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.

### Stress and Strain

<table>
<thead>
<tr>
<th>Stress</th>
<th>( \sigma = \frac{F}{A} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strain</td>
<td>( \varepsilon = \frac{\Delta L}{L} )</td>
</tr>
<tr>
<td>( \Delta L = \frac{FL}{AE} )</td>
<td></td>
</tr>
<tr>
<td>( E = \frac{\sigma}{\varepsilon} )</td>
<td></td>
</tr>
</tbody>
</table>

### Uniform Circular Motion

<table>
<thead>
<tr>
<th>( a_n ) – centripetal acceleration</th>
<th>( v ) – speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r ) – radius of curvature</td>
<td>( \omega ) – rotational speed</td>
</tr>
<tr>
<td>( T ) – period</td>
<td>( f ) – frequency</td>
</tr>
<tr>
<td>( \phi ) – angle</td>
<td></td>
</tr>
</tbody>
</table>

\[ a_n = \frac{v^2}{r} \text{ (any curve)} \]
\[ a_n = r \omega^2 \]
\[ v = \omega r \]
\[ T = \frac{2\pi}{\omega} \]
\[ f = \frac{1}{T} \]
\[ \Delta s = r \Delta \phi \]
\[ \omega = 2\pi f \]

### Universal Law of Gravitation

\[ F_G = G \frac{m_1 m_2}{r^2} \]
\[ G = 6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2 \]

### Kepler’s Third Law

\[ T^2 = \left( \frac{2\pi}{a} \right)^2 \]
\[ \frac{1}{\pi^2} = \frac{G M}{a^3} \]

### Satellites

\[ v = \sqrt{\frac{G m_e}{r_e + h}} \]
\[ v_{esc} = \sqrt{\frac{2G m_e}{r_e}} \]
\[ r_{earth} = 6.378 \times 10^6 \text{ m} \]
\[ m_{earth} = 5.976 \times 10^{24} \text{ kg} \]

### Density of Water

- 62.4 lb/ft³
- 1000 kg/m³

### Atmospheric Pressure

- 1 atm = 101.3 kPa
- 1 atm = 14.7 psi

### Conversions

- \( 1 \text{ ft}^3 = 7.48 \text{ gal} \)
- \( 1 \text{ m}^3 = 1000 \text{ L} \)

### Conservation of Mass (Continuity)

\[ v_1 A_1 = v_2 A_2 \]

### Bernoulli’s Equation

\[ p_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2 \]

### Lift

\[ L = \rho v^2 \]

### Pressure in a fluid

\[ p = \rho gd + p_0 \]

### Stokes’ Law

Sphere through fluid for laminar flow
\[ F_{drag} = 6\pi \eta R v \]

### Poiseuille’s Equation

\[ Q = \frac{\pi r^4 (P_1 - P_2)}{8\eta L} \]

\( \eta \) – viscosity
\( L \) – characteristic length
\( v \) – velocity
\( \rho \) – mass density
\( R \) – sphere radius

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*The equation sheets may be removed when the test begins.*
Wave Equation
v – wave velocity
A – amplitude
k – wave number
ω – angular frequency
T – frequency
z(x,t) = A sin(ωt - kx)
v = λf
k = \frac{2\pi}{\lambda}
v is positive if sign of ω is negative

Harmonic Motion
ω – angular frequency
A – amplitude
k – stiffness
m – mass
δ – phase angle
x0 – initial displacement
v0 – initial velocity
T – period
f – frequency

\[ x(t) = A \sin(\omega t + \delta) \]
\[ v(t) = \omega A \cos(\omega t + \delta) \]
\[ a(t) = -A \omega^2 \sin(\omega t + \delta) \]
\[ \omega = \sqrt{\frac{k}{m}} \]
\[ A = \sqrt{a_1^2 + a_2^2} \]
\[ \delta = \tan^{-1}\left(\frac{a_2}{a_1}\right) \]
\[ a_1 = \frac{v_0}{\omega} \quad a_2 = x_0 \]
\[ T = \frac{2\pi}{\omega} \quad f = \frac{1}{T} \]
\[ \omega = 2\pi f \]

Parallel Axis Theorem
I = I_{cm} + Mr^2

Pendulums
Simple: \[ \omega = \sqrt{\frac{g}{I}} \]
Physical: \[ \omega = \sqrt{\frac{Mgr}{I}} \]

Speed of Sound in Air
\[ v \approx (331 + 0.606T) \text{ m/s} \]
T in °C

Beat Frequency: \[ |f_2 - f_1| \]

Natural Frequencies:
\[ \lambda \] – wavelength
\[ L \] – Length
\[ n \] – harmonic
\[ T \] – tension
\[ \mu \] – mass per unit length
\[ f \] – frequency
\[ v \] – wave velocity in medium

String
\[ \lambda_n = \frac{2L}{n} \]
\[ f_n = \frac{v}{\lambda_n} = \frac{n}{2L}\sqrt{\frac{T}{\mu}} \]

Air Columns
closed pipe: \[ \lambda_n = \frac{4L}{n} \]
open pipe: \[ \lambda_n = \frac{2L}{n} \]

Wave Speed
Cables, Ropes, etc.
T – tension
\[ v = \sqrt{\frac{T}{\mu}} \]

Transverse: \[ v = \sqrt{\frac{T}{\rho}} \]

Sound Level
\[ I_0 \] – reference intensity, \[ 1 \times 10^{-12} \text{ W/m}^2 \]
I – intensity
\[ \beta \text{ (dB)} = 10 \log \left( \frac{I}{I_0} \right) \]

Doppler Shift
\[ f_0 \] – frequency
\[ f' \] – shifted frequency
\[ v \] – velocity of medium
\[ v_S \] – velocity of source
\[ v_L \] – velocity of listener
\[ f' = f_0 \frac{v + v_L}{v - v_S} \]
Positive is from listener to source.

Wave Energy, Power, Intensity
E – energy
I – intensity
P – power
\[ \bar{P} \] – average power
\[ E = 2\pi^2 \mu v f^2 A^2 \]
\[ \bar{P} = \langle P \rangle = 2\pi^2 \mu v f^2 A^2 \]
\[ P = 4\pi^2 \mu v f^2 A^2 \cos^2(kx - \omega t) \]
\[ I = \frac{\bar{P}}{4\pi^2} \quad \frac{I_2}{I_1} = \frac{r_2^2}{r_1^2} \]

Light Waves
Law of Reflection \[ \theta_1 = \theta_2 \]
Index of Refraction \[ n = \frac{c}{v} \]
Law of Refraction \[ n_a \sin \theta_a = n_b \sin \theta_b \]
Light Wavelength \[ \lambda = \frac{\lambda_a}{n} \]
Total Internal Reflection \[ \sin \theta_{crit} = \frac{n_b}{n_a} \]
**Work of Thermal Systems**

- **Isobaric (constant pressure)**
  \[ W = \int p \, dv \]

- **Isochoric (constant volume)**
  \[ W = p(V_B - V_A) \]

- **Isothermal (constant temp)**
  \[ W = 0 \]

- **Adiabatic (\( \Delta Q = 0 \))**
  \[ \int W = \frac{1}{\gamma - 1} (p_A V_A - p_B V_B) \]

**Efficiency**

- **General**
  \[ \eta = \frac{W}{Q_h} = 1 - \left| \frac{Q_c}{Q_h} \right| \]

- **Otto Cycle**
  \[ \eta = 1 - \frac{T_c}{T_h} \]

- **Carnot Cycle**
  \[ \eta = 1 - \frac{T_c}{T_h} \left| \frac{Q_c}{Q_h} \right| = \frac{T_c}{T_h} \]

**Entropy**

- **Ideal Gas**
  \[ \Delta S = c_i \ln \frac{T_2}{T_1} + nR \ln \frac{V_B}{V_A} \]

**Heat**

- \( Q \) – heat
- \( c \) – specific heat
- \( \kappa \) – thermal conductivity
- \( R \) – thermal resistance

**Heat Capacity**

- \( Q = mc\Delta T \)

**Thermal Conductivity**

- \( \Delta Q = -\kappa A \frac{T_2 - T_1}{L} = A \frac{T_2 - T_1}{R} \)

**Thermal Resistance**

- \( R = \frac{L}{\kappa} \)

**Thermal Resistance, Series**

- \( R_{eff} = R_1 + R_2 \)

**Thermal Resistance, Parallel**

- \( \frac{1}{R_{eff}} = \frac{1}{A_1 + A_2} \left( \frac{A_1}{R_1} + \frac{A_2}{R_2} \right) \)

**Refrigerators**

- **General**
  \[ K = \frac{H}{W} \]

- **Carnot**
  \[ K_{Carnot} = \frac{T_c}{T_h - T_c} \]

**Water Properties**

- \( c = 1 \text{ cal/(g\cdot°C)} = 4.186 \text{J/(g\cdot°C)} \)
- \( L_f = 79.6 \text{ cal/g} \)
- \( L_v = 540 \text{ cal/g} \)
- \( \rho = 1 \text{ g/cm}^3 = 1 \text{ kg/L} = 1000 \text{ kg/m}^3 = 62.4 \text{ lb/ft}^3 \)
- \( L_f = \text{Latent heat of fusion} \)
- \( L_v = \text{Latent heat of vaporization} \)

**Ideal Gas Law**

- \( pV = nRT \)
- \( R = 8.314 \text{J/(mol\cdot K)} \)
- Avogadro’s Number: \( 6.02 \times 10^{23} \)

**Thermal Expansion**

- **Linear**
  \[ \Delta l = \alpha l \Delta T \]

- **Volumetric**
  \[ \Delta V = \beta V_0 \Delta T \]
### Constants

- \( m_e = 9.109 \times 10^{-31} \text{ kg} \)
- \( m_p = 1.673 \times 10^{-27} \text{ kg} \)
- \( m_n = 1.675 \times 10^{-27} \text{ kg} \)
- \( k = 9 \times 10^9 \text{ Nm}^2 \text{ C}^2 \)
- \( \varepsilon_0 = 8.854 \times 10^{-12} \text{ Nm}^{-2} \text{ C}^{-2} \)
- \( e = -1.6022 \times 10^{-19} \text{ C} \)
- \( eV = 1.6022 \times 10^{-19} \text{ J} \)

### Capacitance

- \( C = \frac{Q}{V} \quad \text{1 F} = \frac{1 \text{ C}}{1 \text{ V}} \)

### Capacitance – parallel plates

- \( C = \frac{\varepsilon_0 A}{d} \quad \text{in a vacuum} \)

### Capacitance – energy storage

- \( U = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2 = \frac{1}{2} QV \)

### Resistors in series

- \( \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \)

### Resistors in parallel

- \( \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \)

### Current

- \( I = \frac{dQ}{dt} \quad 1 \text{ A} = \frac{1 \text{ C}}{1 \text{ sec}} \)

### Voltage, Resistance, Current, Power

- \( V = I \cdot R \quad P = I \cdot V \quad R = \frac{\rho L}{A} \)

### Magnetism

- \( 1 \text{T} = 1 \text{ V} \cdot \text{s} = 1 \text{ N} \cdot \text{m} \cdot \text{A}^{-1} = 10000 \text{ gauss} \)
- \( \mu_0 = 4 \pi \times 10^{-7} \text{ T} \cdot \text{m} \cdot \text{A}^{-1} \)

### Magnetic force on moving charged particle

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

### Magnetic field of a moving charged particle

- \( \vec{B} = \frac{\mu_0}{4\pi} \frac{\vec{q} \times \vec{r}}{r^2} \)

### Magnetic field of a straight wire

- \( B = \frac{\mu_0 I}{2\pi r} \)

### Magnetic field along the axis of a looped wire

- \( B_x = \frac{\mu_0 N I a^2}{2(x^2 + a^2)^{3/2}} \)

- \( a \) – radius of the loop
- \( x \) – distance from the center of the loop to point of interest on the axis.
- \( I \) – current in the wires
- \( N \) – number of loops

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**Diagram:**

- **Electric Flux:** \( \Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0} \)
- **Power:** \( P = V \times I \)
- **Voltage:** \( V = \frac{P}{I} \)
- **Resistance:** \( R = \frac{V}{I} \)
- **Current:** \( I = \frac{P}{V} \)
- **Resistance:** \( R = \frac{V^2}{P} \)
- **Voltage:** \( V = \frac{P}{I^2} \)

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**Equations:**

- \( \Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0} \)
- \( \vec{E} = \vec{\nabla} \Phi \)
- \( \vec{E} \cdot d\vec{A} = \frac{dQ}{dt} \)
Remove the 2 equation sheets, leaving the exam questions stapled together.
CLEARLY PRINT the information below.

Name: __________________________________________________   EF 152 Section: ____________

1. (1 pt) The moment of the 80 lb force about point A is: (CCW positive)
   a. $4[80\cos(30°)] + 7[80\sin(30°)]$
   b. $4[80\cos(30°)] - 7[80\sin(30°)]$
   c. $7[80\cos(30°)] + 4[80\sin(30°)]$
   d. $7[80\cos(30°)] - 4[80\sin(30°)]$

2. (1 pt) The best place to sum moments about to find the force
to cause the crate to tip over is:

3. (1 pt) A material has a breaking strength of 40000 psi. The maximum load that could be applied to 2 square
   inch piece of material with a factor of safety of 3 is:
   a. 6670 lb   b. 13300 lb   c. 26700 lb   d. 60000 lb   e. 240000 lb

4. (1 pt) A satellite is orbiting the earth at three times the
   radius of the earth above the earth. The gravitational
   force of the earth on the satellite is:
   a. the same as on earth
   b. 1/3 of that on earth
   c. 1/4 of that on earth
   d. 1/9 of that on earth
   e. 1/16 of that on earth

5. (1 pt) A cargo ship goes from freshwater ($p=1000 \text{ kg/m}^3$) to saltwater (1029 kg/m$^3$). The ship will:
   a. float lower in the saltwater than in the freshwater
   b. float at the same level in the saltwater and the freshwater
   c. float higher in the saltwater than in the freshwater

6. (1 pt) Water is flowing through a 2 inch diameter pipe.
The pipe diameter the increases to 3 inches. The pressure
in the 3 inch diameter pipe is:
   a. less than in the 2 inch diameter pipe
   b. the same as in the 2 inch diameter pipe
   c. greater than in the 2 inch diameter pipe

7. (1 pt) We are draining the water out of a sink. The time to drain half of the water is:
   a. less than half the time to drain the entire sink
   b. equal to half the time to drain the entire sink
   c. greater than half the time to drain the entire sink
8. (9 pts) The cable has a modulus of elasticity of $11 \times 10^6$ psi and a cross-sectional area of 0.14 in$^2$. The deflection of the cable is measured to be 0.026 inches. Determine the distance, $x$. A separate, complete FBD is required for full credit.

9. (9 pts) The pump can provide 80 psi of pressure. Determine how long it takes to fill the tank with water.
10. (1 pt) An object is vibrating in simple harmonic motion with an equation: 
\[ x(t) = (0.2\text{mm})\cos(24t) - (0.16\text{mm})\sin(24t) \]. The amplitude of motion is:
   a. 0.066 mm  
   b. 0.12 mm  
   c. 0.26 mm  
   d. 0.36 mm 

11. (1 pt) A simple pendulum has a length of 0.13 smoots and a period of T. A simple pendulum with a length of 0.26 smoots will have a period of:
   a. 0.5T  
   b. 0.7T  
   c. 1.0T  
   d. 1.4T  
   e. 2.0T 

12. (1 pt) A wave is moving at 6 m/s and has a frequency of 4 Hz. The wavelength is:
   a. 0.67 m  
   b. 1.5 m  
   c. 24 m  

13. (1 pt) A string has a natural frequency of 246 Hz. A string with the same length, same tension, same material, but twice the diameter will have:
   a. a higher natural frequency  
   b. the same natural frequency  
   c. a lower natural frequency 

14. (1 pt) One person singing “Rocky Top” with a certain intensity creates a sound level of 70 db. Two people singing at the same intensity will have a combined sound level of:
   a. 73 db  
   b. 76 db  
   c. 79 db  
   d. 140 db 

15. (1 pt) You are standing by the side of the railroad tracks when a train approaches you and blows its horn. The proper equation to determine the Doppler shift is: (v is the speed of sound in air, v, is the speed of the train)
   a. \( f' = f_0 \left( \frac{v + v_t}{v} \right) \)  
   b. \( f' = f_0 \left( \frac{v - v_t}{v} \right) \)  
   c. \( f' = f_0 \left( \frac{v}{v + v_t} \right) \)  
   d. \( f' = f_0 \left( \frac{v}{v - v_t} \right) \) 

16. (1 pt) Glass fiber optics (n=1.52) will have total internal reflection in air. The glass fiber optic is now placed in Cinnamaldehyde (n=1.62). Will there still be total internal reflection?
   a. Yes  
   b. No  
   c. Cannot tell
17. (9 pts) A 2500 pound car is supported on four springs, each with a stiffness of 13000 pound/ft. The Mythbusters would like to excite the car at its natural frequency by using the sound from an open tube. Determine the length of an open tube that would have the same frequency as the natural frequency of the car. Assume the speed of sound to be 1116 ft/sec.

18. (9 pts) The threshold of hearing of 57 year old men for frequencies between 4000 and 6000 Hz can be determined as $\beta = 0.0025 f + 23$, where $\beta$ is the sound level in decibels, and $f$ is the frequency in Hz. A guitar string is 0.7m long, has a tension of 400N, and a mass per unit length of $7.6 \times 10^{-6}$ kg/m. Determine the minimum intensity that this guitar string must emit for the 57 year old man to hear it.
19. (1 pt) A steel guitar string is stretched so that it is in tension. The guitar string is now heated. What will happen to the string?
   a. The tension will increase
   b. The tension will remain the same
   c. The tension will decrease.

20. (1 pt) One part of wall has a thermal resistance of $R_1$. A second part of the wall, which is in parallel with the first part, has a thermal resistance $R_2$, which is greater than $R_1$. The effective thermal resistance of the entire wall is:
   a. $R_{\text{eff}} < R_1$
   b. $R_1 \leq R_{\text{eff}} < R_2$
   c. $R_2 \leq R_{\text{eff}} < R_2 + R_1$

21. (1 pt) An ideal gas is in a closed container (constant volume) at pressure $p_1$. The temperature is increased from 100°C to 200°C. The new pressure is:
   a. $0.5p_1$
   b. $0.79p_1$
   c. $1.27p_1$
   d. $2p_1$

22. (1 pt) Heat is added to a system at constant temperature. The work done is equal to:
   a. 0
   b. $Q$
   c. $-Q$
   d. $\Delta U$
   e. $-\Delta U$

23. (1 pt) In a diesel engine, heat is added at:
   a. constant volume
   b. constant temperature
   c. constant pressure

24. (1 pt) The Mythbusters are checking a claim that a heat engine acting between 300K and 350K is 26% efficient. Is this myth:
   a. Busted (not possible)
   b. Plausible (might be true)
   c. Confirmed (definitely true)

25. (1 pt) A block of ice is placed in a room and it melts. Which of the following statements is true?
   a. Entropy of ice increases, entropy of room decreases, total entropy increases
   b. Entropy of ice increases, entropy of room decreases, total entropy decreases
   c. Entropy of ice decreases, entropy of room increases, total entropy increases
   d. Entropy of ice decreases, entropy of room increases, total entropy decreases
26. (9 pts) It is required to heat 35 kg of water from 20°C to 70°C. 60% of the work from the thermodynamic process shown is used to heat water. Determine the number of cycles that are needed to heat the water.

27. (9 pts) A 60 Watt refrigerator has a coefficient of performance of 2.8, where 60 W is the amount of power the refrigerator consumes. The surface area of the refrigerator is 5.3 m², and the insulation has an R value of 1.6 m²·K/W. Determine the maximum temperature difference that this refrigerator can maintain between the inside and outside.
28. (1 pt) The net force on Charge #3 is in:
   a. Quadrant 1
   b. Quadrant 2
   c. Quadrant 3
   d. Quadrant 4

29. (1 pt) An electron is shot into an electric field created by two parallel plates. The trajectory of the electron will be:
   a. Path A
   b. Path B
   c. Path C

30. (1 pt) What charge must be put through a 12 V battery so there is 480 J of energy? __________

31. (1 pt) All three resistors have the same resistance. Other than the resistance, what is the same for resistor $R_1$ and $R_3$?
   a. Voltage drop across resistor
   b. Current through the resistor
   c. Power dissipated by the resistor
   d. Nothing besides the resistance is the same for resistors $R_1$ and $R_3$

32. (1 pt) If each of the resistors in the circuit shown above has a resistance of $R$, the equivalent resistance for the circuit is:
   a. 0.33R
   b. 0.67R
   c. 1.5R
   d. 3R

33. (1 pt) A capacitor is charged, and then put in the RC circuit shown. The switch is closed. When will there be the maximum current?
   a. Immediately after the switch is closed
   b. A long time after the switch is closed (infinity)
   c. The current will be constant

34. (1 pt) The magnetic field outside a coaxial cable is:
   a. Constant
   b. Decreases as $1/r$
   c. Decreases as $1/r^2$
   d. 0
35. (9 pts) The 10 Ω resistor represents a small heater. Determine the power that the heater can put out.

36. (9 pts) An air capacitor is made from two flat 2400 mm² parallel plates 1.5 mm apart. Determine the maximum energy that can be stored in this capacitor before dielectric breakdown. Dielectric breakdown for air occurs at an electric field strength of 3.0x10⁶ V/m. **Note:** The dielectric constant for air is the same as that of a vacuum.