Practice Final Exam

Please bring this with you to the practice final exam on Saturday, May 3, 2014.
1. A projectile is fired from point 0 at the edge of a high cliff, with initial velocity components of \( v_{0x} = 60.0 \text{ m/s} \) and \( v_{0y} = 175 \text{ m/s} \), as shown in the figure. The projectile rises and then falls into the sea at point P. The time of flight of the projectile is 40.0 s, and it experiences no appreciable air resistance in flight. The height of the cliff is closest to ...

A) 120 m  
B) 180 m  
C) 230 m  
D) 410 m  
E) 850 m

\[ v_{0y} = 175 \text{ m/s}, \quad t = 40.0 \text{ s}, \quad a_y = -9.81 \text{ m/s}^2 \]

![Projectile Diagram]

2. A system comprising blocks, a massless frictionless pulley, a frictionless incline, and connecting massless ropes is shown. The 9-kg block accelerates downward when the system is released from rest. The tension in the rope connecting the 6-kg block and the 4-kg block is closest to ...

A) 39 N  
B) 30 N  
C) 36 N  
D) 42 N  
E) 33 N

\[ F_y = m_3 g - \frac{1}{2} m_2 a \]

\[ F_k = T_2 - (m_1 + m_2) g \sin(\theta) = (m_1 + m_2 + m_3) a \]

\[ a = \frac{(m_2 g - (m_1 + m_2) g \sin(\theta))}{(m_1 + m_2 + m_3) \cos(\theta)} = 2.045 \text{ m/s}^2 \]

\[ T_1 - (m_2 g \sin(\theta)) = m_2 a + m_3 g \sin(\theta) = 42 \text{ N} \]

3. A metal bar is hanging from a hook in the ceiling when a ball that is moving horizontally suddenly strikes it. The ball is covered with glue, so it sticks to the bar. During this collision...

A) ... the angular momentum of the system (ball and bar) is conserved about the hook because neither the hook nor gravity exerts any torque on this system about the hook.  
B) ... the angular momentum of the system (ball and bar) is not conserved because the hook exerts a force on the bar.  
C) ... the angular momentum of the system (ball and bar) is conserved about the hook because only gravity is acting on the system.  
D) ... both the angular momentum of the system (ball and bar) and its kinetic energy are conserved.  
E) ... both the linear momentum and the angular momentum of the system (ball and bar) are conserved.

The only external forces acting on the ball and bar are gravity and the hook. Neither one or the other exerts a torque during the collision.
4. In the figure, four point masses are placed as shown. The x and y coordinates of the center of mass are closest to

\[ x_{cm} = (2.0\text{ m} - 2.0\text{ kg}) + (3.0\text{ m} + 4.0\text{ kg}) + (5.0\text{ m} - 6.0\text{ kg}) = 2.3\text{ m} \]
\[ y_{cm} = 3.0\text{ m} - 8.0\text{ kg} + 5.0\text{ m} - 4.0\text{ kg} + 2.0\text{ m} - 6.0\text{ kg} = 2.8\text{ m} \]

5. The sound from a single source can reach point P by two different paths. One path is 20.0 m long and the second path is 21.0 m long. The sound destructively interferes at point P. What is the minimum frequency of the source if the speed of sound is 343 m/s?

A) 343 Hz  
B) 515 Hz  
C) 686 Hz  
D) 6860 Hz  
E) 172 Hz  

Destructive interference occurs when the difference in path length is an odd, integer multiple of \( \frac{1}{2} \lambda \). The largest wavelength corresponds to the lowest frequency.

\[ \Delta L = \frac{\lambda}{2} = 1.0\text{ m}, \quad f = \frac{v}{\lambda} = \frac{343\text{ m/s}}{2.0\text{ m}} = 172 \text{ Hz} \]

6. Consider two pistons filled with ideal gases. One piston has a volume of 10 liters and contains 0.5 mol of Xenon gas at atmospheric pressure. The other piston has a volume of 16 liters and contains 1.0 mol of Argon gas at a temperature of 400K. The atomic mass of Argon is 39.9 gram/mol and the atomic mass of Xenon is 131 gram/mol. The ratio of rms speeds/ \( v_{rms}(\text{Xenon})/v_{rms}(\text{Argon}) \) of the gas atoms is closest to...

A) 0.43  
B) 5.2  
C) 0.81  
D) 8.4  
E) 0.12  

\[ T_{xen} = 400\text{ K} \]
\[ v_{rms} = \left( \frac{3RT}{M} \right)^{1/2} \]
\[ nRT \]
\[ \frac{v_{rms}(\text{Xe})}{v_{rms}(\text{Ar})} = \left( \frac{3RT_{xen}}{M_{xen}} \right)^{1/2} \]
\[ \frac{400\text{ K}}{131\text{ g/mol}} \]
\[ = 0.43 \]
7. The figure shows a pV diagram for 0.47 mol of gas that undergoes the process then undergoes an isochoric heating from point 2 until the pressure is restored to the value it had at point 1. What is the final temperature of the gas?

\[ n = 0.47 \text{ mol} \]
\[ p_f = 3.6 \text{ atm} = 1.37 \times 10^5 \text{ Pa} \]
\[ V_f = 3.04 \times 10^3 \text{ Pa} \]
\[ T_f = 3000 \text{ cm}^3 = 3.0 \times 10^{-3} \text{ m}^3 \]
\[ T_f = \frac{\left( 3.03 \times 10^5 \text{ Pa} \times 0.03 \text{ m}^3 \right)}{0.47 \text{ mol} \times 8.31 \text{ J/(mol K)}} = 233 \text{ K} = 40.0 \text{ C} \]

A) 400°C
B) 2°C
C) 130°C
D) 230°C
E) 510°C

8. A glass window is 2.6 m high, 2.3 m wide, and 3.0 mm thick. The temperature at the inner surface of the glass is 24°C, and at the outer surface is 4.0°C. How much heat is lost each hour through the window? (Properties of glass: density: 2300 kg/m³, specific heat: 840 J/kg·°C, coefficient of linear thermal expansion: 8.5 × 10⁻⁶ (°C⁻¹), thermal conductivity: 0.80 W/(m·°C))

\[ t \times \left( \frac{dQ}{dt} \right) = \frac{dQ_{net}}{dt} = \frac{t}{\frac{T_h - T_c}{L}} = 3.60 \times 10^5 \text{ W/(m·°C)} \left( 26 \times 23 \text{ m} \right)^2 \left( \frac{20}{3 \times 10^5} \right) \]
\[ = 1.1 \times 10^8 \text{ J} \]

A) 1.1 × 10^8 J
B) 1.1 × 10^6 J
C) 1.1 × 10^5 J
D) 32 J
E) 320 J

9. Carnot refrigerator operates between a hot reservoir at 600K and a cold reservoir at 200K. The refrigerator consumes 50 W of power. How much heat is removed from the interior of the refrigerator in 1 hour?

Coefficient of performance, refrigerator = \( K_r \)

\[ K_r = \frac{T_c}{T_h - T_c} = \frac{200K}{600K - 200K} = 0.5 \]

\[ Q_c = K_r \cdot P \cdot t \]

\[ Q_c = \frac{Q_c}{W} = K_r \cdot P \cdot t \]

\[ = 0.5 \times 50 \text{ W} \cdot 3600 \text{ s} \]

\[ = 90 \text{ kJ} \]

A) 180 kJ
B) 72 kJ
C) 720 kJ
D) 7.5 kJ
E) 90 kJ
10. When a fixed amount of a monatomic ideal gas is expanded in volume at constant pressure, the average kinetic energy of the gas molecules ______.

A) increases.
B) decreases.
C) does not change.
D) may either increase or decrease, depending on whether or not the process is carried out adiabatically.
E) may or may not change, but insufficient information is given at make such a determination.

\[ \text{KE}_{\text{gas}, \text{avg}} \propto T_{\text{gas}}, \quad \left< k_{\text{trans}} \right> = \frac{a}{2} kT, \quad \text{and if} \quad \Delta T > 0, \Delta V > 0 \Rightarrow \Delta \text{KE} > 0 \]

\[ T = \frac{PV}{nR} \]

11. In designing buildings to be erected in an area prone to earthquakes, what relationship should the designer try to achieve between the natural frequency of the building and the typical earthquake frequencies?

A) The natural frequency of the building should be almost the same as typical earthquake frequencies but slightly lower.
B) The natural frequency of the building should be almost the same as typical earthquake frequencies but slightly higher.
C) The natural frequency of the building should be very different from typical earthquake frequencies.
D) The natural frequency of the building should be exactly the same as typical earthquake frequencies.
E) The designer does not have to worry about typical earthquake frequencies.

If the natural frequency of a building \( \approx \) typical earthquake frequencies \( \rightarrow \) resonance \( \rightarrow \) failure of building/long.
So, the 2 frequencies should be very different.

12. The figure below shows the measured displacement of a mass oscillating at the end of a spring as a function of time. What is the frequency of the oscillations?

A) 0.47 Hz
B) 0.94 Hz
C) 1.2 Hz
D) 1.9 Hz
E) 2.6 Hz

\[ \frac{2}{16.75} \text{ periods in 20 s} \]

So, \( \frac{2}{16.75} = 0.12 \), \( \frac{1}{T} = 0.12 \text{ s}^{-1} \]

oscillation \( f = \frac{1}{T} = 0.94 \text{ Hz} \)
13. A 40-cm³ closed flask full of air is slowly heated. A thermometer and a pressure probe are used to monitor temperature $T$ and pressure $p$ throughout the process. The results are shown in the figure below as open squares, along with the corresponding linear fit.

The linear fit shown is: $p = (0.00218 \text{ atm}) + (0.00349 \text{ atm/K})T$.

![Graph showing linear fit with values]

How many moles of air are inside the flask? (1 Liter = 1000 cm³)

- A) 0.0017 moles
- B) 0.0025 moles
- C) 0.032 moles
- D) 0.041 moles
- E) 0.52 moles

\[
\begin{align*}
\text{Pressure (atm)} & \\
\text{Temperature (K)} & \\
\end{align*}
\]

\[
\begin{align*}
\text{Linear Fit } y = mx + b \\
m(\text{slope}) & = 0.00349 \\
b(\text{y-intercept}) & = 0.00218 \\
\text{Correlation: } & = 0.999
\end{align*}
\]

\[
\begin{align*}
n = \frac{V_p}{R \cdot T} = \frac{40 \times 10^{-6} \text{ m}^3}{9.31 \times 10^5 \text{ J/mol K}} \\
\end{align*}
\]

\[
\begin{align*}
\n & \approx 0.0017 \text{ mol}
\end{align*}
\]