EF 152 Final Exam – Spring 2022

Name: Solution

Seat Assignment: ________________________________

Specify your EXAM ID on the right.

Circle your SECTION

<table>
<thead>
<tr>
<th>Time</th>
<th>A270 Cooper</th>
<th>A277 Ben</th>
<th>A278 Tennessee</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:10a</td>
<td>B270 Nick</td>
<td>B277 Dr. Eliestad</td>
<td>B278 Tennessee</td>
</tr>
<tr>
<td>9:50a</td>
<td>B271 Joey</td>
<td>B277 Dr. Eliestad</td>
<td>B278 Tennessee</td>
</tr>
<tr>
<td>11:30a</td>
<td>C270 Nick</td>
<td>C271 Joey</td>
<td>C278 Ben</td>
</tr>
<tr>
<td>1:10p</td>
<td>D270 Gavin</td>
<td>D271 Joey</td>
<td>D278 Ben</td>
</tr>
<tr>
<td>2:50p</td>
<td>E270 Gavin</td>
<td>E271 Nick</td>
<td>E278 Tennessee</td>
</tr>
</tbody>
</table>

Instructions
- Do not open the exam until instructed to do so.
- When time is called, immediately stop writing, remain seated, and turn in your exam to a proctor.
- Working after time is called results in an automatic deduction.
- Turn your equation sheets in with your exam.

Guidelines
- Use at least a No. 2 pencil
- Completely fill in multiple choice bubble answer; do not make marks in any other bubble
- Assume 3 significant figures for all given numbers unless otherwise stated
- Show all of your work – no work, no credit
1. (1 pt) A planet makes a circular orbit with period $T$ around a star. If the planet were at the same distance from the star, but had $\frac{1}{3}$ times the mass, what would be its new period (in terms of $T$)?

<table>
<thead>
<tr>
<th>0.45/1 (45%)</th>
<th>$\frac{T}{3}$</th>
<th>$\sqrt{\frac{T}{3}}$</th>
<th>$T$</th>
<th>$\sqrt{3T}$</th>
<th>$3T$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

2. (1 pt) A 200 lb force is applied to a piece of plastic with an area of 0.5 square inches. The material has a strength of 1000 psi. The factor of safety is:

<table>
<thead>
<tr>
<th>0.82/1 (82%)</th>
<th>2.5</th>
<th>4</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. (1 pt) In a Venturi Tube, how does the pressure in the restriction ($p_2$) compare to the inlet pressure ($p_1$)?

<table>
<thead>
<tr>
<th>0.54/1 (54%)</th>
<th>$p_2 &gt; p_1$</th>
<th>$p_2 = p_1$</th>
<th>$p_2 &lt; p_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. (1 pt) If you bring a positively charged insulator near two uncharged metallic spheres that are in contact and then separate the spheres, the sphere on the right will have:

<table>
<thead>
<tr>
<th>0.64/1 (64%)</th>
<th>net charge</th>
<th>Positive charge</th>
<th>Negative charge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. (1 pt) The current $I_2$ is:

<table>
<thead>
<tr>
<th>0.60/1 (60%)</th>
<th>&lt; 2 amp</th>
<th>2 amp</th>
<th>&gt; 2 amp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. (1 pt) What is the direction of the magnetic force on a positive charge that moves as shown?
7. (1 pt) What has to be the same for two insulating materials that are in parallel?

<table>
<thead>
<tr>
<th>[ \Delta Q / \Delta t ]</th>
<th>[ T_2 - T_1 ]</th>
<th>[ R_1 \text{ and } R_2 ]</th>
<th>[ \kappa_1 \text{ and } \kappa_2 ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.53/1 (53%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

8. (1 pt) A given mass of gas in a rigid container is heated from 100°C to 500°C. Which of the following best describes what will happen to the pressure of the gas?

<table>
<thead>
<tr>
<th>Pressure will decrease by a factor of five</th>
<th>Pressure will increase by a factor of five</th>
<th>Pressure will decrease by a factor of about two</th>
<th>Pressure will increase by a factor of about two</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.40/1 (40%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

9. (1 pt) Which type of heat engine is the most efficient?

<table>
<thead>
<tr>
<th>Carnot</th>
<th>Stirling</th>
<th>Diesel</th>
<th>Otto</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.82/1 (82%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

10. (1 pt) What is the value \( r \) that would be used in the parallel axis theorem for the physical pendulum shown?

\[
\text{Pivot} \\
\text{Center of mass} \quad \begin{array}{c}
\text{2 cm} \\
\text{9 cm}
\end{array} \quad \begin{array}{c}
\text{3 cm} \\
\text{7 cm}
\end{array}
\]

<table>
<thead>
<tr>
<th>cm</th>
<th>3 cm</th>
<th>4 cm</th>
<th>6 cm</th>
<th>7 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.93/1 (93%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

11. (1 pt) A wave is described by the equation \( y(x, t) = 0.3m \cos \left( \frac{0.5}{m} x - 23 \frac{\text{rad}}{s} t \right) \). What is the maximum speed of a particle?

<table>
<thead>
<tr>
<th>6.9 m/s</th>
<th>11.5 m/s</th>
<th>46 m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.76/1 (76%)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

12. (1 pt) A sound level of 50 decibels is how much more intense than a sound level of 20 decibels?

<table>
<thead>
<tr>
<th>100 times</th>
<th>250 times</th>
<th>1000 times</th>
<th>2500 times</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.74/1 (74%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
13. (5 pts) Determine the force \( T \) required to keep the 180 kg, 0.15 cubic meter box from sinking in a fluid with a specific gravity of 0.9.

\[
\sum F_y = T + F_b - W = 0
\]

\[
T + 1324 \text{ N} - 176 \text{ GN} = 0
\]

\[
T = 442 \text{ N}
\]
14. (9 pts) Determine the magnitude and direction of the reaction at point A. A complete FBD is required for full credit.

Magnitude: $38.5\text{ lb}$

Direction: $121^\circ$ Ccw w/ x-axis

\[ \sum M_B = 20\text{ lb} (4\text{ ft}) - A_y (7\text{ ft}) + 30\text{ lb} (5\text{ ft}) = 0 \text{ lb} \]

\[ A_y = 32.86 \text{ lb} \]

\[ \sum F_x = 20\text{ lb} - A_x = 0 \]

\[ A_x = 20\text{ lb} \]

\[ A = \sqrt{A_x^2 + A_y^2} = \sqrt{(32.86\text{ lb})^2 + (20\text{ lb})^2} = 38.47 \text{ lb} \]

\[ \theta = \tan^{-1}\left(\frac{32.86\text{ lb}}{20\text{ lb}}\right) = 58.7^\circ \]

\[ \alpha = 180^\circ - \theta = 180^\circ - 58.7^\circ = 121.3^\circ \]
15. (8 pts) A hose has a radius of 20 mm and discharges water into the atmosphere at a velocity of 16 m/s through a 12 mm radius nozzle. Determine the required gage pressure at A.

\[ P_A + \frac{1}{2} \rho v_A^2 + \rho g h_A = P_B + \frac{1}{2} \rho v_B^2 + \rho g h_B \]

**Continuity**

\[ v_A A_A = v_B A_B \]
\[ v_A \pi (20 \text{ mm})^2 = 16 \text{ m/s} \pi (12 \text{ mm})^2 \]
\[ v_A = 5.76 \text{ m/s} \]

\[ P_A + \frac{1}{2} \left(1000 \frac{\text{kg}}{\text{m}^3}\right)(5.76 \text{ m/s})^2 + 1000 \frac{\text{kg}}{\text{m}^3}(9.81 \frac{\text{m}}{\text{s}^2})(0) \]

\[ = 0 + \frac{1}{2} \left(1000 \frac{\text{kg}}{\text{m}^3}\right)(16 \text{ m})^2 + 1000 \frac{\text{kg}}{\text{m}^3}(9.81 \frac{\text{m}}{\text{s}^2})(6 \text{ m}) \]

\[ P_A + 16588 + 0 = 0 + 128000 + 5886 \]

\[ P_A = 170300 \text{ Pa} \]
16. (5 pts) A particle with a charge of $-2.5 \times 10^{-14}$ C has a velocity of $(7.6 \times 10^5 \, \hat{i})$ m/s. When the particle goes through a magnetic field the force on the particle is $(4.3 \times 10^{-9} \, \hat{k})$ N. Determine the magnetic field.

$$ F = q (\vec{v} \times \vec{B}) $$

$$ 4.3 \times 10^{-9} \, \hat{k} = (-2.5 \times 10^{-14} \, C) \left[ (7.6 \times 10^5 \, \hat{i}) \times \vec{B} \right] $$

$\vec{B}$ would need to be in $-\hat{j}$ direction

$$ -\left( \hat{i} \times (-\hat{j}) \right) = \hat{k} $$

$$ B_y = -0.226 \, T $$

$$ \vec{B} = -0.226 \, \hat{j} \, T $$

$\vec{B}$ could also have a non-zero $\hat{k}$ term.
17. (9 pts) Determine the magnitude of the electric field at point A.

\[ E_{AB} = k \frac{q_1}{r^2} = 9 \times 10^9 \frac{N \cdot m^2}{C^2} \frac{3 \times 10^{-9} C}{(0.04 m)^2} \]

\[ = 16875 \text{ N/C} \]

\[ E_{CA} = k \frac{q_2}{r^2} = 9 \times 10^9 \frac{N \cdot m^2}{C^2} \frac{-5 \times 10^{-9} C}{(0.05657 m)^2} \]

\[ = 14062 \text{ N/C} \]

\[ \tan 45^\circ = \frac{16875}{14062} \]

\[ x = 16875 \cos 45^\circ = 6932 \text{ N/C} \]

\[ y = 14062 \sin 45^\circ = 9943 \text{ N/C} \]

\[ |E| = \sqrt{E_x^2 + E_y^2} = \sqrt{(6932 \text{ N/C})^2 + (9943 \text{ N/C})^2} \]

\[ = 12120 \text{ N/C} \]
18. (8 pts) Determine the voltage $V_1$.

$$V_1 = 4.85 \text{ V}$$

Kirchhoff's Laws

Junction A

$$0.05A + 0.07A - I = 0$$

$$I = 0.12A$$

Loop 1

$$V_1 - 0.05A(25\Omega) - 0.12A(30\Omega) = 0$$

$$V_1 = 4.85\text{ V}$$
19. (5 pts) Determine the effective thermal resistance, R, of the system.

\[ R = 10.4 \text{ ft}^2\cdot\text{hr}^\circ\text{F}/\text{Btu} \]

Parallel system

\[ A_{wall} = 12\text{ ft}(20\text{ ft}) - 15\text{ ft}^2 - 21\text{ ft}^2 \]
\[ = 204 \text{ ft}^2 \]

\[ R_{wall} = \frac{A}{R} = \frac{12\text{ ft}(20\text{ ft})}{204 \text{ ft}^2 + 15\text{ ft}^2 + 21\text{ ft}^2} \]
\[ = \frac{12\text{ ft}(20\text{ ft})}{204 + 15 + 21} \]
\[ = 10.43 \text{ ft}^2\cdot\text{hr}^\circ\text{F}/\text{Btu} \]
20. (9 pts) Determine the work done during one cycle of the heat engine. Use $\gamma = 1.4$.

$$W_{AB} = \frac{1}{\gamma - 1} \left( P_B V_A - P_B V_B \right)$$

$$P_B = 696.4 \text{ kPa}$$

$$W_{AB} = \frac{1}{1.4 - 1} \left( 100 \text{ kPa} \left( 0.08 \text{ m}^3 \right) - 696.4 \text{ kPa} \left( 0.02 \text{ m}^3 \right) \right)$$

$$W_{AB} = -14.82 \text{ kJ}$$

$$W_{BC} = W_{DA} = 0$$

$$W_{CD} = 800 \text{ kPa} \left( 0.08 \text{ m}^3 - 0.02 \text{ m}^3 \right) = 48 \text{ kJ}$$

$$W = 48 \text{ kJ} - 14.82 \text{ kJ} = 33.18 \text{ kJ}$$
21. (8 pts) An ice maker converts 3 kg of water at 35°C to ice at 0°C. The coefficient of performance of the ice maker is 4.0. Determine the amount of heat released by the ice maker.

\[
Q_c = mc \Delta T + L_f \quad m
\]

\[
= 3000g \left[ 1 \text{ cal/g} \left( 0^\circ C - 35^\circ C \right) + \left(-79.6 \text{ cal/g} \right) \right] \frac{4.186 \text{ J}}{\text{cal}}
\]

\[
= 3000g \left( -114.6 \text{ cal/g} \right) \frac{4.186 \text{ J}}{\text{cal}} 
\]

\[
= -1439 \text{ kJ} \quad \left(-343800 \text{ cal} \right)
\]

COP = \frac{1}{\text{c}} \quad \frac{W}{Q_c}

\[
W = \frac{1}{\text{COP}} \frac{1439 \text{ kJ}}{4} = 360 \text{ kJ}
\]

\[
Q_h = Q_c + W = 1439 \text{ kJ} + 360 \text{ kJ}
\]

\[
= 1799 \text{ kJ} \quad \left(430 \text{ kcal} \right)
\]
22. (5 pts) A 0.002 ft radius, 3 ft long steel string has a tension of 80 lb. Determine the fundamental frequency of the string. The density of steel is 400 lb/ft³.

\[ f = \frac{n}{2L} \sqrt{\frac{T}{\mu}} \]

\[ \mu = \rho A = 490 \frac{lb}{ft^2} \cdot \frac{1}{32.2 \text{ slug/ft}^3} \cdot \pi \left(0.002\text{ ft}\right)^2 \]

\[ = 1.912 \times 10^{-4} \text{ slug/ft} \]

\[ f = \frac{1}{2(3\text{ft})} \sqrt{\frac{80 \text{ lb}}{1.912 \times 10^{-4} \text{ slug/ft}}} = 107.8 \text{ Hz} \]
23. (8 pts) The system shown is pulled down 0.25 m from the equilibrium position and then released. Determine the maximum acceleration of the system.

\[ k = k_1 + k_2 = 300 \text{N/m} + 400 \text{N/m} = 700 \text{N/m} \]

\[ w = \sqrt{\frac{k}{m}} = \sqrt{\frac{700 \text{N/m}}{6 \text{ kg}}} = 10.80 \text{ rad/sec} \]

\[ A = 0.25 \text{ m} \]

\[ a_{\text{max}} = A w^2 = 0.25 \text{ m} \left( 10.80 \text{ rad/sec} \right)^2 = 29.17 \text{ m/s}^2 \]
24. (9 pts) Car A emits a sound at a frequency of 2000 Hz. The sound wave bounces off car B and returns to car A. What is the return frequency that car A hear? Assume the speed of sound in air to be 343 m/s.

\[ f' = \frac{V + V_L}{V - V_S} \times 2000 \text{ Hz} \left( \frac{343 \text{ m/s} - 30 \text{ m/s}}{343 \text{ m/s} - 20 \text{ m/s}} \right) = 1938 \text{ Hz} \]

First shift

Second shift (reflected wave)

\[ f'' = \frac{V + V_L}{V - V_S} \times 1938 \text{ Hz} \left( \frac{343 \text{ m/s} + 20 \text{ m/s}}{343 \text{ m/s} + 30 \text{ m/s}} \right) = 1886 \text{ Hz} \]