A spring with a force constant $k=40 \text{ N/m}$ is attached to a 1.0 kg mass. The mass oscillates on a horizontal, frictionless track. At the time $t=0$, the mass is released from rest at $x=2.0 \text{ cm}$ to the right of the equilibrium position.

a) Find the period of the motion.

$$\omega = \sqrt{\frac{k}{m}} \Rightarrow T = \frac{2\pi}{\omega} = \frac{2\pi \sqrt{m}}{\sqrt{k}} = \frac{2\pi \sqrt{1}}{40}$$

$$\text{Period} = 1.0 \text{ s}$$

b) Below is a graph of the displacement of a mass as time progresses. Could it describe the motion of the mass as stated above? If not explain why not and use the axes to sketch the correct function.

c) You would like to determine whether or not another spring and mass system behaves like a simple harmonic oscillator. So you measure the period for several different masses and plot your data. Your results are shown below. Does this system behave like a simple harmonic oscillator? Explain.

No, if it behaved like a SHO then period $\propto \sqrt{m}$. In this case period $\propto m$ so it doesn't behave like a SHO.
A cyclic process involving one mole of an ideal gas is shown at right.

\[ PV = nRT \Rightarrow T = \frac{PV}{nR} \]
\[ T_i = \frac{(6.1 \text{ Si}) \times 831}{8.31} = 602 \text{ K} \]

a) Find the temperature at each point, 1, 2, and 3, and use that to find the change in the internal energy in each cycle, A, B, and C.

\[ \Delta U = \left( \frac{3}{2} nR \right) \Delta T \]
\[ \left( \frac{3}{2} nR \right) = 12.465 \]
\[ \Delta T_A = 1805 \text{ K} \Rightarrow \Delta U_A = 22.5 \text{ kJ} \]
\[ \Delta T_B = -2106 \text{ K} \Rightarrow \Delta U_B = -26.3 \text{ kJ} \]
\[ \Delta T_C = 301 \text{ K} \Rightarrow \Delta U_C = 3.75 \text{ kJ} \]

<table>
<thead>
<tr>
<th>T</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>602 K</td>
<td>2,407 K</td>
<td>301 K</td>
</tr>
<tr>
<td>\Delta U</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>+22.5 kJ</td>
<td>-26.3 kJ</td>
<td>+3.75 kJ</td>
<td></td>
</tr>
</tbody>
</table>

b) Find the work done on the gas in each leg of the cycle, A, B, and C and the total work done in one cycle.

\[ W_A = -P \Delta V = (50 \times 10^3 \text{ Pa}) \times (0.3 \text{ m}^3) \]
\[ W_B = \text{AREA UNDER DIAGONAL LINE} = \left( \frac{1}{2} \right) (0.3 \text{ m}^3) (25 \times 10^3 \text{ Pa}) \]
\[ W_C = 0 \]

<table>
<thead>
<tr>
<th>W_A</th>
<th>-15 kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>W_B</td>
<td>+11.2 kJ</td>
</tr>
<tr>
<td>W_C</td>
<td>0</td>
</tr>
<tr>
<td>W_D</td>
<td>0</td>
</tr>
<tr>
<td>W_total</td>
<td>-3.8 kJ</td>
</tr>
</tbody>
</table>

c) Use the 1st law of thermodynamics to help you determine the real efficiency of this engine. Compare it to the Carnot efficiency. If these efficiencies are different, explain why.

\[ \Delta U = Q + W_{\text{on gas}} \Rightarrow Q = \Delta U - W_{\text{on gas}} \]
\[ Q_A = 37.5 \text{ kJ} \quad Q_B = -37.5 \text{ kJ} \]
\[ Q_C = 3.75 \text{ kJ} \quad Q_D = 41.25 \text{ kJ} \]
\[ \Delta W_{\text{exergy}} = 3.8 / 41.25 = 9 \% \quad \varepsilon_{\text{exergy}} = 1 - \frac{301}{2407} = 87 \% \]
III. Sound travels at 340 m/s in air and 1500 m/s in water. A source that oscillates at 256 Hz creates a sound wave under water. Then the source is taken out of the water and it creates sound wave in air.

a) When the 256 Hz sound is made in the air (circle all possible correct responses)

i. the frequency is the same but the wavelength is longer than in water.

ii. the frequency is lower but the wavelength is longer than in water.

iii. the frequency is higher but the wavelength is the same as in water.

iv. the frequency is the same but the wavelength is shorter than in water.

v. both the frequency and the wavelength are the same as in water.

b) Fill in the table below with the frequencies and wavelengths of this specific sound in air and in water.

<table>
<thead>
<tr>
<th></th>
<th>frequency</th>
<th>wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>water</td>
<td>256 Hz</td>
<td>5.86 m</td>
</tr>
<tr>
<td>air</td>
<td>256 Hz</td>
<td>1.33 m</td>
</tr>
</tbody>
</table>

\[ V = \lambda f \quad \Rightarrow \quad \lambda = \frac{V}{f} \]

\[ \lambda_{\text{Air}} = \frac{340 \text{ m/s}}{256 \text{ s}^{-1}} = 1.33 \text{ m} \]

\[ \lambda_{\text{Water}} = \frac{1500 \text{ m/s}}{256 \text{ s}^{-1}} = 5.86 \text{ m} \]

c) The source is then used to set up a standing wave in an air column, which is 1.0 m long and is described by the equation below. Make a sketch that describes the amplitude of the standing wave in the column, and indicate which harmonic is heard.

\[ k = \frac{4\pi}{\lambda} \quad \Rightarrow \quad \lambda = \frac{4\pi}{4.8} \]

\[ y(x,t) = A \sin(4.8 \pi x) \cos(160 t) \]

\[ \lambda = 1.33 \text{ m} \]

\[ L = 1.0 \text{ m} \]

So \[ \lambda = 1.33 L = \frac{4}{3} L \]

\[ L = \frac{3}{4} \lambda \]

\[ n = 3 \]

\[ \frac{3}{4} \lambda \]
4. A fly sits on a potter’s wheel 0.3 m from its axle. The wheel’s rotational speed steadily decreases from 4.0 rad/s to 1.0 rad/s in 5.0 s. Which of the choices below is closest to the value of the linear distance covered by the fly during the 5s that the wheel slows down?

a) 3.0 m  
\[ \omega_0 = 4 \text{ rad}/s \quad \omega_f = 1 \text{ rad}/s \quad t = 5 \text{s} \]
b) 17 m  
\[ \omega = -0.6 \text{ rad}/s^2 \quad \Delta \theta = (4)(5) - \frac{1}{2} (0.6)(5)^2 \]
c) 5.1 m  
\[ \Delta \theta = 12.5 \text{ rad} \quad \Delta x = \Delta \theta \cdot r = 3.75 \text{ m} \]
d) 13 m  
e) 3.8 m

5. A ferris wheel speeds up from rest, and acquires a rotational velocity of \( \omega_x \) rad/s after completing \( x \) revolutions. Which of the following expressions correctly describe the angular acceleration of the ferris wheel?

\[ \alpha = \frac{\omega_x^2}{4 \pi x} \quad \alpha = \frac{\omega_x^2}{\pi x} \quad \alpha = \frac{\omega_x^2}{2 \pi x} \quad \alpha = \frac{\omega_x}{2 \pi} \quad \alpha = \frac{\omega_x}{\pi x} \]

6. A grindstone, which is a solid disk, has a mass of 4.0 kg and a radius of 0.15 m. It is spinning freely with \( \omega = 12 \) rad/s. When you put a knife blade against the outer rim, the grindstone slows steadily to rest in 3.5 s. The frictional force between the knife and the grindstone is closest to

\[ \text{Disk} \Rightarrow I_{\text{Disk}} = \frac{1}{2} MR^2 \]

a) 12 N  
\[ M = 4.0 \text{ kg} \quad R = 0.15 \text{ m} \quad \omega_0 = 12 \text{ rad/s} \quad \omega_f = 0 \]
\[ t = 3.5 \text{ s} \]
b) 2.2 N  
c) 6.4 N  
d) 0.5 N  
e) 1.0 N
7. Consider two spinning solid spheres, A and B. A weighs more than B, A is more dense than B, but both spheres have the same radius and the same angular momentum. Which of the following is true?
   a) B has a larger moment of inertia.
   b) Both spheres have the same moments of inertia.
   c) A has more kinetic energy than B.
   d) B has more kinetic energy than A.
   e) None of the above are true.

\[ K = \frac{I \omega^2}{2} \quad \text{since } I_A > I_B \quad \text{and} \quad L_A = L_B \Rightarrow \kappa_A > \kappa_B \]

8. A cable suspends a 0.8 m stick of mass 0.5 kg in static equilibrium as shown. The left side of the stick is attached to the wall with a hinge. Assuming the stick is of uniform density find the force between the stick and the hinge.

   a) 11.3 N
   b) 7.5 N
   c) 5.7 N
   d) 4.9 N
   e) 9.1 N

9. The figures below show hollow spheres (not drawn to scale) that are rolling at a constant rate without slipping. The spheres all have the same mass, but their radii as well as their linear and angular speeds vary. Rank the rotational kinetic energy of the spheres from GREATEST to LEAST.

\[ K_{\text{Total}} = \frac{1}{2} m v_{\text{CM}}^2 + \left( \frac{1}{2} m v_{\text{CM}}^2 \right) = \left( 1 + \frac{1}{2} \right) m v_{\text{CM}}^2 \]

Since all are hollow spheres, \[ K_{\text{Total}} = K_{\text{Total}} + v_{\text{CM}}^2 \quad E=F, D=B, C, A \]
10. Beth has a helium-filled balloon outside and it is a very cold day. The helium in her balloon has a density $D$. She takes her balloon inside her house and it warms up. Inside the house she notices that the balloon expands, and that it takes up $\frac{10}{9}$ of the space that it did outside. If no helium escapes from the balloon, then the density of the helium in the balloon after expanding is:

(a) $(9/10) \cdot D$
(b) $(10/9) \cdot D$
(c) $D$
(d) $(10/11) \cdot D$
(e) $(11/10) \cdot D$

\[
\frac{10}{9} V_{\text{out}} = V_{\text{in}} \quad M_{\text{out}} = M_{\text{in}}
\]

\[
D = \frac{D_{\text{out}}}{V_{\text{out}}} = \frac{M_{\text{out}}}{V_{\text{out}}} = \frac{M_{\text{in}}}{V_{\text{in}}} = \frac{M_{\text{in}}}{\frac{10}{9} V_{\text{out}}}
\]

\[
D_{\text{in}} = \frac{M_{\text{out}}}{\frac{10}{9} V_{\text{out}}} = \frac{9}{10} D_{\text{out}}
\]

11. A hole is punched two-thirds of the way down from the top a full milk carton that is 30 cm tall. Which of the following is closest to the initial velocity of outflow?

(a) 2.0 m/s
(b) 2.8 m/s
(c) 3.9 m/s
(d) 2.8 m/s
(e) 1.4 m/s

\[
\gamma g h = \frac{1}{2} \rho V_o^2 \quad \Rightarrow \quad V_o = \sqrt{2 \gamma g h}
\]

\[
V_o = \sqrt{(2)\left(1.8\right)(0.3)} = 2.4 \text{ m/s}
\]

12. 50 g of steam at 100°C and 50 g of water at 80°C are mixed together in an insulated container. The heat capacity of steam is 2.09 kJ/kg $\cdot$ °C and of water is 4.18 kJ/kg $\cdot$ °C. The latent heats of fusion and vaporization of water are $L_f = 333.5$ kJ/kg and $L_v = 2257$ kJ/kg. When the combination reaches thermal equilibrium the final temperature will be closest to

(a) 100°C
(b) 95°C
(c) 90°C
(d) 85°C
(e) 80°C

So, steam does not

\begin{center}
\textit{Can the water absorb enough energy to condense the steam?}
\end{center}

\begin{center}
\textit{If all steam condenses: (0.05 kg) \times \left( \frac{2257}{49} \right) = 1.13 \times 10^5 J}
\end{center}

This would result in a temp change of $\Delta T = \frac{Q}{m c_{\text{water}}} = \frac{540°C}{m c_{\text{water}}}$
13. Several moles of gas expands adiabatically, pushing a piston and doing 214 J of work. Which of the following is true.

- a) The internal energy decreases by more than 214 J.
- b) The internal energy decreases by 214 J.
- c) The expansion is adiabatic so there cannot be a temperature change.
- d) The internal energy increases by 214 J.
- e) The internal energy increases by more than 214 J.

\[ \Delta U = W_{\text{on gases}} \]
\[ \Delta U = -214 \text{ J} \]

14. All of the strings below (not drawn to scale) exhibit standing waves. All of the strings are identical except for their lengths, and all of the string tensions are identical. The string lengths and the standing wave amplitudes are given in each figure.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>A=5 cm</td>
<td>A=9 cm</td>
</tr>
<tr>
<td>L=35 cm</td>
<td>L=42 cm</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>A=7 cm</td>
<td>A=6 cm</td>
</tr>
<tr>
<td>L=24 cm</td>
<td>L=28 cm</td>
</tr>
</tbody>
</table>

Which of the following represent the correct ranking of the frequencies, from GREATEST to LEAST.

- a) B, A, C, D
- b) B, C, D, A
- c) D, C, A, B
- d) B, A=D, C
- e) A=B, D, C

\[ \text{IS SAME FOR ALL STRINGS.} \]
\[ f_1 \text{ IS THE SAME} \]
\[ f_2 \neq f_1 \]
\[ \lambda \text{ is the same} \]
\[ \lambda_1 = 14 \text{ cm} \]
\[ \lambda_2 = 12 \text{ cm} \]
\[ \lambda_3 > \lambda_4 = \lambda_5 > \lambda_6 \]
\[ \lambda_6 = 14 \text{ cm} \]
\[ f_6 > f_4 = f_5 > f_3 \]
\[ \Rightarrow B, A=D, C \]
I. A spring with a force constant $k=40 \text{ N/m}$ is attached to a 2.3 kg mass. The mass oscillates on a horizontal, frictionless track. At the time $t=0$, the mass is released from rest at $x=2.0 \text{ cm}$ to the right of the equilibrium position.

a) Find the period of the motion.

$$\text{Period} = 2\pi \sqrt{\frac{m}{k}} = 2\pi \sqrt{\frac{2.3}{40}}$$

$$\text{Period} = 1.5 \text{ s}$$

b) Below is a graph of the displacement of a mass as time progresses. Could it describe the motion of the mass as stated above? If not explain why not and use the axes to sketch the correct function.

![Displacement vs. Time Graph]

- Initial displacement: $y(0) = 2.0 \text{ cm}$
- Time: $t = 1.5 \text{ s}$

(c) You would like to determine whether or not another spring and mass system behaves like a simple harmonic oscillator. So you measure the period for several different masses and plot your data. Your results are shown below. Does this system behave like a simple harmonic oscillator? Explain.

![Period vs. Mass Graph]

See V.1
II. A cyclic process involving one mole of an ideal gas is shown at right.

![Graph showing a cyclic process with temperatures and pressures.]

a) Find the temperature at each point, 1, 2 and 3, and use that to find the change in the internal energy in each cycle, A, B, and C.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ΔU</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

b) Find the work done on the gas in each leg of the cycle, A, B, and C and the total work done in one cycle.

<table>
<thead>
<tr>
<th>W</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>W_A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W_B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W_C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W_{total}</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c) Use the 1st law of thermodynamics to help you determine the real efficiency of this engine. Compare it to the Carnot efficiency. If these efficiencies are different, explain why.
III. Sound travels at 340 m/s in air and 1500 m/s in water. A source that oscillates at 512 Hz creates a sound wave under water. Then the source is taken out of the water and it creates sound wave in air.

a) When the 512 Hz sound is made in the air (circle all possible correct responses)

i. the frequency is the same but the wavelength is longer than in water.

ii. the frequency is lower but the wavelength is longer than in water.

iii. the frequency is higher but the wavelength is the same as in water.

iv. the frequency is the same but the wavelength is shorter than in water.

v. both the frequency and the wavelength are the same as in water.

b) Fill in the table below with the frequencies and wavelengths of this specific sound in air and in water.

<table>
<thead>
<tr>
<th></th>
<th>frequency</th>
<th>wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>water</td>
<td>512 Hz</td>
<td>2.73 m</td>
</tr>
<tr>
<td>air</td>
<td>512 Hz</td>
<td>0.664 m</td>
</tr>
</tbody>
</table>

c) The source is then used to set up a standing wave in an air column, which is 0.498 m long and is described by the equation below. Make a sketch that describes the amplitude of the standing wave in the column, and indicate which harmonic is heard.

\[ y(x,t) = A\sin(9.46x)\cos(3217t) \]

\[ \lambda = \frac{L}{n} = 0.664 \text{ m} \]

\[ L = 0.498 \text{ m} \]

\[ n = 3 \]
4. A fly sits on a potter's wheel 0.4 m from its axle. The wheel's rotational speed steadily decreases from 4.0 rad/s to 1.0 rad/s in 5.0s. Which of the choices below is closest to the value of the linear distance covered by the fly during the 5s that the wheel slows down?

\[
\begin{align*}
\text{a)} & \quad 3.0 \text{ m} & \quad \omega_0 = 4 \text{ rad/s} \quad \omega_f = 1 \text{ rad/s} \quad t = 5 \text{s} \\
\text{b)} & \quad 17 \text{ m} & \\
\text{c)} & \quad 5.1 \text{ m} & \\
\text{d)} & \quad 13 \text{ m} & \Delta \theta = 4.5 - \frac{1}{2} \cdot 0.6 \cdot 5^2 = 12.5 \text{ rad} \\
\text{e)} & \quad 3.8 \text{ m} & \Delta x = \Delta \theta \cdot r = 3.0 \\
\end{align*}
\]

5. A ferris wheel speeds up from rest, and acquires a rotational velocity of \( \omega_f \) rad/s after completing \( x \) revolutions. Which of the following expressions correctly describe the angular acceleration of the ferris wheel?

\[
\begin{align*}
\text{a)} & \quad \alpha = \frac{\omega_f^2}{2 \pi x} \\
\text{b)} & \quad \alpha = \frac{\omega_f}{\pi x} \\
\text{c)} & \quad \alpha = \frac{\omega_f}{2 \pi} \\
\text{d)} & \quad \alpha = \frac{\omega_f^2}{4 \pi x} & \text{(Correct)} \\
\text{e)} & \quad \alpha = \frac{\omega_f^2}{\pi x} \\
\end{align*}
\]

6. A grindstone, which is a solid disk, has a mass of 4.0 kg and a radius of 0.15m. It is spinning freely at 12 rad/s. When you put a knife blade against the outer rim, the grindstone slows steadily to rest in 3.5s. The frictional force between the knife and the grindstone is closest to

\[
\begin{align*}
\text{a)} & \quad 0.5 \text{ N} \\
\text{b)} & \quad 1.0 \text{ N} & \text{(Correct)} \\
\text{c)} & \quad 12 \text{ N} \\
\text{d)} & \quad 2.2 \text{ N} \\
\text{e)} & \quad 6.4 \text{ N} \\
\end{align*}
\]
7. Consider two spinning solid spheres, A and B. B weighs more than A, B is more dense than A, but both spheres have the same radius and the same angular momentum. Which of the following is true?

a) B has a larger moment of inertia.

b) Both spheres have the same moments of inertia.

(c) A has more kinetic energy than B. \( K = \frac{L^2}{2I} \)

\( I_A > I_B \)

\( K_A > K_B \)

d) B has more kinetic energy than A.

e) None of the above are true.

8. A cable suspends a 0.8 m stick of mass 0.5 kg in static equilibrium as shown. The left side of the stick is attached to the wall with a hinge. Assuming the stick is of uniform density, find the magnitude of the force between the stick and the hinge.

a) 7.5 N

b) 5.7 N

(c) 4.9 N

d) 9.1 N

e) 11.3 N

9. The figures below show hollow spheres (not drawn to scale) that are rolling at a constant rate without slipping. The spheres all have the same mass, but their radii as well as their linear and angular speeds vary. Rank the total kinetic energy of the spheres from GREATEST to LEAST.

a) E, F, D, A=B=C

b) A, B, C=D=E, F

c) E, B=E, D, C, A

d) E, F, D, B, C, A

e) F, E, B=D, C, A
10. Beth has a helium-filled balloon outside and it is a very cold day. The helium in her balloon has a density $D$. She takes her balloon inside her house and it warms up. Inside the house she notices that the balloon expands, and that it takes up $11/10$ of the space that it did outside. If no helium escapes from the balloon, then the density of the helium in the balloon after expanding is:

a) $(9/10)*D$

b) $(10/9)*D$

c) $D$

d) $(10/11)*D$

e) $(11/10)*D$

11. A hole is punched two-thirds of the way down from the top a full milk carton that is 60 cm tall. Which of the following is closest to the initial velocity of outflow?

a) 2.0 m/s

b) 2.4 m/s

c) 3.9 m/s

d) 2.8 m/s

e) 1.4 m/s

12. 50 g of steam at 100°C and 50 g of water at 80°C are mixed together in an insulated container. The heat capacity of steam is 2.09 kJ/kg · °C and of water is 4.18 kJ/kg · °C the latent heats of fusion and vaporization of water are $L_f = 333.5$ kJ/kg and $L_v = 2257$ kJ/kg. When the combination reaches thermal equilibrium the final temperature will be closest to

a) 85°C

b) 80°C

c) 95°C

d) 90°C

e) 100°C
13. Several moles of gas expands adiabatically, pushing a piston and doing 214 J of work. Which of the following is true.

a) The expansion is adiabatic so there cannot be a temperature change.

b) The internal energy increases by more than 214 J.

c) The internal energy increases by 214 J.

d) The internal energy decreases by 214 J.

e) The internal energy decreases by more than 214 J.

\[ Q = 0 \]
\[ \Delta U = + W_{\text{external}} \]
\[ \Delta U = - 214 J \]

14. All of the strings below (not drawn to scale) exhibit standing waves. All of the strings are identical except for their lengths, and all of the string tensions are identical. The string lengths and the standing wave amplitudes are given in each figure.

<table>
<thead>
<tr>
<th>A</th>
<th>A= 5 cm</th>
<th>L= 35 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>A= 9 cm</td>
<td>L= 42 cm</td>
</tr>
<tr>
<td>C</td>
<td>A= 7 cm</td>
<td>L= 24 cm</td>
</tr>
<tr>
<td>D</td>
<td>A= 6 cm</td>
<td>L= 28 cm</td>
</tr>
</tbody>
</table>

Which of the following represent the correct ranking of the frequencies, from GREATEST to LEAST.

a) D, C, A, B

b) B, A=D, C

c) A=B, D, C

d) B, A, C, D

e) B, C, D, A

\[ \frac{1}{\lambda_B} > \frac{1}{\lambda_A} = \frac{1}{\lambda_D} > \frac{1}{\lambda_C} \]

B, A = D, C