The equation sheets may be removed when the test begins

Guidelines:
- Assume 3 significant figures for all given numbers unless otherwise stated
- Show all of your work — no work, no credit
- Write your final answer in the box provided — include units for all answers
- If you finish with less than 5 minutes remaining, remain seated until the end of the exam and all exams are collected.

<table>
<thead>
<tr>
<th>Stress and Strain</th>
<th>Uniform Circular Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress = \sigma = F/A</td>
<td>( a_c = \text{centripetal acceleration} )</td>
</tr>
<tr>
<td>Strain = \varepsilon = \frac{\Delta L}{L}</td>
<td>v = speed</td>
</tr>
<tr>
<td>E = \frac{\sigma}{\varepsilon}</td>
<td>T = period</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factor of Safety (FS)</th>
<th>Universal Law of Gravitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS = \frac{\text{Strength}}{\text{Load}}</td>
<td>( F_G = G \frac{m_1 m_2}{r^2} )</td>
</tr>
<tr>
<td>E = 6.67 \times 10^{-11} \text{ N m}^2 \text{ Kg}^{-2}</td>
<td>G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ Kg}^{-2}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conservation of Mass (Continuity)</th>
<th>Density of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho \rho \rho \rho \rho \rho )</td>
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<table>
<thead>
<tr>
<th>Bernoulli's Equation</th>
<th>Pressure in a fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2 )</td>
<td>( p = \rho gd + p_h )</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Law of Reflection</th>
<th>Total Internal Reflection</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta_1 = \theta_2 )</td>
<td>( \sin \theta_2 = \frac{m \lambda}{n} )</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Wave Speed, Cables, Ropes, etc.</th>
<th>Sound Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v = \sqrt{\frac{E}{\rho}} )</td>
<td>( h = \text{reference intensity, } 1 \times 10^{-12} \text{ W} \text{ m}^2 \text{ Hz}^{-1} )</td>
</tr>
</tbody>
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<th>Sound Power, Intensity</th>
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<tbody>
<tr>
<td>( P = \text{average power} )</td>
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<table>
<thead>
<tr>
<th>Light Waves</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n = \frac{c}{v} )</td>
</tr>
</tbody>
</table>
Thermal Expansion
Linear
\[ \Delta L = \alpha t \Delta T \]
\[ \sigma = \frac{\Delta L}{L} \Delta T \]
Volumetric
\[ \Delta V = \beta V \Delta T \]

Ideal Gas Law
\[ pV = nRT \]
\[ A_v = \frac{V}{n} \] (Avogadro’s Number: 6.02x10^23)

Standard Pressure and Temp
273K 1 atm (101.3kPa)

1st Law of Thermodynamics
\[ W = \int pdV \]
\[ Q \text{ – heat flow into thermal system} \]
\[ \Delta U = -W_{\text{heat}} + Q_{\text{heat}} \]

Molecular Thermal Physics
\[ m \text{ – mass of a molecule} \]
\[ M \text{ – molecular mass} \]
\[ k \text{ – Boltzmann constant} = 1.38065 \times 10^{-23} \text{J/K} \]

\[ U = N \left( \frac{1}{2} m v^2 \right) \]
\[ U = \frac{3}{2} nRT \]
\[ v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3M}{m}} \]

Conversions
1 cal = 4.186 J
1 L = 1000 cm
1 m = 1000 L

\[ \text{Work of Thermal Systems} \]
\[ W = \int pdV \]
\[ \text{Heat} \]
\[ Q \text{ – specific heat} \]
\[ c \text{ – thermal conductivity} \]
\[ R \text{ – thermal resistance} \]

\[ \Delta Q = n \ell c \Delta T \]

Isochoric (constant volume)
\[ W = 0 \]
\[ \Delta Q = n \ell c \Delta T \]

Isothermal (constant temp)
\[ W = nRT \ln \left( \frac{V_f}{V_i} \right) \]
\[ \Delta Q = W \]

Adiabatic (\( \Delta Q = 0 \))
\[ W = \frac{1}{\gamma - 1} \left( p_f V_f - p_i V_i \right) \]

\[ \text{Efficiency} \]
\[ \eta = \frac{W}{Q_i} \]
\[ \text{Otto Cycle} \]
\[ r \text{ – compression ratio} \]
\[ \eta = 1 - \frac{1}{r} \]
\[ \text{Carnot Cycle} \]
\[ \eta = 1 - \frac{T_c}{T_h} \]
\[ \frac{Q_i}{Q_o} = \frac{T_o}{T_i} \]

\[ \text{Entropy} \]
\[ \Delta S = \frac{\Delta Q}{T} \]
\[ \text{Ideal Gas} \]
\[ \Delta S = C_L \ln \frac{T_f}{T_i} + nR \ln \frac{V_f}{V_i} \]

\[ \text{Water Properties} \]
\[ c = 1 \text{ cal/(g·C)} = 4.186\text{J/(g·C)} \]
\[ L = 79.6 \text{ cal/g} \]
\[ L = 840 \text{ cal/g} \]
\[ \rho = 1 \text{ g/cm}^3 = 1 \text{ kg/L} \]
\[ \rho = 1000 \text{ kg/m}^3 = 62.4 \text{ lb/ft}^3 \]
\[ L_i = \text{Latent heat of fusion} \]
\[ L_v = \text{Latent heat of vaporization} \]

\[ \text{Magnetic field along the axis of a looped wire} \]
\[ B_0 = \frac{\mu_0 I}{2\pi r} \]
\[ \text{Magnetic field of a moving charged particle} \]
\[ B = \frac{\mu_0 I}{2\pi r} \]

\[ \text{Electric Field – point charge} \]
\[ E = \frac{1}{4\pi \varepsilon_0} \frac{Q}{r^2} \]

\[ \text{Potential energy - point charges} \]
\[ U = \frac{1}{4\pi \varepsilon_0} \sum_{i} \frac{q_i q_j}{r_{ij}} \]

\[ \text{Potential} \]
\[ V = \frac{U}{q_0} \]

\[ \text{Potential of a set of point charges} \]
\[ V = \frac{1}{4\pi \varepsilon_0} \sum_{i} q_i \frac{1}{r_i} \]

\[ \text{Kirchhoff’s Rules} \]
\[ \sum V = 0 \text{ for a closed loop} \]
\[ \sum I = 0 \text{ for a junction} \]

\[ \text{Thermal Resistance, Parallel} \]
\[ R_{\text{parallel}} = \frac{1}{\sum R_i} \]

\[ \text{Thermal Resistance, Series} \]
\[ R_{\text{series}} = \sum R_i \]

\[ \text{Capacitance} \]
\[ C = \frac{Q}{V} \]

\[ \text{Capacitance – parallel plates} \]
\[ C = \frac{k A}{d} \]

\[ \text{Capacitance – energy storage} \]
\[ \frac{1}{2} C V^2 = \frac{1}{2} QV \]

\[ \text{Capacitors in series} \]
\[ C_{\text{eq}} = \frac{1}{C_1 + C_2 + C_3 + ...} \]

\[ \text{Capacitors in parallel} \]
\[ C_{\text{eq}} = C_1 + C_2 + C_3 + ... \]

\[ \text{Resistors in series} \]
\[ R_{\text{eq}} = R_1 + R_2 + R_3 + ... \]

\[ \text{Resistors in parallel} \]
\[ R_{\text{eq}} = \frac{1}{R_1 + R_2 + R_3 + ...} \]

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\[ m = \text{mass of a molecule} \]
\[ M = \text{molecular mass} \]
\[ k = \text{Boltzmann constant} = 1.38065 \times 10^{-23} \text{J/K} \]

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\[ \Delta S = C_L \ln \frac{T_f}{T_i} + nR \ln \frac{V_f}{V_i} \]

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\[ \text{Kirchhoff’s Rules} \]
\[ \sum V = 0 \text{ for a closed loop} \]
\[ \sum I = 0 \text{ for a junction} \]
1. (2 pts) Remove the 2 equation sheets, leaving the exam questions stapled together. CLEARLY PRINT the information below. If we can't read it, you will not get these free points!

Name: ______________________________________________________________________
NetID: ____________________________ (your computer login, NOT your student #)
Student #: _________________________
EF 152 Section: ____________

2. (7 pts) A 30 lb tricycle carries a 180 lb rider. The center of mass of the rider (pt B) and trike (pt A) are shown. At what angle θ will the trike/rider combination begin to tip over?

3. (7 pts) The 100 lb sign shown here is supported by a rope from A to C and a pin at B. What diameter of rope is required to have a factor of safety of at least 4.07? Ropes are only available in diameters that are multiples of 1/16". (Ultimate Strength = 5000 psi)

4. (7 pts) Nashlantis uses a pump and hose as shown to pump water out of the governor's basement. At point A the pump pressure is 32 psig and the hose diameter is 2 inches. At point B the hose diameter is 1.5 inches and is open to the air. What is the speed of the water as it leaves the hose at point B?

5. (7 pts) An abandoned EF heat engine has a mass of 154 g. Prof Schleter throws the device into the Tennessee River and it sinks, accelerating downward at a rate of 1.4 m/s². What was the mass density of the device?
6. (7 pts) A 0.18 kg apple is connected to an ideal spring (k=142 N/m) and is oscillating on a horizontal frictionless surface. It is given an initial displacement of +15 cm and an unknown initial velocity. After 3.2 seconds its velocity is +8.55 m/s. What was the apple’s initial velocity?

7. (7 pts) Dr. Bennett wants to determine the location of the center of mass of his new saw. He uses Google to determine that \( I = 0.0042 \text{ kg} \cdot \text{m}^2 \) for the 0.32 kg saw. He then hangs the saw on a frictionless peg and gives it a small displacement and determines that it takes 86 seconds to complete 80 oscillations. How far is the center of mass from the pivot point? If you end up with two possible answers, choose the larger of the two.

8. (7 pts) The average acoustic power output of a person clapping is 7.25 mW. What is the sound level (in decibels) a professor hears if he is 12 m away from 300 clapping students? Assume all students are the same distance from the professor.

9. (7 pts) A freezer has a coefficient of performance of 2.4. The freezer must change 1.8 kg of water at 25 °C to all ice at 0 °C in one hour. What is the electrical power required?
10. (7 pts) An ideal gas in a closed piston goes through the cycle shown in the pV diagram. The temperature of the gas at state a is 20 °C. What is the temperature of the gas at state b?

11. (7 pts) The 1.8 kg block of ice at 0 °C from the previous problem is taken out of the freezer and tossed into the Tennessee River when the river water is 11 °C. What is the change in entropy of the entire system (river and additional ice/water) after the ice has all melted and reached an equilibrium temperature?

12. (7 pts) An Otto cycle engine has a compression ratio of 7.9. What is the power output of the engine if the burning fuel releases 8.5 kJ of heat in one second? Use γₐₐir = 1.4.

13. (7 pts) Two point charges are positioned as shown. Q₁ = -2.0 µC and Q₂ = +4.0 µC. What is the electric field vector at the origin?
14. (7 pts) How much power is dissipated by the 2 Ω resistor in this circuit?

![Circuit Diagram]

15. (7 pts) What is the magnetic force on a +7πC charged particle moving at a velocity of $(3 \times 10^5 \text{ i} + 4 \times 10^5 \text{ j}) \text{ m/s}$ through a uniform magnetic field of -0.5 T?

![Diagram]