Name: SOLUTION

Seat Assignment: ____________________________

Specify your EXAM ID on the right.

<table>
<thead>
<tr>
<th>Lab Start Time</th>
<th>Lab Location</th>
<th>ZEC 271</th>
<th>ZEC 277</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:10a</td>
<td>A1X1</td>
<td>A7X2</td>
<td>John</td>
</tr>
<tr>
<td>8:10a</td>
<td>Saeed</td>
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<tr>
<td>9:45a</td>
<td>B1X1</td>
<td>B7X2</td>
<td>John</td>
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<tr>
<td>9:45a</td>
<td>Saeed</td>
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<tr>
<td>11:20a</td>
<td>C1X1</td>
<td>C7X2</td>
<td>Hunter</td>
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<tr>
<td>11:20a</td>
<td>Saeed</td>
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<tr>
<td>12:55p</td>
<td>D1X1</td>
<td>D7X2</td>
<td>John</td>
</tr>
<tr>
<td>12:55p</td>
<td>Hunter</td>
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</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: \[ P = 101,300 \text{ Pa} = 1 \text{ atm} = 14.7 \text{ psi} \]
- Gravitational Constant: \[ G = 6.6742 \times 10^{-11} \text{ (N m}^2)/\text{kg}^2 \]
- Electrostatic Constant: \[ k = 9 \times 10^9 \text{ (N m}^2)/\text{C}^2 \]
- Universal Gas Constant: \[ R = 8.314 \text{ (Pa m}^3)/(\text{mol K}) = 8.314 \text{ J/(mol K)} = 0.0821 \text{ (atm L)/(mol K)} \]
- Speed of Sound at 20°C: \[ v = 343 \text{ m/s} \]
- Threshold of Hearing: \[ I_0 = 1 \times 10^{-12} \text{ W/m}^2 \]
- Speed of Light in a Vacuum: \[ c = 3 \times 10^8 \text{ m/s} \]

Selected SI Prefixes and Conversion Factors
- \[ 10^{-2} = \text{cent} = c \]
- \[ 10^{-6} = \text{micro} = \mu \]
- \[ 1 \text{ m}^3 = 1000 \text{ L} \]
- \[ 10^{-3} = \text{milli} = m \]
- \[ 10^{-6} = \text{nano} = n \]
- \[ 1 \text{ atm} = 101,300 \text{ Pa} \]
- \[ 1 \text{ W} = 3.413 \text{ BTU/hr} \]
1. (1 pt) A boat is floating on a small lake with its huge steel anchor in the water. The boat hoists the anchor into the boat to set sail. What happens to the water level in the lake (with respect to the shore)?

<table>
<thead>
<tr>
<th></th>
<th>Rises</th>
<th>Falls</th>
<th>Remains the same</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

2. (1 pt) You plug a 1500 W hair dryer into a standard wall outlet in the United States. What is the current passing through the hair dryer while it is turned on?

<table>
<thead>
<tr>
<th></th>
<th>0.25 A</th>
<th>12.5 A</th>
<th>15.0 A</th>
<th>120 W</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

3. (1 pt) 30 mL/s of water flows through a pipe of radius 2 cm. The pipe widens to 6 cm. What is the flow rate of water in the 6 cm section of pipe?

<table>
<thead>
<tr>
<th></th>
<th>10 mL/s</th>
<th>30 mL/s</th>
<th>90 mL/s</th>
<th>180 mL/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

4. (1 pt) For a pair of springs holding the same weight arranged in parallel and in series, which will experience the greatest deflection?

<table>
<thead>
<tr>
<th></th>
<th>Springs in parallel</th>
<th>Springs in series</th>
<th>They will have the same deflection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

5. (1 pt) Make the statement true. A refrigerator has an inside temperature of 2.5 °C, and the temperature in the room it is within is 22 °C. If the refrigerator door open is left open for a long time, the temperature of the room would be

<table>
<thead>
<tr>
<th></th>
<th>2.5 °C</th>
<th>2.5 °C &lt; T_R &lt; 22 °C</th>
<th>T_R = 22 °C</th>
<th>T_R &gt; 22 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

6. (1 pt) Where does an object moving in simple harmonic motion have its maximum speed?

<table>
<thead>
<tr>
<th></th>
<th>x=0 A</th>
<th>x=A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

7. (1 pt) Make the statement true. When we touch a piece of metal and a piece of wood that are placed in the same room, the piece of metal feels much colder than the piece of wood. This happens because of the difference in:

<table>
<thead>
<tr>
<th></th>
<th>Specific heat</th>
<th>Temperature</th>
<th>Thermal conductivity</th>
<th>Latent heat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

8. (1 pt) Make the statement true. Two copper wires of equal length but different diameters are joined end to end and connected to a battery. The current flowing through the connected wires is

<table>
<thead>
<tr>
<th></th>
<th>greater in the wire with the larger diameter</th>
<th>greater in the wire with the smaller diameter</th>
<th>The same in both wires</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
9. (1 pt) Make the statement true. When 2 resistors are connected in parallel, the ____________ each resistor is the same.

<table>
<thead>
<tr>
<th>0.86/1 (86%)</th>
<th>Voltage across</th>
<th>Power dissipated by</th>
<th>Resistance of</th>
</tr>
</thead>
</table>

10. (1 pt) Which of these quantities needs to be zero for thermal efficiency to be 100 percent?

<table>
<thead>
<tr>
<th>0.39/1 (39%)</th>
<th>ΔU</th>
<th>W</th>
<th>Q_H</th>
<th>Q_c</th>
</tr>
</thead>
</table>

11. (1 pt) Make this statement true. If the temperature of an ideal gas doubles while the pressure stays the same, then the Volume of the gas is __________ the original volume.

<table>
<thead>
<tr>
<th>0.64/1 (64%)</th>
<th>double</th>
<th>quadruple</th>
<th>half</th>
<th>a quarter</th>
</tr>
</thead>
</table>

12. (1 pt) The pendulum on your clock is oscillating too fast. Which of the following would slow it down, assuming it is a simple pendulum?

<table>
<thead>
<tr>
<th>0.80/1 (80%)</th>
<th>Decrease the mass</th>
<th>Decrease the length</th>
</tr>
</thead>
</table>

13. (1 pt) A concrete support column is reinforced with steel beams that run the length of the column. A 25,000 lb load is applied axially to the column. What quantity will be the same for both the concrete and steel beams?

<table>
<thead>
<tr>
<th>0.50/1 (50%)</th>
<th>Stress</th>
<th>Strain</th>
<th>Force</th>
<th>Modulus of Elasticity</th>
</tr>
</thead>
</table>

14. (1 pt) Make the statement true. Sonic booms occur when the source of the waves moves __________ the wave speed.

<table>
<thead>
<tr>
<th>0.80/1 (80%)</th>
<th>Slower than</th>
<th>Faster than</th>
<th>The same speed as</th>
</tr>
</thead>
</table>

15. (1 pt) Which statement must be true about the currents passing through the resistors in the circuit shown on the right?

<table>
<thead>
<tr>
<th>0.68/1 (68%)</th>
<th>I_A &gt; I_C</th>
<th>I_A = I_C</th>
<th>I_A = I_C</th>
</tr>
</thead>
</table>

16. (1 pt) A 6 ft deep swimming pool is drained through a ½" hole in the bottom of the pool. It takes 8 hours for the top half of the pool to drain. How long does it take the entire pool to drain?

<table>
<thead>
<tr>
<th>0.73/1 (73%)</th>
<th>Between 8 and 16 hours</th>
<th>Exactly 16 hours</th>
<th>More than 16 hours</th>
</tr>
</thead>
</table>
17. (6 pts) A 4.0 kg silver ingot is taken from a furnace, where its temperature is 750 °C, and placed on a large block of ice at 0 °C. Assuming that all the heat given up by silver is used to melt the ice, how much ice must be melted to cool the silver to a temperature of 0 °C?

**Final Answer**

\[ m_i = 2102 \text{ g} \]

**Problem Statement**

Find \( m_i \)

**Organize Information**
You must include all the heat processes for each material in some form to receive full credit.

\[ Q_i + Q_s = 0 \]

\[ m_i L_f + m_s C_s \Delta T_s \]

\[ \Delta T_s = -750 \degree C \]

\[ m_s = 4.0 \text{ kg} \]

\[ = 4000 \text{ g} \]

<table>
<thead>
<tr>
<th>Material</th>
<th>( c [\text{J/g} \cdot \degree \text{C}] )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>2.093</td>
</tr>
<tr>
<td>Water</td>
<td>4.186</td>
</tr>
<tr>
<td>Silver</td>
<td>0.234</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Latent Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
</tr>
<tr>
<td>( L_f )</td>
</tr>
<tr>
<td>( L_v )</td>
</tr>
</tbody>
</table>

\[ m_i = \frac{-m_s C_s \Delta T_s}{L_f} = \frac{-4000 \times (0.234 \times 4.186 \times (-750) \degree \text{C})}{334 \times (6)} \]

\[ m_i = 2102 \text{ g} \]

\[ +1 \text{ Listed all Q processes (silver and ice)} \]

\[ +2 \text{ correctly calculated or equation for heat lost by silver} \]

\[ +2 \text{ correct equation for heat gained by ice} \]

\[ +1 \text{ correctly calculated mass of ice melted} \]

18. (6 pts) What is the current in a 95 m long piece of 12-gauge aluminum wire (2.053 mm diameter) fed into a 9 V battery? \( \rho_{\text{aluminum}} = 2.7 \times 10^{-8} \Omega \cdot \text{m} \)

**Final Answer**

**Problem Statement**

Find \( I \)

\[ L = 95 \text{ m} \]

\[ r = \frac{0.02053 \text{ m}}{2} \]

\[ R = \frac{\rho L}{A} \]

\[ I = \frac{V}{R} \]

**Organize Information**

\[ A = \pi \cdot r^2 = \pi \left( \frac{0.02053 \text{ m}}{2} \right)^2 = 3.31 \times 10^{-6} \text{ m}^2 \]

\[ +1 \text{ correct area} \]

\[ R = \frac{\rho L}{A} = \frac{(2.7 \times 10^{-8} \Omega \cdot \text{m})(95 \text{ m})}{(3.31 \times 10^{-6} \text{ m}^2)} = 0.7749 \Omega \]

\[ +2 \text{ correct resistance calculation} \]

\[ I = \frac{V}{R} = \frac{9 \text{ V}}{0.7749 \Omega} \]

\[ I = 11.6 \text{ A} \]

\[ +1 \text{ correct calculation of I} \]

\[ +1 \text{ correct equation for I (Ohm's Law)} \]
19. (6 pts) The displacement (in meters) of a wave is \( y(x,t) = 0.28 \cos(10.5x - 4.3t) \) where \( t \) is in seconds. Determine the speed of propagation.

**Problem Statement:**

Find \( v \)

**Organize Information:**

\[
\begin{align*}
V & = \text{wavelength} \\
W & = 2\pi f = \text{angular frequency} \\
k & = \frac{2\pi}{\lambda} = \text{wave number}
\end{align*}
\]

**Calculations:**

\[
\begin{align*}
\lambda &= \frac{2\pi}{10.5} \text{ m} = 0.5984 \text{ m} \\
f &= \frac{(4.3 \text{ rad/s})}{(2\pi \text{ rad})} = 0.6844 \text{ s}^{-1} \\
V &= f\lambda = (0.6844 \text{ s}^{-1})(0.5984 \text{ m}) = 0.4095 \text{ m/s}
\end{align*}
\]

---

20. (7 pts) On the 2nd floor of ZEC (elevation of 20 m), water flows through a 4 cm diameter pipe at a speed of 6.3 m/s and gauge pressure of 275 kPa. The pipe widens to a diameter of 8 cm on the 4th floor of 35 m. Determine the pressure in the pipe at this point.

**Problem Statement:**

Find \( P_2 \)

**Represent the Problem & Organize Information:**

A fully labeled diagram is required for full credit on this problem.

\[
\begin{align*}
P_1 &= 125,000 \text{ Pa} \\
V_1 &= 6.3 \text{ m/s} \\
h_1 &= 20 \text{ m} \\
V_2 &= ? \\
h_2 &= 35 \text{ m} \\
P_2 &= ? \\
R_1 &= 2 \text{ cm} = 0.02 \text{ m} \\
R_2 &= 4 \text{ cm} = 0.04 \text{ m} \\
\rho &= 1000 \text{ kg/m}^3
\end{align*}
\]

**Calculations:**

\[
\begin{align*}
V_1 A_1 &= V_2 A_2 \\
V_2 &= \frac{A_1}{A_2} V_1 = \frac{\pi (0.02 \text{ m})^2}{\pi (0.04 \text{ m})^2} (6.3 \text{ m/s}) = 1.575 \text{ m/s}
\end{align*}
\]

\[
\begin{align*}
P_1 + \rho g h_1 + \frac{1}{2} \rho V_1^2 &= P_2 + \rho g h_2 + \frac{1}{2} \rho V_2^2 \\
275000 \text{ Pa} + (1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(20 \text{ m}) + \frac{1}{2} (1000 \text{ kg/m}^3)(6.3 \text{ m/s})^2 &= P_2 + (1000 \text{ kg/m}^3)(9.8 \text{ m/s}^2)(35 \text{ m}) + \frac{1}{2} (1000 \text{ kg/m}^3)(1.575 \text{ m/s})^2 \\
P_2 &= 147000 \text{ Pa or 147 kPa}
\end{align*}
\]
21. (7 pts) A carpenter builds an exterior house wall with a layer of wood, 3.0 cm thick on the outside and a layer of Styrofoam insulation 2.2 cm thick on the inside surface. The wood has a k = 0.08 W/m·K and the Styrofoam has a k = 0.01 W/m·K. The interior surface temp is 19 °C and the outside is -10 °C. If the house is 10.6 m and the height is 6.0 m. **What is the rate of heat flow through the wall?**

**Final Answer**
\[
\frac{Q}{\Delta t} = 716 \text{ W}
\]

**Problem Statement**
Find \( \frac{Q}{\Delta t} \)

Represent the Problem & Organize Information
A fully labeled diagram showing the materials in series or parallel is required for full credit on this problem

- Lw = 0.03 m, Kw = 0.08 m²·K/W
- Ls = 0.022 m, Ks = 0.01 m²·K/W

Calculation
\[
A = (10.6 \text{ m}) \times (6.0 \text{ m}) = 63.6 \text{ m}^2
\]
\[
R_w = \frac{L_w}{K_w} = \frac{0.03 \text{ m}}{0.08 \text{ m}^2 \cdot \text{K}/\text{W}} = 0.375 \text{ m}^2 \cdot \text{K}/\text{W}
\]
\[
R_s = \frac{L_s}{K_s} = \frac{0.022 \text{ m}}{0.01 \text{ m}^2 \cdot \text{K}/\text{W}} = 2.2 \text{ m}^2 \cdot \text{K}/\text{W}
\]
\[
\frac{Q}{\Delta t} = \frac{A}{R_w + R_s} = \frac{63.6 \text{ m}^2}{2.575 \text{ m}^2 \cdot \text{K}/\text{W}}
\]
\[
= (63.6 \text{ m}^2) \times \left( \frac{29 \text{°C}}{2.575 \text{ m}^2 \cdot \text{K}/\text{W}} \right)
\]
\[
= 716 \text{ W}
\]

22. (7 pts) A piano is placed in the back of a pickup truck and Hunter is playing the piano as the truck drives down the road at 12 m/s. A stationary listener hears a frequency of 760 Hz as the truck approaches. **What is the tension in the piano string Hunter is playing if the string has a length of mass of 0.8 grams?** Assume a temperature of 20°C.

**Final Answer**
\[
T = 930 \text{ N}
\]

**Problem Statement**
Find \( T \)

Represent the Problem & Organize Information
You must include a representation of the problem identifying the source and listener and indicating the signs of all velocities to receive full credit.

\[
\begin{align*}
\text{Source} & : V = V_s = -12 \text{ m/s} \\
\text{Listener} & : L = 0.84 \text{ m} \\
\text{Mass} & : m = 0.8 \text{ g} \\
\text{Velocity} & : V = 343 \text{ m/s}
\end{align*}
\]

Calculation
\[
\begin{align*}
\lambda & = \frac{c}{V} = \frac{343 \text{ m/s}}{343 \text{ m/s}} = 1.08 \text{ m} \\
V & = f \lambda = (733.4 \text{ Hz})(1.08 \text{ m}) = 792 \text{ m/s} \\
T & = \sqrt{\mu \cdot \frac{m}{V}} = \sqrt{0.001488 \frac{\text{kg}}{\text{m}} \cdot \frac{0.8 \text{ g}}{0.54 \text{ m}}} = 929 \text{ N}
\end{align*}
\]
23. (7 pts) Find the equivalent resistance of the circuit shown below.

**Final Answer**

\[ R_{eq} = 590 \, \Omega \]

**Problem Statement**

Find \( R_{eq} \)

**Calculations**

\[ R_s = \frac{100 \, \Omega + 300 \, \Omega}{350 \, \Omega} = 400 \, \Omega \]

\[ R_p = \frac{1}{\frac{600 \, \Omega}{100 \, \Omega}} = 240 \, \Omega \]

\[ 5V - \frac{240 \, \Omega}{350 \, \Omega} = 240 \, \Omega \]

\[ R_{eq} = 350 \, \Omega + 240 \, \Omega = 590 \, \Omega \]

24. (7 pts) A proposed elevator design calls for the elevator to be suspended by a steel cable with a cross-sectional area of \(5 \times 10^{-4} \text{m}^2\) and an ultimate strength of \(10.5 \times 10^8 \text{ Pa}\). If the elevator weighs 15,000 N, how many 80 kg students can the elevator hold if the minimum factor of safety is 15?

**Final Answer**

\( N = 25 \text{ students} \)

**Problem Statement**

Find \( N \)

**Organize Information**

- \( T \) (vertical tension)
- \( W_e = 15,000 \text{ N} \)
- \( W_s = n(80 \text{ kg})(9.8 \text{ m/s}^2) \)
- \( A = 5 \times 10^{-4} \text{ m}^2 \)
- \( \sigma = \frac{T}{A} \) (stress)
- \( \sigma_{max} = 10.5 \times 10^8 \text{ Pa} \)
- \( \text{F.S.} = \frac{\sigma_{max}}{\sigma_{app}} \)

**Calculations**

\[ \Sigma F_y = 0 \]

\[ T - W_e - W_s = 0 \]

\[ T = 15,000 \text{ N} + (784 \text{ N})n \]

\[ 15 = \frac{10.5 \times 10^8 \text{ Pa}}{\sigma_{app}} \quad \sigma_{app} = 7 \times 10^7 \text{ Pa} \]

\[ 7 \times 10^7 \text{ Pa} = \frac{T}{5 \times 10^{-4} \text{ m}^2} \quad T = 35000 \text{ N} \]

\[ 35000 \text{ N} = 15000 \text{ N} + (784 \text{ N})n \]

\[ n = 25 \]
25. (7 pts) Two charges are arranged along the x-axis as shown in the figure below. What is the electric field at x = 20 cm?

Final Answer: \[ E = \frac{1.598 \times 10^7}{N/C} \]

Problem Statement: Find E at x = 20 cm

Calculations:
The diagram on the right must be fully labeled, clearly indicating the direction of the electric field due to each charge at the point x = 20 cm.

\[ E_1 = \frac{k Q_1}{r_1^2} = \frac{(9 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(25 \times 10^{-6} \text{ C})}{(0.2 \text{ m})^2} = 5.625 \times 10^6 \text{ N/C} \]

\[ E_2 = \frac{k Q_2}{r_2^2} = \frac{(9 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(6 \times 10^{-4} \text{ C})}{(0.05 \text{ m})^2} = 2.16 \times 10^7 \text{ N/C} \]

\[ E = E_1 - E_2 = \frac{1.598 \times 10^7}{N/C} \]

26. (8 pts) The Frankel Cycle is shown in the figure below. Determine the work done in one cycle.

Problem Statement: Find W

Final Answer: W = 952 J

Calculate Information:
- Isothermal: \( W = P \cdot (V_f - V_i) \)
- Isobaric: \( W = P \cdot \Delta V \)

Calculations:

\[ P_3 V_3 = P_4 V_4 \Rightarrow V_4 = \frac{(480 \text{ kPa})(0.003 \text{ m}^3)}{(160 \text{ kPa})} = 0.009 \text{ m}^3 \] +2 correct calculation of V1/V4

\[ W_{1-2} = \Delta V (105000 \text{ Pa})(-0.006 \text{ m}^3) = -630 \text{ J} \] +2 correct calculation of W1-2

\[ W_{2-3} = 0 \] +1 correct calculation of W2-3 and W4-1

\[ W_{3-4} = P_i (V_4 - V_1) = (480000 \text{ Pa})(0.003 \text{ m}^3)[\ln(0.006 \text{ m}^3) - \ln(0.003 \text{ m}^3)] = 1582 \text{ J} \] +2 correct calculation of W3-4

\[ W_{4-1} = 0 \] +1 correct calculation of total work

\[ W_{\text{total}} = 952 \text{ J} \]
27. (8 pts) A loaded cement truck \((m_t = 30,000 \text{ kg})\) drives onto an old drawbridge that is 50.0 m long \((m_b = 18,000 \text{ kg})\), where it stalls with its center of mass 20.0 m from the end of the bridge. The truck sets his brakes and waits for help. Meanwhile, a boat approaches so the drawbridge is raised by a cable at the end. When the drawbridge is raised to an angle of 30° above the horizontal, the cable makes an angle of 90° with the surface of the bridge. What is the tension \(T\) in the cable at this point?

Final Answer

\[
T = 91,660 \text{ N}
\]

Problem Statement

Find \(T\)

Represent the Problem & Organize Information

A complete free body diagram (separate from the diagram above) is required for full credit.

Calculation

\[
\sum M_0 = 0
\]

\[
-W_b \cdot (25 \text{ m}) \cos 30° - W_t (30 \text{ m}) \cos 30° + T (50 \text{ m}) = 0
\]

\[
T = \frac{(176,400 \text{ N})(25 \text{ m}) \cos 30° + (294,000 \text{ N})(30 \text{ m}) \cos 30°}{50 \text{ m}}
\]

\[
T = 91,660 \text{ N}
\]
28. (8 pts) A light beam strikes a 2.0 cm thick piece of plastic with a refractive index of 1.62 at a 42° angle from the surface of the plastic. The plastic is on top of a 3.0 cm thick piece of glass for which n = 1.47. What is the total horizontal distance (x) the light travels before exiting the glass?

**Final Answer**

\[ x = 2.79 \text{ m} \]

**Problem Statement**

Find x

**Represent the Problem & Organize Information**

You must include all light rays as they are refracted through each material and label the angles from respective normal in air, plastic, and glass to receive full credit.

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

+1 wrote Snell's Law

+1 correctly labeled diagram

**Calculations**

\[ \sin 48° = 1.62 \sin \theta_2 \]

+1 used correct angle (48 deg)

\[ \theta_2 = 27.3° \]

+1 calculated correct 2nd angle (27.3 deg)

\[ \tan 27.3° = \frac{x_1}{2.0 \text{ cm}} \]

+1 calculated correct x1

\[ x_1 = 1.03 \text{ m} \]

\[ 1.62 \sin 27.3° = 1.47 \sin \theta_3 \]

+1 calculated correct 3rd angle (30.4 deg)

\[ \theta_3 = 30.4° \]

\[ \tan 30.4° = \frac{x_2}{3.0 \text{ cm}} \]

+1 calculated correct x2

\[ x_2 = 1.76 \text{ m} \]

+1 calculated correct x (x1+x2)

\[ x = x_1 + x_2 = 2.79 \text{ m} \]