

SOLUTIONS

Phys 111.01 Sample Final

A. MULTIPLE-CHOICE QUESTIONS. CIRCLE THE BEST ANSWER (5 Pts. each):

1. Vector **A** has an x-component of +22 units and a y-component of -10 units. Vector **B** has an x-component of +44 units and a y-component of -60 units. Determine the magnitude of the vector sum **A+B**.

- a. -4 units
- b. 4 units
- c. 20 units
- d. 96 units
- e. 136 units

$$R_x = A_x + B_x = 22 + 44 = 66$$

$$R_y = A_y + B_y = -10 - 60 = -70$$

$$R = \sqrt{R_x^2 + R_y^2} = \sqrt{(66)^2 + (-70)^2} = 96$$

2. A car of mass 80 kg, traveling at a constant speed of 20 m/s around a circular track, has a centripetal acceleration of 5 m/s^2 . What is the radius of the circular track?

- a) 4.0 m
- b) 8.0 m
- c) 80 m
- d) 160 m
- e) 640 m
- f) 1600 m

$$a_{\text{cen}} = \frac{v^2}{R} = 5 \text{ m/s}^2$$

$$R = \frac{v^2}{a_{\text{cen}}} = \frac{(20 \text{ m/s})^2}{5 \text{ m/s}^2} = 80 \text{ m}$$

3. Which of the following is **not** possible:

- a) A body has zero velocity and non-zero acceleration
- b) A body travels with a northward velocity and a northward acceleration
- c) A body travels with a northward velocity and a southward acceleration
- d) A body travels with a constant velocity and a time-varying acceleration
- e) A body travels with a constant acceleration and a time-varying velocity

4. A disk with a rotational inertia of $8.0 \text{ kg}\cdot\text{m}^2$ is spinning with an angular speed of 5.0 rad/s on a frictionless axle. A ring at rest with rotational inertia of $2 \text{ kg}\cdot\text{m}^2$ falls onto the disk and sticks to it. What is the new rotational speed of the disk and ring?

- a) 20 rad/s
- b) 10 rad/s
- c) 8.0 rad/s
- d) 5.0 rad/s
- e) 4.0 rad/s

$$L_f = L_i$$

$$I_f \omega_f = I_i \omega_i \Rightarrow \omega_f = \left(\frac{I_i}{I_f} \right) \omega_i = \left(\frac{8 \text{ kg}\cdot\text{m}^2}{10 \text{ kg}\cdot\text{m}^2} \right) (5 \text{ rad/s}) = 4.0 \text{ rad/s}$$

5. A rock is thrown straight up from the Earth's surface. Which of the following statements describes the energy transformation of the rock as it rises?

- a) The total energy of the rock increases
- b) The kinetic energy increases and the potential energy decreases
- c) Both the potential energy and the total energy of the rock increase
- d) The kinetic energy decreases and the potential energy increases
- e) Both the kinetic energy and the potential energy of the rock remain the same

6. Which one of the following statements is true concerning an object in simple harmonic motion?

- a) Its velocity is never zero
- b) Its acceleration is never zero
- c) Its velocity and acceleration are simultaneously zero
- d) Its velocity is zero when its acceleration is at a maximum
- e) Its maximum acceleration is equal to its maximum velocity

7. An 80-kg astronaut carrying a 20-kg toolkit is initially drifting toward a stationary space shuttle at a speed of 2 m/s. If she throws the toolkit toward the shuttle with a speed of 6 m/s as seen from the shuttle, her final speed is

- a) 1 m/s toward the shuttle
- b) 1 m/s away from the shuttle
- c) 2 m/s toward the shuttle
- d) 4 m/s toward the shuttle
- e) 6 m/s away from the shuttle

$$P_i = P_f$$

$$(m_A + m_T) V_i = m_A V_A + m_T V_T$$

$$V_A = \frac{(m_A + m_T) V_i - m_T V_T}{m_A} = \frac{200 \text{ kg} \cdot \text{m/s} - 120 \frac{\text{kg}}{\text{s}}}{80 \text{ kg}} = 1 \text{ m/s}$$

8. A balloon inflated with helium gas (density 0.2 kg/m^3) has volume of $6 \times 10^{-3} \text{ m}^3$. If the density of the air is 1.3 kg/m^3 , what is the buoyant force on the balloon?

- a) 0.01 N
- b) 0.08 N
- c) 0.8 N
- d) 1.3 N
- e) 7.8 N

$$F_B = \rho_f g V_{\text{sub}}$$

$$= (1.3 \text{ kg/m}^3) (9.8 \text{ N/kg}) (6 \times 10^{-3} \text{ m}^3) = 0.076 \text{ N}$$

9. The coefficient of linear expansion of aluminum is $23 \times 10^{-6}/^\circ\text{C}$. A circular hole in an aluminum plate is 2.725 cm diameter at 0°C . What is the diameter of the hole if the temperature of the plate is raised to 100°C ?

- a) 0.0063 cm
- b) 2.728 cm
- c) 2.731 cm
- d) 2.757 cm
- e) 2.788 cm

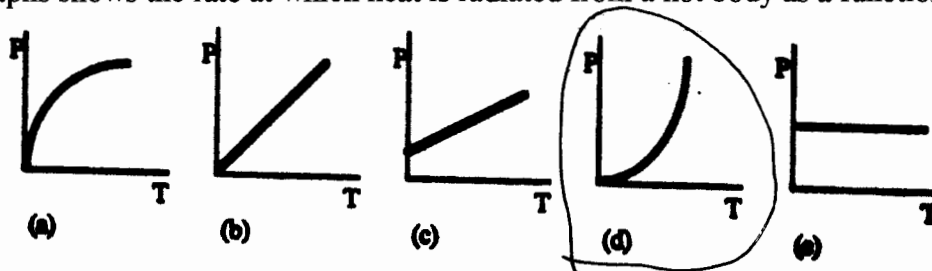
$$\Delta L = \alpha L_0 \Delta T$$

$$= (23 \times 10^{-6}/^\circ\text{C}) (2.725 \text{ cm}) (100^\circ\text{C})$$

$$= .0063 \text{ cm} \Rightarrow L = 2.731 \text{ cm}$$

10. Which one of the following graphs shows the rate at which heat is radiated from a hot body as a function of its Kelvin temperature?

$$P = \epsilon \sigma A T^4$$



11. A 1.00-kg sample of steam at 100.0°C condenses to water at 100.0°C . What is the entropy change of the sample if the heat of vaporization of water is $2.26 \times 10^6 \text{ J/kg}$?

- a) $-6.05 \times 10^3 \text{ J/K}$
- b) $+6.05 \times 10^3 \text{ J/K}$
- c) $-2.26 \times 10^4 \text{ J/K}$
- d) $+2.26 \times 10^4 \text{ J/K}$
- e) Zero

$$Q = -m L_v = -(1 \text{ kg}) (2.26 \times 10^6 \text{ J/kg}) = -2.26 \times 10^6 \text{ J}$$

$$\Delta S = \frac{Q}{T} = \frac{-2.26 \times 10^6 \text{ J}}{373 \text{ K}} = -6.05 \times 10^3 \text{ J/K}$$

12. A train moving at constant speed passes a fixed observer. A flute player on the train is playing a note of frequency 440 Hz, but the observer hears it as 392 Hz after the train passes. What is the speed of the train if the speed of sound in air is 343 m/s?

- a) 7.3 m/s
- b) 12 m/s
- c) 26 m/s
- d) 42 m/s
- e) 48 m/s

Moving source, moving away

$$F' = \left(\frac{1}{1 + \frac{u}{v}} \right) F \Rightarrow 1 + \frac{u}{v} = \frac{F}{F'}$$

$$u = v \left(\frac{F}{F'} - 1 \right) = 343 \frac{\text{m}}{\text{s}} \left(\frac{440}{392} - 1 \right) = 42 \text{ m/s}$$

PROBLEMS. BE SURE TO SHOW YOUR METHOD CLEARLY. (5 points for each problem part.)

1. A ball is shot from the ground at an angle of 50° relative to the ground with a speed of 40 m/s. Neglect air resistance.

a) What was the acceleration of the ball at its highest point?

$\uparrow \hat{y}$
 $-g \hat{y}$; g downward; $-9.8 \frac{m}{s^2}$ (down)

$a = -g \hat{y}$

b) How high above the ground will the ball reach at its highest point?

$$V_y^2 = V_{yi}^2 + 2a_y \Delta y = 0$$
$$\Delta y = \frac{-V_{yi}^2}{2(-9.8 \frac{m}{s^2})} = \frac{-[(40 \frac{m}{s}) (\sin 50^\circ)]^2}{2(-9.8 \frac{m}{s^2})} = 47.9 m$$

48 m

c) What was the vertical component of the ball's velocity just before it hit the ground (numerical answer)?

$$V_{yf} = -V_{yi} \text{ (symmetry)} = (40 \frac{m}{s}) (\sin 50^\circ) = -30.6 \frac{m}{s}$$

-31 m/s

d) When the ball hits the ground, how far is it from the starting point (10 points for this part)?

$$x = x_0 + v_{0x} t_f$$

Get t_f from $V_y = 0 = v_{0y} - g t_{top} \Rightarrow t_{top} = \frac{v_{0y}}{g} = \frac{(40 \frac{m}{s}) \sin 50^\circ}{9.8 \frac{m}{s^2}} = 3.135$

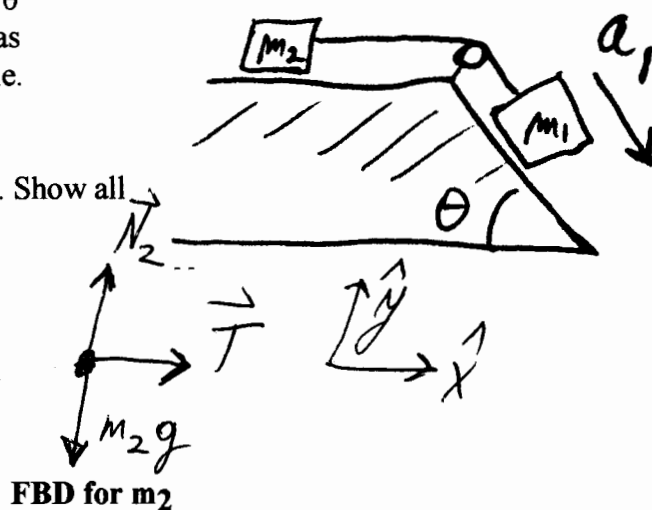
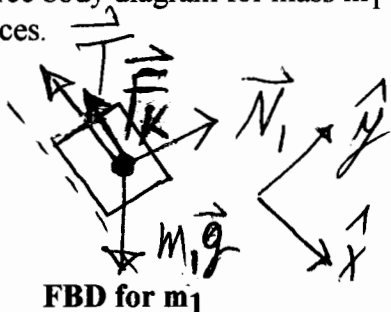
Then $t_f = 2 t_{top} = 6.255$

160 m

$$x = (40 \frac{m}{s}) (\cos 50^\circ) (6.255) = 161 m$$

2. A mass m_1 on an inclined plane (with friction) of angle θ is connected to a mass m_2 by a rope running over a pulley as shown in the diagram. Mass m_2 slides on a frictionless table. It is found that mass m_1 has an acceleration a_1 downward along the plane. Neglect the mass of the rope.

a) Draw a free body diagram for mass m_1 and for mass m_2 . Show all relevant forces.



b) What will be the acceleration of m_2 ?

$$a_2 = a_1$$

$$a_1$$

c) Write the Newton's 2nd Law equation for mass m_2

$$\Sigma F_x = T = m_2 a_{2x} ; \Sigma F_y = N_2 - m_2 g = 0$$

d) From the equation of part (c) find the magnitude of the tension in the rope. [Give the answers to these questions in terms of m_1 , m_2 , a_1 , θ , and g as needed.]

$$T = m_2 a_{2x} = m_2 a_1$$

$$m_2 a_1$$

e) Write a Newton's 2nd Law equation for mass m_1 and from this equation, find the magnitude of the force exerted on mass m_1 by friction between the mass and the plane. [Give the answer in terms of m_1 , m_2 , a_1 , g , and θ as needed.]

$$\Sigma F_x = m_1 g \sin \theta - T - F_k = m_1 a_{1x} = m_1 a_1$$

$$\Sigma F_y = N - m_1 g \cos \theta = 0 \Rightarrow N = m_1 g \cos \theta$$

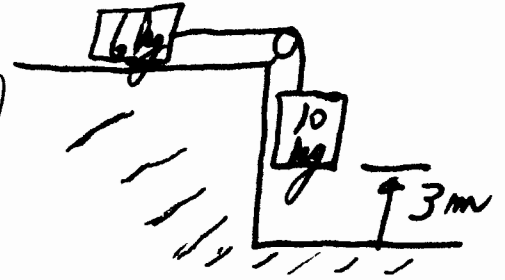
$$F_k = m_1 g \sin \theta - T - m_1 a_1$$

$$F_k = m_1 g \sin \theta - (m_1 + m_2) a_1$$

3. A mass of 6 kg on a table (friction coefficients μ_k and μ_s) is attached by a string to a mass of 10 kg which starts out 3 m above the ground. Both masses are initially at rest. The 10 kg mass falls to the ground and is found to have a speed of 5 m/s just as it hits the ground.

a) What is the initial gravitational potential energy of the 10 kg mass?

$$U = mgh = (10 \text{ kg})(9.8 \text{ N/kg})(3 \text{ m}) = 294 \text{ J}$$



294 J

b) What is the final kinetic energy of the system (the 6 kg mass and the 10 kg mass) just as the 10 kg mass hits the ground?

$$K = \frac{1}{2} m v^2 = \frac{1}{2} (16 \text{ kg}) (5 \text{ m/s})^2 = 200 \text{ J}$$

200 J

c) What work was done by friction during the motion?

$$W_{Nc} = \Delta E = E_f - E_i = 200 \text{ J} - 294 \text{ J} = -94 \text{ J}$$

-94 J

d) What is the value of the friction coefficient μ_k ?

$$W_{Nc} = -F_R d \Rightarrow F_R = \frac{-W_{Nc}}{d} = \frac{94 \text{ J}}{3 \text{ m}} = 31.3 \text{ N}$$

$$F_R = \mu_R m_6 g \Rightarrow \mu_R = \frac{F_R}{m_6 g} = \frac{31.3 \text{ N}}{(6 \text{ kg})(9.8 \text{ N/kg})}$$

$\mu_k = 0.53$

4. A wheel (a solid disk) of mass 0.40 kg and radius 0.30 m is turning at 260 rad/s when the brakes are applied. In 5.0 seconds, the rotational speed of the wheel is reduced to 60 rad/s.

a) What was the angular acceleration during the 5.0 seconds?

$$\omega = \omega_0 + \alpha t$$

$$(60 \text{ rad/s}) = (260 \text{ rad/s}) + \alpha (5.0 \text{ s})$$

$$\alpha = \frac{-200 \text{ rad/s}}{5 \text{ s}} = \underline{\underline{-40 \text{ rad/s}^2}}$$

b) Through what angle did the wheel turn in the 5.0 seconds?

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$$

$$= 0 + (260 \text{ rad/s})(5 \text{ s}) + \frac{1}{2} (-40 \text{ rad/s}^2)(5 \text{ s})^2$$

$$= \underline{\underline{800 \text{ rad}}}$$

c) What is the moment of inertia of the wheel?

$$I = \frac{1}{2} MR^2 = \frac{1}{2} (0.4 \text{ kg})(0.3 \text{ m})^2 = \underline{\underline{0.018 \text{ kg}\cdot\text{m}^2}}$$

d) Assuming the brakes acted on the rim of the wheel, what is the smallest force they could have exerted during the 5.0 seconds?

$$\tau = I\alpha = (0.018 \text{ kg}\cdot\text{m}^2)(40 \text{ rad/s}^2) = 0.72 \text{ N}\cdot\text{m}$$

$$\tau = RF \Rightarrow F = \frac{\tau}{R} = \frac{0.72 \text{ N}\cdot\text{m}}{0.3 \text{ m}} = \underline{\underline{2.4 \text{ N}}}$$

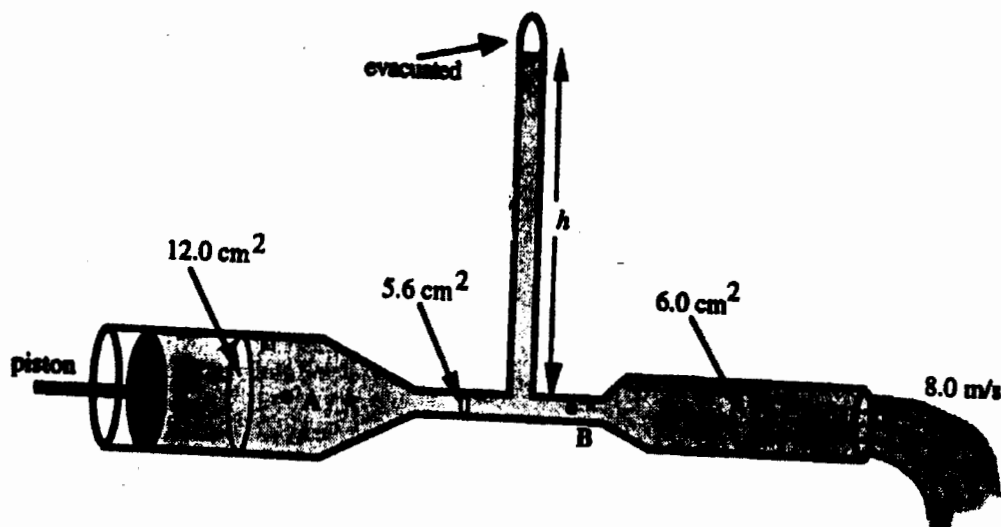
e) What work did the brakes do on the wheel during the 5.0 seconds?

$$W_F = W_{nc} = \Delta E = \frac{1}{2} I \omega^2 - \frac{1}{2} I \omega_0^2$$

$$= \frac{1}{2} (0.018 \text{ kg}\cdot\text{m}^2) \left[(60 \frac{\text{rad}}{\text{s}})^2 - (260 \frac{\text{rad}}{\text{s}})^2 \right]$$

$$= \underline{\underline{-576 \text{ J}}}$$

5. A glass tube has several different cross-sectional areas, as shown in the figure. A piston at the end of the tube exerts pressure so that the mercury sample within the tube flows out of the right-hand end with a speed of 8.0 m/s. Take atmospheric pressure to be $1.0 \times 10^5 \text{ N/m}^2$ and the density of mercury to be $1.4 \times 10^4 \text{ kg/m}^3$. (Assume no fluid friction.)



a) At what speed is the mercury flowing past point B?

$$\text{Continuity: } A_c v_c = A_B v_B$$

$$v_B = \left(\frac{A_c}{A_B} \right) v_c = \left(\frac{6.0 \text{ cm}^2}{5.6 \text{ cm}^2} \right) 8 \frac{\text{m}}{\text{s}}$$

$$= 8.57 \frac{\text{m}}{\text{s}} \text{ or } \underline{\underline{8.6 \frac{\text{m}}{\text{s}}}}$$

b) What is the total pressure at point B?

$$\frac{1}{2} \rho v_B^2 + P_B = \frac{1}{2} \rho v_c^2 + P_c$$

$$P_B = P_{atm} + \frac{1}{2} \rho [v_c^2 - v_B^2] = 101 \text{ kPa} + \frac{1}{2} (1.4 \times 10^4 \text{ kg/m}^3) \cdot \left[\left(8 \frac{\text{m}}{\text{s}} \right)^2 - \left(8.6 \frac{\text{m}}{\text{s}} \right)^2 \right]$$

$$= \underline{\underline{3.1 \times 10^4 \text{ Pa}}}$$

c) Determine the height h of mercury in the vertical tube with the evacuated (zero pressure) closed top.

$$P_B = \rho g h$$

$$h = \frac{P_B}{\rho g} = \frac{3.1 \times 10^4 \text{ Pa}}{(1.4 \times 10^4 \text{ kg/m}^3)(9.8 \text{ N/kg})} = \underline{\underline{0.23 \text{ m}}}$$

d) What force must be applied to the piston to make the fluid flow as shown (ignoring friction)?

$$v_A = \left(\frac{A_c}{A_A} \right) v_c = \left(\frac{6}{12} \right) 8 \frac{\text{m}}{\text{s}} = 4 \frac{\text{m}}{\text{s}}$$

$$P_A = P_c + \frac{1}{2} \rho [v_c^2 - v_A^2] = P_{atm} + \frac{1}{2} (1.4 \times 10^4 \text{ kg/m}^3) \cdot \left[\left(8 \frac{\text{m}}{\text{s}} \right)^2 - \left(4 \frac{\text{m}}{\text{s}} \right)^2 \right]$$

$$= 437 \text{ kPa}$$

$$F_A = P_A A_A = (437 \text{ kPa})(12 \times 10^{-4} \text{ m}^2) = \underline{\underline{524 \text{ N}}}$$

6. A listener stands between two loudspeakers, at a distance of 4.5 m from speaker A and a distance d from speaker B, where $0.5 \text{ m} < d < 4.5 \text{ m}$. Take the speed of sound in air to be 330 m/s.

a) If the listener observes the wavelength of the sound from speaker A to be 3.0 m, what is the frequency of the sound?

$$f\lambda = v_w$$

$$f = \frac{v_w}{\lambda} = \frac{330 \text{ m/s}}{3.0 \text{ m}} = \underline{\underline{110 \text{ Hz}}}$$

b) If speaker A emits a sound power of 5.0 W equally in all directions, what will be the intensity of the sound at the listener's position?

$$I = \frac{P}{4\pi R^2} = \frac{5.0 \text{ W}}{4\pi (4.5 \text{ m})^2} = \underline{\underline{2.0 \times 10^{-2} \text{ W/m}^2}}$$

c) Speaker B is now turned on; it emits the same frequency and phase of sound as speaker A, and it produces the same wave amplitude at the listener's position as does speaker A. If the listener hears no sound when both speakers are on, how far away from him is speaker B?

Sounds from A & B out of phase

Distance must differ by $\frac{\lambda}{2} = 1.5 \text{ m}$

$$\text{Thus } d_B = 4.5 \text{ m} - 1.5 \text{ m} = \underline{\underline{3.0 \text{ m}}}$$

d) What is the minimum length of an organ pipe open at both ends that could produce sound of this frequency?

$$f_1 = \frac{v_w}{2L}$$

$$L = \frac{v_w}{2f_1} = \frac{330 \text{ m/s}}{2(110 \text{ Hz})} = \underline{\underline{1.5 \text{ m}}}$$