

Your Name: _____

PHY203
Final Exam
Chapters 1-11,15
12/17/21

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

Solutions

1. A ball is thrown with an initial speed of 25.0 m/s at $t=0$ straight up from a cliff with a height of 550 m. Take "up" as the +x-direction. Assume the ball just misses the cliff on the way down.

a. Find the acceleration and velocity of the ball (magnitudes and signs) at the highest point and the time it takes to reach the highest point. **15**

$$a = -9.81 \text{ m/s}^2$$

$$v = 0$$

$$t: 0 = 25.0 - g t \quad t = 2.55 \text{ s}$$

~~0.00~~

b. Find the acceleration and velocity of the ball (magnitudes and signs) at $t=8.00$ sec. **15**

$$a = -9.81 \text{ m/s}^2$$

$$v = 25.0 - g(8.00)$$

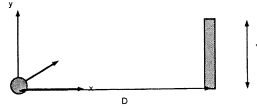
$$= -53.5 \text{ s}$$

c. Find the distance the ball travels between the 8th and 10th seconds the ball is in the air. **20**

$$\begin{aligned} x(8) &= 550 + 25.0(8.00) - \frac{1}{2}g(8.00)^2 \\ &= 436 \text{ m} \end{aligned}$$

$$\begin{aligned} x(10) &= 550 + 25.0(10.0) - \frac{1}{2}g(10.0)^2 \\ &= 310 \text{ m} \end{aligned}$$

$$436 - 310 = 126 \text{ m}$$



2. A cannonball is shot from ground level at a castle wall. The castle wall is $Y = 105$ m high and a horizontal distance $D = 245$ m from the cannon. The initial horizontal component of velocity of the ball is 65.0 m/s in magnitude. Take $y = 0$ at ground level. Assume the ball just grazes the top of the wall.

a. Find the initial velocity of the cannonball and write it in vector notation using the coordinate system above. **20**

$$t: \quad 245 = 65.0t, \quad t = 3.77 \text{ s}$$

$$y: \quad 105 = 0 + v_{y0}(3.77) - \frac{1}{2}g(3.77)^2$$

$$v_{y0} = 46.3 \text{ m/s}$$

$$\vec{v}_0 = (65.0\hat{i} + 46.3\hat{j}) \text{ m/s}$$

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

$$v_y = 46.3 - g(3.77) = 9.36 \text{ m/s}$$

$$\vec{v} = (65.0\hat{i} + 9.36\hat{j}) \text{ m/s}$$

c. Find the velocity, acceleration, and position of the cannonball at its highest point (assuming it just misses the top of the wall) and write them in vector notation. **20**

$$\vec{a} = -9.81\hat{j} \text{ m/s}^2$$

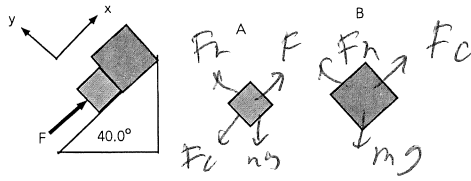
$$\vec{v} = 65.0\hat{i} \text{ m/s}$$

$$t: \quad 0 = 46.3 - gt, \quad t = 4.72 \text{ s}$$

$$x: \quad x = 0 + 65.0(4.72) = 307 \text{ m}$$

$$y: \quad y = 0 + 46.3(4.72) - \frac{1}{2}g(4.72)^2 = 109 \text{ m}$$

$$\vec{r} = (307\hat{i} + 109\hat{j}) \text{ m}$$



3. Blocks A and B are being pushed up a frictionless ramp which makes an angle of 40.0° with respect to the horizontal. A force, F , is applied to block A, parallel to the ramp.

a. Draw free body diagrams on the blocks shown above and on the right. 5

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

$$A: x: F - F_C - m_A g \sin 40^\circ = m_A a$$

$$y: F_{NA} - m_A g \cos 40^\circ = 0$$

$$B: x: F_C - m_B g \sin 40^\circ = m_B a$$

$$y: F_{NB} - m_B g \cos 40^\circ = 0$$

c. Assuming that $M_A = 5.50$ kg, $M_B = 8.50$ kg, and $F = 125$ N, find the magnitude of the acceleration of the blocks and the magnitude of the contact force between the blocks.

15

combine A/x and B/x

$$F - (m_A + m_B) g \sin 40^\circ = (m_A + m_B) a$$

$$a = \frac{125 - (14.0) g \sin 40^\circ}{14.0}$$

$$= 2.62 \text{ m/s}^2$$

$$B: x: F_C = m_B (a + g \sin 40^\circ)$$

$$= 8.50 (2.62 + g \sin 40^\circ)$$

$$= 75.9 \text{ N}$$



4. A block of mass 7.50 kg is sliding on a horizontal surface and has an initial speed of 21.5 m/s. It encounters a rough patch of length, L , which has a coefficient of kinetic friction of 0.250. At the end of that rough patch the speed of the block is 12.5 m/s.
- a. Use Conservation of Energy to find the length of the rough patch. **30**

$$\frac{1}{2} m (21.5)^2 = \frac{1}{2} m (12.5)^2 + \mu_k F_n L$$

$$= \frac{1}{2} m (12.5)^2 + \mu_k m g L$$

$$(21.5^2 - 12.5^2) = 2 \mu_k g L$$

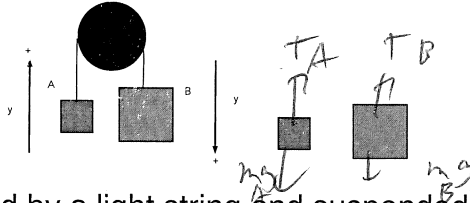
$$L = \frac{(21.5^2 - 12.5^2)}{2 \cdot (0.250) g} = 62.7 \text{ m}$$

The block then slides up a smooth ramp that makes an angle of 55.0° with respect to the horizontal.

- b. Use Conservation of Energy to find the maximum height the block reaches. **20**

$$\frac{1}{2} m v^2 = m g h$$

$$h = \frac{v^2}{2g} = \frac{12.5^2}{2g} = 7.96 \text{ m}$$



5. Blocks A and B are attached by a light string and suspended over a frictionless pulley. The masses of the blocks are M_A and M_B . The mass and radius of the pulley (a solid disk) are M and R . The blocks are then released. Assume $M_B > M_A$

a. Sketch free body diagrams of the blocks as they are moving on the sketch above and to the right. 5

b. Write out Newton's 2nd Law for the blocks using the coordinate systems shown above and write out the torque equation for the pulley. 30

$$A: T_A - m_A g = m_A a$$

$$B: m_B g - T_B = m_B a$$

$$\tau: (T_B - T_A)R = I\alpha = \frac{1}{2}MR^2 \frac{a}{R}$$

Assume that $M_{\text{pulley}} = 2.50$ kg, $R_{\text{pulley}} = 0.750$ m, $M_A = 3.50$ kg, and $M_B = 4.75$ kg.

c. Using forces and torques find the magnitude of the linear acceleration of the blocks.

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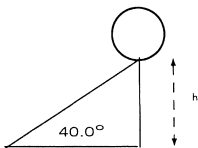
combine:

$$(m_B - m_A)g = (m_A + m_B + \frac{M}{2})a$$

$$a = \frac{(4.75 - 3.50)g}{(3.50 + 4.75 + \frac{2.50}{2})}$$

$$= \frac{1.25g}{9.50}$$

$$= \frac{1.25g}{9.50} = 1.29 \text{ m/s}^2$$



6. A hollow sphere starts from rest at the top of a ramp which has a height of $h = 5.00$ m. The sphere has a mass of 5.00 kg and a radius of 0.600 m.
- a. Find the moment of inertia of the sphere about its center of mass. **10**

$$I = \frac{2}{3} M R^2 = \frac{2}{3} (5.00) (0.600)^2 = 1.20 \text{ kg m}^2$$

- b. If the sphere were to slide down the ramp (assuming the ramp was frictionless), use Conservation of Energy to find the linear speed of the sphere at the bottom of the ramp. **10**

$$mgh = \frac{1}{2} mv^2$$

$$v = \sqrt{2gh}$$

$$= \sqrt{2 \cdot 9.8 \cdot 5.00} = 9.90 \text{ m/s}$$

- c. Now assume the ramp is rough and the sphere rolls without slipping down the ramp. Use Conservation of Energy to find the linear speed of the sphere at the bottom of the ramp. **30**

$$mgh = \frac{1}{2} mv^2 + \frac{1}{2} I \omega^2$$

$$= \frac{1}{2} mv^2 + \frac{1}{2} \frac{2}{3} m r^2 \frac{v^2}{r^2}$$

$$gh = \frac{1}{2} (v^2 + \frac{2}{3} v^2)$$

$$2gh = (1 + \frac{2}{3}) v^2$$

$$v = \left(\frac{2gh}{1.667} \right)^{1/2} = \left(\frac{2 \cdot 9.8 \cdot 5}{1.667} \right)^{1/2}$$

$$= 7.67 \text{ m/s}$$