

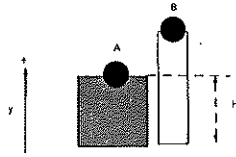
Your Name: _____

PHY203
Final Exam
Chapters 1-11,15
Wed., May 11, 2022

- Show work
- Use correct SI units
- Use scientific notation
- All answers with 3 significant figures
- use $g = 9.81 \text{ m/s}^2$

Solutions

Final1S22



1. Stones are released from two nearby cliffs at different heights. Stone A is dropped at $t=0$ from cliff A at a height of H . Stone B is thrown down with a speed of 12.5 m/s at $t=0$ from cliff B at a height of 35.0 m above cliff A.

a. Using the coordinate system depicted above, write an equation of motion (y vs. t) for stone A: **10**

$$y_A = H - \frac{1}{2} g t^2$$

b. Using the coordinate system depicted above, write an equation of motion (y vs. t) for stone B: **20**

$$y_B = H + 35.0 - 12.5t - \frac{1}{2} g t^2$$

c. Assuming the stones reach the bottom of the cliffs at the same time, find the height, H , of cliff A. **20**

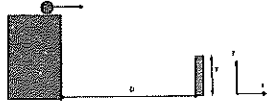
$$\cancel{H - \frac{1}{2} g t^2} = \cancel{H + 35.0 - 12.5t - \frac{1}{2} g t^2}$$

$$12.5t = 35.0$$

$$t = \frac{35.0}{12.5} = 2.80 \text{ s}$$

$$0 = H - \frac{1}{2} g (2.80)^2$$

$$H = 38.5 \text{ m}$$



2. A cannonball is shot from a cliff at a castle wall. The castle wall is $Y = 55.0$ m high and a horizontal distance $D = 205$ m from the cannon. Initially, the ball is shot in a horizontal direction. Assume the ball just grazes the top of the wall on the way down after traveling for 1.75 s

a. Find the initial velocity of the cannonball and write it in vector notation using the coordinate system above. **10**

$$x: \quad 205 = 0 + v_{0x}(1.75) + 0$$

$$v_{0x} = 205 / 1.75 = 117 \text{ m/s}$$

$$\vec{v}_0 = 117 \vec{i} \text{ m/s}$$

b. Find the height of the cliff. **10**

$$55.0 = H + 0 - \frac{1}{2}g(1.75)^2$$

$$H = 70.0 \text{ m}$$

c. Find the velocity of the cannonball in vector notation just as it grazes the top of the wall. **10**

$$y: \quad v_y = 0 - g(1.75) = -17.2 \text{ m/s}$$

$$\vec{v} = (117 \vec{i} - 17.2 \vec{j}) \text{ m/s}$$

$$\left(\text{or } v_y^2 = 0 - 2g(-15) \quad v_y = -17.2 \right)$$

d. Find the velocity of the cannonball in vector notation just before it hits the ground. **20**

$$t: \quad 0 = 70.0 + 0 - \frac{1}{2}g t^2$$

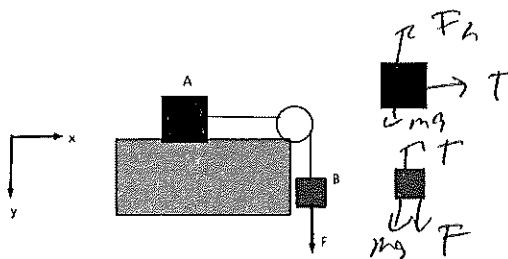
$$t = 3.78 \text{ s}$$

$$v_y = 0 - g(3.78) = -37.1 \text{ m/s}$$

$$\left(\text{or } v_y^2 = 0 - 2g(-70), \quad v_y = -37.1 \text{ m/s} \right)$$

$$\vec{v} = (117 \vec{i} - 37.1 \vec{j}) \text{ m/s}$$

Final2S22



3. Blocks A and B are connected by a light string and attached over a massless pulley and are initially at rest. Assume a frictionless surface under block A and masses m_A and m_B . A vertical force, F , is applied to block B as shown, and the blocks start moving.

a. Draw free body diagrams of the blocks as they are moving on the figures above and to the right. **10**

b. Write out Newton's 2nd Law for both blocks in the x- and y-directions. **30**

$$A: \quad x: \quad T = m_A a \quad (1)$$

$$y: \quad -F_{nA} + m_A g = 0 \quad (2)$$

$$B: \quad y: \quad m_B g + F - T = m_B a \quad (3)$$

Assume that $m_A = 6.50$ kg, $m_B = 8.00$ kg, and $F = 75.0$ N.

c. Find the magnitude of the acceleration of the blocks. **10**

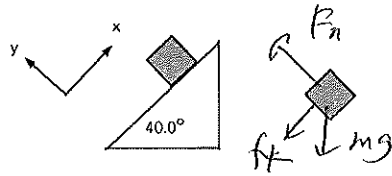
Add (1) + (3) left, right sides

$$\cancel{T} + m_B g + F - \cancel{T} = (m_A + m_B) a$$

$$a = \frac{m_B g + F}{m_A + m_B}$$

$$= \frac{8.00 g + 75.0}{14.5}$$

$$= 10.6 \text{ m/s}^2$$



4. A 5.50-kg block slides up a rough inclined plane that makes an angle of 40.0° with the horizontal. Starting with a speed of 6.50 m/s, the block slides a distance of 2.20 m before coming to rest (momentarily).

a. Draw a free body diagram of the block as it is sliding on the incline on the figure above and to the right. **5**

b. Write out Newton's 2nd Law for the block in the x- and y-directions. **15**

$$x: -mg \sin \theta - \mu_k F_n = ma$$

$$y: F_n - mg \cos \theta = 0$$

c. Using Conservation of Energy, find the coefficient of kinetic friction between block and ramp. **30**

$$\frac{1}{2} m v_0^2 = mgh + f_k \Delta s$$

$$= mgh + \mu_k mg \cos \theta \Delta s$$

$$\frac{v_0^2}{2g} = h + \mu_k \cos \theta \Delta s$$

$$\frac{6.50^2}{2 \cdot 9.8} = \frac{2.20 \sin 40.0^\circ}{\sin 40.0^\circ} + \mu_k \cos 40.0^\circ (2.20)$$

$$= 1.41$$

$$\frac{6.50^2}{2g} = 1.41 + \mu_k \cos 40.0^\circ (2.20)$$

$$0.773 = \mu_k \cos 40.0^\circ (2.20)$$

$$\mu_k = 0.411$$

Final3S22

5. A block of mass 3.25 kg is traveling with a constant speed of 5.50 m/s in the +x-direction on a frictionless table. The block is given an impulse of $\vec{I} = (9.50\hat{i} - 12.0\hat{j}) \text{ N}\cdot\text{s}$.

a. Find the momentum of the block in vector notation after the impulse. 20

$$\vec{p}_i = (3.25)(5.50)\hat{i} = 17.9 \text{ kg}\frac{\text{m}}{\text{s}}\hat{i}$$

$$\begin{aligned}\vec{p}_f &= \vec{p}_i + \vec{I} = 17.9\hat{i} + (9.50\hat{i} - 12.0\hat{j}) \\ &= (27.4\hat{i} - 12.0\hat{j}) \text{ kg}\frac{\text{m}}{\text{s}}\end{aligned}$$

b. The same block after the impulse slides along the table and collides with a block of mass 4.50 kg that was initially at rest. That 4.50 kg block flies off with velocity $(5.50\hat{i} + 8.50\hat{j})\text{m/s}$. Find the velocity of the 3.25 kg block after the collision in vector notation. 30

$$\begin{aligned}\vec{p}_{f, 4.50} &= 4.50(5.50\hat{i} + 8.50\hat{j}) \\ &= (24.7\hat{i} + 38.25\hat{j}) \text{ kg}\frac{\text{m}}{\text{s}}\end{aligned}$$

$$\vec{p}_{f, 3.25} = 3.25(v_x\hat{i} + v_y\hat{j})$$

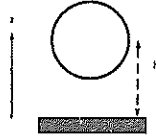
$$x^a \quad 27.4 = 24.7 + 3.25v_x$$

$$v_x = 0.831 \text{ m/s}$$

$$y^a \quad -12.0 = 38.25 + 3.25v_y$$

$$v_y = -15.5 \text{ m/s}$$

$$\vec{v}_{f, 3.25} = (0.831\hat{i} - 15.5\hat{j}) \text{ m/s}$$



6. A hollow sphere has a mass of 3.50 kg and a radius of 2.50 m. The sphere is initially spinning in a clockwise direction as viewed from above with an angular speed of 8.50 rad/s. Initially the sphere is held at a height of $h = 6.50$ (from the center of mass) above a solid disk that is initially at rest. The disk has a radius of 4.00 m and a mass of 5.00 kg and is pinned through its axis. The z-axis is shown above.

a. Find the moment of inertia of the hollow sphere about its axis. **5**

$$I = \frac{2}{3} MR^2 = \frac{2}{3} (3.50) (2.50)^2 = 14.6 \text{ kg m}^2$$

b. Find the moment of inertia of the solid disk about its axis. **5**

$$I = \frac{1}{2} MR^2 = \frac{1}{2} (5.00) (4.00)^2 = 40.0 \text{ kg m}^2$$

c. Find the angular momentum of the sphere in vector notation. **10**

$$L = I \omega = 14.6 (8.50) = 124$$

$$\vec{L} = -124 \text{ kg m}^2/\text{s} \hat{k} \quad \text{by rth hand rule}$$

d. Find the kinetic energy of the sphere. **5**

$$K = \frac{1}{2} I \omega^2 = \frac{1}{2} (14.6) (8.50)^2 = 527 \text{ J}$$

The sphere is released. It drops and hits the disk, sticking to it.

e. Find the angular speed of the sphere-disk system after the collision. **25**

$$124 = (I_{\text{sphere}} + I_{\text{disk}}) \omega$$

$$= (14.6 + 40.0) \omega$$

$$= 54.6 \omega$$

$$\omega = 2.27 \frac{\text{rad}}{\text{s}}$$