the pressure exerted by the same bear walking on all four legs.

- less than
- the same as
- greater than

9. (1 pt) Two simple pendulums have the same length, but Pendulum #1 is heavier than Pendulum #2. How do the periods T1 and T2 compare?

- T1 > T2
- T1 = T2
- T1 < T2

\[ \omega_{sp} = \sqrt{\frac{g}{l}} \]
10. (1 pt) When the switch is closed, what happens to the current flowing through the battery in the circuit shown?

<table>
<thead>
<tr>
<th>0.39/1 (39%)</th>
<th>0.39/1 (39%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>Stays the Same</td>
<td></td>
</tr>
</tbody>
</table>

11. (1 pt) **Make the statement true.** The index of refraction of a transparent material will ___ be less than one.

<table>
<thead>
<tr>
<th>0.92/1 (92%)</th>
<th>0.92/1 (92%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>always</td>
<td>sometimes</td>
</tr>
<tr>
<td>never</td>
<td></td>
</tr>
</tbody>
</table>

12. (1 pt) 70 L/s of water is flowing through a pipe. The cross-sectional area of the pipe decreases by half. What is the flow rate of water in the narrower section of pipe?

<table>
<thead>
<tr>
<th>0.36/1 (36%)</th>
<th>0.36/1 (36%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 L/s</td>
<td>70 L/s</td>
</tr>
<tr>
<td>140 L/s</td>
<td></td>
</tr>
</tbody>
</table>

13. (1 pt) You plug a hair dryer that uses 1500 W of power into a standard electrical outlet in the United States. What is the resistance of the hair dryer?

<table>
<thead>
<tr>
<th>0.83/1 (83%)</th>
<th>0.83/1 (83%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Ohms</td>
<td>0.28 Ohms</td>
</tr>
<tr>
<td>9.6 Ohms</td>
<td>12.5 Ohms</td>
</tr>
</tbody>
</table>

14. (1 pt) **Make the statement true.** To minimize the amount of heat transfer, we should select a material that is a ___ conductor of heat and has a ___ thermal conductivity.

<table>
<thead>
<tr>
<th>0.69/1 (69%)</th>
<th>0.69/1 (69%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>good; high</td>
<td>good; low</td>
</tr>
<tr>
<td>poor; high</td>
<td>poor; low</td>
</tr>
</tbody>
</table>

15. (1 pt) The intensity of a sound is I at a distance of 1 m. What is the intensity of the sound at 2 m away?

<table>
<thead>
<tr>
<th>0.85/1 (85%)</th>
<th>0.85/1 (85%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/4</td>
<td>I/2</td>
</tr>
<tr>
<td>2I</td>
<td>4I</td>
</tr>
</tbody>
</table>

16. (1 pt) The position of an object moving in simple harmonic motion has an equation represented as \(x(t) = 5.6 \sin(4t) - 2.4 \cos(4t) \text{ m} \). **What is the initial displacement of the object?**

<table>
<thead>
<tr>
<th>0.90/1 (90%)</th>
<th>0.90/1 (90%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 m</td>
<td>4.0 m</td>
</tr>
<tr>
<td>5.6 m</td>
<td>5.8 m</td>
</tr>
</tbody>
</table>
17. Find Req

**Final Answer**

\[ \text{Req} = 29.3 \Omega \]

**Problem Statement**

Find Req

**Calculations**

\[ R_{12} = R_1 + R_2 = 12 \Omega + 75 \Omega = 87 \Omega \]

\[ R_{1234} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}} = \frac{1}{\frac{1}{87} + \frac{1}{40} + \frac{1}{65}} = 19.27 \Omega \]

\[ R_{12345} = R_{1234} + R_5 = 19.27 \Omega + 10 \Omega = 29.27 \Omega \]

**Final Answer**

\[ T_{out} = 102^\circ F \]

**Problem Statement**

Find T_{out}

**Organize Information**

\[ \frac{\Delta Q}{\Delta t} = 480 \text{ BTU/hr} \]

\[ T_{in} = 70^\circ F \]

\[ A = 195 \text{ ft}^2 \]

\[ R = 13 \text{ hr ft}^2 \cdot ^\circ F / \text{ BTU} \]

\[ t = 10 \text{ in} \]

**Calculations**

\[ \frac{\Delta Q}{\Delta t} = -A \left( T_{in} - T_{out} \right) \]

\[ T_{out} = \left( \frac{\Delta Q}{\Delta t} \right) \frac{R}{A} + T_{in} \]

\[ T_{out} = \left( \frac{480 \text{ BTU/hr}}{13 \text{ hr ft}^2 \cdot ^\circ F / \text{ BTU}} \right) \frac{195 \text{ ft}^2}{195 \text{ ft}^2} + 70^\circ F = 102^\circ F \]
19. (6 pts) Megan is operating a crane to unload shipping containers that has a 4.2 cm diameter steel cable, with a modulus of elasticity (E) of 570 x 10^9 Pa. The cable has a length of 34 m and can stretch no more. Determine the maximum weight of a shipping container that can be lifted by the crane.

**Final Answer**

\[ F = 65.0 \text{ kN} \]

**Problem Statement**

Find \( W_{\text{container}} \)

**Organize Information**

\[ \begin{align*}
D &= 4.2 \text{ cm} \\
E &= 570 \times 10^9 \text{ Pa} \\
L &= 34 \text{ m} \\
\Delta x &= 2.8 \text{ mm} \\
\Delta x &= 0.0028 \text{ m} \\
\end{align*} \]

+1 Organized information

**Calculations**

\[ \Delta x = \frac{FL}{EA} \rightarrow F = \frac{\Delta x EA}{L} = \frac{\Delta x E \left( \pi r^2 \right)}{L} = \frac{\Delta x E \left( \pi \left( \frac{D}{2} \right)^2 \right)}{L} \]

+1 Correct calculation of area

\[ F = \left( 0.0028 \text{ m} \right) \left( 570 \times 10^9 \text{ Pa} \right) \left( \pi \left( \frac{0.042 \text{ m}}{2} \right)^2 \right) \]

\[ = 65.034 \text{ kN} \]

+2 Correct calculation of weight

20. (7 pts) Niantai plays a guitar string that is 56 cm long and has a mass of 0.125 kg. To play the designed fundamental frequency, a tension of 940 N is applied to the string. What is the required length of a pipe on a pipe organ (open-open pipe) to play the same fundamental frequency? (Assume the speed of 343 m/s.)

**Final Answer**

\[ L_{\text{pipe}} = 2.96 \text{ m} \]

**Problem Statement**

Find \( L_{\text{pipe}} \)

**Organize Information**

\[ \begin{align*}
L_{\text{string}} &= 56 \text{ cm} \\
M_{\text{string}} &= 0.125 \text{ kg} \\
T &= 940 \text{ N} \\
V_{\text{sound}} &= 343 \text{ m/s} \\
\end{align*} \]

+1 Organized Information

**Calculations**

\[ M_{\text{string}} = \frac{M}{L} = \frac{0.125 \text{ kg}}{0.56 \text{ m}} = 0.2232 \text{ kg/m} \]

+1 correct \( m/L \)

+2 correct process to find \( f_{\text{string}} \)

\[ f_{\text{string}} = \frac{1}{2L \sqrt{\mu}} = \frac{1}{2(0.56 \text{ m}) \sqrt{0.2232 \text{ kg/m}}} = 57.94 \text{ Hz} \]

+1 equations in variable form

+2 correct process to find \( L \)

\[ f_{\text{pipe}} = \frac{NV}{2L} \rightarrow L_{\text{pipe}} = \frac{NV}{2 f_{\text{pipe}}} = \frac{NV}{2 f_{\text{string}}} = \frac{(1)(343 \text{ m/s})}{2(57.94 \text{ Hz})} = 2.96 \text{ m} \]
21. (7 pts) On a 20°C summer day, Journey plays a 210 Hz note on his trumpet while riding on a golf cart moving at 20 m/s directly towards Neyland Stadium. What frequency does he hear when the wave hits the wall of the stadium and returns to him?

**Final Answer**

\[ f'' = 236 \text{ Hz} \]

**Problem Statement**

Find \( f'' \)

**Represent the Problem & Organize Information**

A fully labeled diagram is required for full credit.

\[ \begin{array}{c}
1. \quad L_n \rightarrow S_j \quad 0 \quad \rightarrow 20 \text{ m/s} \\
2. \quad S_n \rightarrow L_j \quad 0 \quad \rightarrow 20 \text{ m/s}
\end{array} \]

- +1 correct diagram 1
- +1 correct diagram 2

**Calculations**

\[ V_{\text{sound}} = 331 + 0.6T = 331 + 0.6(20) = 343 \text{ m/s} \]

- +1 correct \( v(\text{sound}) \)

\[ f' = f \left( \frac{V + V_c}{V + V_s} \right) = 210 \text{ Hz} \left( \frac{343 \text{ m/s} + 20 \text{ m/s}}{343 \text{ m/s} + 20 \text{ m/s}} \right) = 223.0 \text{ Hz} \]

- +1 correct process to find \( f' \)

\[ f'' = f' \left( \frac{V + V_c}{V + V_s} \right) = 223.0 \text{ Hz} \left( \frac{343 \text{ m/s} + 20 \text{ m/s}}{343 \text{ m/s} + 20 \text{ m/s}} \right) = 236.0 \text{ Hz} \]

- +1 correct process to find \( f'' \)

22. (7 pts) Determine the magnitude and direction of the electric field at point P, where \( q_1 = +25 \text{ nC} \) and \( q_2 = -62 \text{ nC} \).

**Final Answer**

\[ E_p = 342 \text{ N/C} \left( \rightarrow \right) \]

**Problem Statement**

Find \( E_p \)

**Represent the Problem & Organize Information**

Two labeled arrows indicating the direction of the electric fields at Point P caused by each particle is required for full credit.

\[ \begin{array}{c}
-62 \text{ nC} \\
q_2 \\
0.14 \text{ m} \\
+25 \text{ nC} \\
q_1 \\
0.29 \text{ m} \\
P
\end{array} \]

- +1 correct diagram

**Calculations**

\[ E_1 = \frac{kq_1}{r_1^2} = \left( 9 \times 10^9 \text{ N m}^2/\text{C}^2 \right) \left( \frac{25 \times 10^{-9} \text{ C}}{(0.29 \text{ m})^2} \right) = 2675.4 \text{ N/C} \left( \rightarrow \right) \]

- +2 correct process to find \( E_1 \)

\[ E_2 = \frac{kq_2}{r_2^2} = \left( 9 \times 10^9 \text{ N m}^2/\text{C}^2 \right) \left( \frac{62 \times 10^{-9} \text{ C}}{(0.14 \text{ m} + 0.29 \text{ m})^2} \right) = 3017.8 \text{ N/C} \left( \rightarrow \right) \]

- +2 correct process to find \( E_2 \)

\[ E_p = E_1 + E_2 = 2675.4 \text{ N/C} \left( \rightarrow \right) + 3017.8 \text{ N/C} \left( \rightarrow \right) = 342.4 \text{ N/C} \left( \rightarrow \right) \]

- +1 correct process to add \( E_1 \) and \( E_2 \)
23. (6.63/7 = 94.7%) 

**Problem Statement:**

A 1.9 cm thick sheet of glass is shown. Determine the distance Δx.

**Find Δx**

**Final Answer:**

Δx = 0.774 cm

**Calculations:**

\[ \Theta_{air} = 90^\circ - 55^\circ = 35^\circ \]

\[ n_{air} \sin (\Theta_{air}) = n_{glass} \sin (\Theta_{glass}) \]

\[ 1.00 \times \sin (35^\circ) = 1.52 \times \sin (\Theta_{glass}) \]

\[ \Theta_{glass} = 22.17^\circ \]

\[ \tan(\Theta_{glass}) = \frac{\Delta x}{1.9 \text{ cm}} \rightarrow \Delta x = 1.9 \text{ cm} \times \tan(\Theta_{glass}) \]

\[ \Delta x = 1.9 \text{ cm} \times \tan(22.17^\circ) \]

\[ \Delta x = 0.774 \text{ cm} \]

- 1 correct angle used
- 1 Snell's law in variable form
- 3 correct process to find angle 2
- 2 correct process to find deltaX

24. (5.02/7 = 71.7%) 

**Problem Statement:**

During off peak hours, a pump refills a water tower. At the base of the tower, the water is at a pressure of 70 psi, gauge, and is flowing at 20 ft/s. The top of the tower is open to the atmosphere and is that the water can be assumed to be stationary. Determine the height of the water tower.

**Find h_{tower}**

**Final Answer:**

h_{tower} = 168 ft

**Organize Information**

\[ P_{base,g} = 70 \text{ psi} \quad V_{base} = 20 \text{ ft/s} \]

\[ P_{top,g} = 0 \text{ psi} \quad V_{top} = 0 \text{ ft/s} \]

**Calculations**

\[ P_{base,g} = \frac{70 \text{ lb}}{1 \text{ in}^2} \left( \frac{12 \text{ in}^2}{1 \text{ ft}^2} \right) = 10080 \text{ psf} \]

\[ P_1 + \rho g h_1^0 + \frac{1}{2} \rho V_1^2 = P_2 + \rho g h_2^0 + \frac{1}{2} \rho V_2^2 \]

\[ h_2 = 167.7 \text{ ft} \]

- 1 Organized information
- 1 Pressure in units of psf
- 2 Bernoulli's equation in variable form
- 1 Correct calculation of height
- 1 Correct use of mass density
- 1 Correct use of weight density
25. (7 pts) Saeed’s heat engine consumes 1700 J of heat from a hot reservoir at 85°C and exhausts heat to a cold reservoir at 12°C. The heat engine operates with an efficiency that is 71% of ideal. Determine the work the heat engine performs.

**Final Answer**

\[ W = 246 \text{ J} \]

**Problem Statement**

**Find** \( W \)

**Represent the Problem & Organize Information**

A completed diagram with arrows is required for full credit.

- Representative temperature arrows are correct on diagram
- Temperatures converted to K

**Calculations**

\[ \eta_{\text{Carnot}} = 1 - \frac{T_{\text{C}}}{T_{\text{H}}} = 1 - \frac{285 \text{ K}}{358 \text{ K}} = 0.2039 \]

\[ \eta_{\text{actual}} = 0.71 \eta_{\text{Carnot}} = 0.71 (0.2039) = 0.1448 \]

\[ W = \eta Q_{\text{H}} = (0.1448)(1700 \text{ J}) \]

\[ W = 246.1 \text{ J} \]

**Problem Statement**

Create the matrix below. You do not need to numerically solve for the values of the currents.

**Complete matrix**

The circuit diagram shown must be fully labeled to receive full credit.

**Represent the Problem & Organize Information**

- Correctly labeled diagram

**Calculations**

\[ J_{\text{H}} : I_1 + I_2 - I_3 = 0 \]

\[ L_1 : +5V - (20 \Omega) I_1 - (30 \Omega) I_3 = 0 \]

\[ -(20 \Omega) I_1 - (30 \Omega) I_3 = +5V \]

\[ L_2 : -12V + (10 \Omega) I_2 + (30 \Omega) I_3 = 0 \]

\[ +(10 \Omega) I_2 + (30 \Omega) I_3 = +12V \]

**1 correct junction equation**

**2 correct loop equations**

**Correct values in table**

<table>
<thead>
<tr>
<th>Junction</th>
<th>I_1</th>
<th>I_2</th>
<th>I_3</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop #1</td>
<td>-20</td>
<td>0</td>
<td>-30</td>
<td>-5</td>
</tr>
<tr>
<td>Loop #2</td>
<td>0</td>
<td>10</td>
<td>30</td>
<td>12</td>
</tr>
</tbody>
</table>

This table must be completed for full credit.
27. (8 pts) An ideal gas initially at atmospheric pressure is compressed in an isobaric process from 0.07 m$^3$ to 0.04 m$^3$. The gas is then further compressed in an isothermal process to a final volume of 0.02 m$^3$. Find the total work required to compress the gas.

**Final Answer**

\[ W_{\text{tot}} = -5848 \text{ J} \]

**Problem Statement**

**Organize Information**

\[
\begin{align*}
\text{P [Pa]} & \quad \text{V [m}^3] \\
101300 & \quad 0.07 \\
101300 & \quad 0.04 \\
P_2 & \quad 0.02
\end{align*}
\]

**Calculations**

\[ W_{1\rightarrow 2} = P(V_2 - V_1) = 101300 \text{ Pa} \left(0.04 \text{ m}^3 - 0.07 \text{ m}^3\right) = -3039 \text{ J} \]

\[ W_{2\rightarrow 3} = P_2 V_2 \left[\ln V_3 - \ln V_2\right] \\
= (101300 \text{ Pa})(0.04 \text{ m}^3) \left[\ln(0.02 \text{ m}^3) - \ln(0.04 \text{ m}^3)\right] = -2809 \text{ J} \]

\[ W_{\text{tot}} = W_{1\rightarrow 2} + W_{2\rightarrow 3} = -3039 \text{ J} - 2809 \text{ J} = -5848 \text{ J} \]

**Grading Notes**

- 2 Organized information
- 1 Equation for work for an isobaric process in variable form
- 1 Correct calculation of work for the isobaric process
- 1 Equation for work for an isothermal process in variable form
- 1 Correct calculation of work for the isothermal process
- 2 Correct calculation of total work required
28. (8 pts) Tennessee, who weighs 180 lb, is standing 7 ft to the right of center on a 120 lb beam. A 50 lb box is placed 10 ft to the left of center of the beam. Determine where Nathan, who weighs 160 lb, is to place himself so that the beam does not rotate about its center.

**Final Answer (including both distance and direction)**

\[ x_{\text{nathan}} = 4.75 \text{ ft to the left} \]

**Problem Statement**

Find \( x_{\text{nathan}} \)

**Represent the Problem & Organize Information**

- A completed FBD is required for full credit.
- +1 Tennessee's weight and distance on FBD
- +1 The box's weight and distance on FBD
- +1 The beam's weight on FBD
- +1 Nathan's weight and unknown distance on FBD

**Calculations**

\[
\sum M_c = + (50 \text{ lb})(10 \text{ ft}) + (160 \text{ lb})(x_{\text{nathan}}) - (180 \text{ lb})(7 \text{ ft}) = 0 \text{ ft lb}
\]

\[ x_{\text{nathan}} = 4.75 \text{ ft to the left} \]

+1 Correct distance of Nathan from center