Your Name: ________________________

PHY203
Final Exam
Wed., 5/5/21

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

Solutions

Final1S21

1. A ball is thrown straight up from a cliff of height 200 m, with an initial speed of 17.5 m/s at t=0. Take "up" as the positive x-direction and x=0 at ground level.

a. Find the velocity, acceleration, and position (magnitude and sign) of the ball at its highest point. (**20**)

$$v = 0$$

$$a = -9.81\ m/s^2$$

x: $0 = (17.5)^2 - 2g\,\Delta x$

$$\Delta x = 15.6$$

$$+200$$

$$x = 216\ m$$

b. Find the time it takes the ball to hit the ground, assuming it just misses the cliff on the way down. (**15**)

$$0 = 200 + 17.5t - \frac{1}{2}g t^2$$

$$4.905t^2 - 17.5t - 200 = 0$$

$$t = \frac{17.5 \pm \sqrt{17.5^2 + 4 \cdot 4.905 \cdot 200}}{9.81}$$

$$= 8.41\ s$$

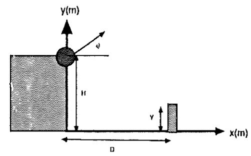
c. Find the distance the ball travels in its last second before hitting the ground. (**15**)

$t = 7.41\ s$

$$x = 200 + 17.5(7.41) - \frac{1}{2}g(7.41)^2$$

$$= 60.1\ m$$

$$\Delta x = 60.1\ m$$



2. A cannonball is shot from a cliff of height H = 65.0 m at a castle wall. The castle wall is Y = 55.0 m high and a horizontal distance D = 205 m from the cannon. Take y = 0 at ground level. Assume the ball just grazes the top of the wall after 3.25 s.

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

x: $205 = 0 + v_{0x}(3.25)$

$v_{0x} = 63.1$ m/s

y: $55.0 = 65.0 + v_{0y}(3.25) - \frac{1}{2}g(3.25)^2$

$v_{0y} = 12.9$ m/s

$\vec{v_0} = (63.1\,\hat{i} + 12.9\,\hat{j})$ m/s

b. Find the position of the cannonball at its highest point and write it in vector notation. (**20**)

y: $0 = 12.9 - gt$, $t = 1.31$ s

$x = 0 + 63.1(1.31) = 83.0$

$y = 65.0 + 12.9(1.31) - \frac{1}{2}g(1.31)^2$

$= 73.4$

$\vec{r} = (83.0\,\hat{i} + 73.4\,\hat{j})$ m/s

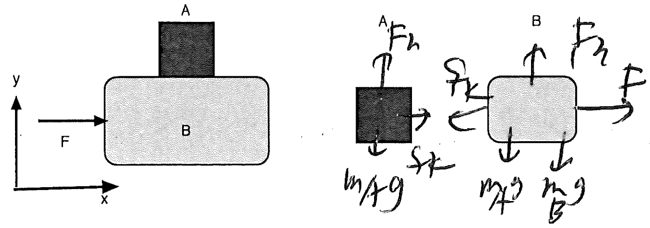
c. Find the velocity of the cannonball in vector notation just before it hits the ground. (**10**)

y: $v_y^2 = (12.9)^2 - 2g(-65.0)$

$v_y = \mp 38.0$

$\vec{v} = (63.1\,\hat{i} - 38.0\,\hat{j})$ m/s

Final2S21



3. Block B is being pushed by a force, F. Assume a frictionless surface under block B. Assume the top surface of block B is rough with coefficient of kinetic friction coefficient μ_k. The masses are M_A and M_B.

a. Draw free body diagrams on the blocks shown above and on the right. (~~**10**~~) 5

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

A: x: $f_k = m_A a_A$

y: $F_{nA} - m_A g = 0$

B: $F - f_k = m_B a_B$

y: $F_{nB} - (m_A + m_B) g = 0$

c. Assuming that M_A = 6.50 kg, M_B = 9.50 kg, F = 75.0 N, and μ_k= 0.350, find the magnitudes of the accelerations of the blocks. (~~**10**~~) 15

$f_k = \mu_k F_{NA} = 0.350(m_A g)$

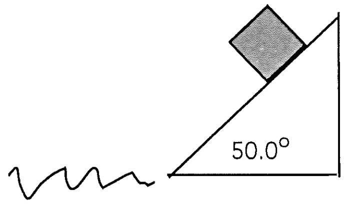
$= 0.350(6.50)g = 22.3\ N$

A: x: $f_k = \mu_k F_{nA} = \mu_k \cancel{m_A} g = \cancel{m_A} a_A$

$a_A = \mu_k g = 3.43\ m/s^2$

B: x: $75.0 - 22.3 = (9.50)\, a_B$

$a_B = 5.55\ m/s^2$



4. A 6.50 kg block is sliding down a frictionless ramp which makes an angle of 50.0° with respect to the horizontal. When the block is at a height of 3.75 m, it has a speed of 12.5 m/s.
a. Use Conservation of Energy to find the speed of the block at the bottom of the ramp. (**25**)

$$\cancel{m} g h_i + \frac{1}{2} \cancel{m} v_0^2 = \frac{1}{2} \cancel{m} v_f^2$$

$$v_f^2 = v_0^2 + 2gh$$

$$= (12.5)^2 + 2g(3.75)$$

$$v_f = 15.2 \text{ m/s}$$

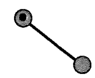
At the bottom of the ramp, the block slides onto a rough surface and eventually comes to rest after sliding an additional 16.5 m.
b. Using Conservation of Energy, find the coefficient of kinetic friction. (**25**)

$$\frac{1}{2} \cancel{m} v^2 = f_k \Delta s = \mu_k F_n \Delta s$$

$$= \mu_k \cancel{m} g \Delta s$$

$$\mu_k = \frac{v^2}{2g \Delta s} = \frac{15.2^2}{2g(16.5)}$$

$$= 0.710$$



5. A barbell consists of a rod of length 2.50 m and mass 1.50 kg and two balls of mass 0.750 kg at the ends of the rod (treat the balls as point masses). The barbell is pinned through one ball and is rotating around the pinned ball on a horizontal, frictionless surface with an angular speed of 15.5 rad/s in a clockwise direction as viewed from above.

a. Find the moment of inertia of the barbell/ball system about the pivot point. (**10**)

$$I = mL^2 + \frac{1}{3} M L^2$$
$$= \left[.750 + \frac{1}{3}(1.50)\right] 2.50^2 = 7.81\ kg\,m^2$$

b. Find the angular momentum of the barbell in vector notation. Assume "up" (out of the paper) is the +z-direction. (**10**)

$$L = I\omega = (7.81)(15.5) = 121$$
$$\vec{L} = -121\ kg\frac{m^2}{s}\hat{k}$$

c. Find the kinetic energy of the rotating barbell. (**5**)

$$K = \frac{1}{2} I\omega^2 = \frac{1}{2}(7.81)(15.5)^2$$
$$= 938\ J$$

A force of 18.0 N is applied to the ball at the end of the barbell in a direction perpendicular to its motion and in the direction in which it is rotating.

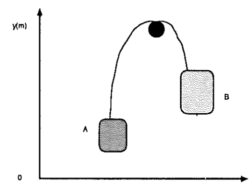
d. Find the magnitude of the torque on the barbell due to the force. (**5**)

$$\tau = rF\sin\theta = (2.50)(18.0) = 45.0\ N\,m$$

e. Find the angular speed of the barbell after the force has been applied for 4.50 s. (**20**)

$$\tau = I\alpha, \quad \alpha = \frac{45.0}{7.81} = 5.76\ \frac{rad}{s^2}$$

$$\omega = 15.5 + 5.76(4.50)$$
$$= 41.4\ \frac{rad}{s}$$



6. Blocks A and B are attached by a light string and suspended over a pulley. The masses and initial positions of the blocks are M_A, h_A, M_B, and h_B. The mass and radius of the pulley (a solid disk) are M and R. The blocks are then released. Assume that M=2.50 kg, R=0.750 m, M_A= 3.50 kg, h_A = 1.50m, M_B =5.25 kg, and h_B=4.50 m.

a. Find the gravitational potential energy of the blocks before they are released. (**10**)

$$U_i = g[m_A h_A + m_B h_B]$$
$$= g[3.50 \cdot 1.50 + 5.25 \cdot 4.50]$$
$$= 283\ J$$

b. Find the gravitational potential energy of the blocks after they have moved 2.50 m. (**10**)

$$U_f = g[3.50 \cdot 4.00 + 5.25 \cdot 2.00]$$
$$= 240\ J$$

c. Using Conservation of Energy, find the speed of the blocks after they have moved 2.50 m. (**30**)

$$283 = 240 + \frac{1}{2}(m_A + m_B)v^2 + \frac{1}{2}I\omega^2$$
$$43 = \frac{1}{2}(8.75)v^2 + \frac{1}{2}\left(\frac{1}{2}M\cancel{R^2}\right)\frac{v^2}{\cancel{R^2}}$$
$$= \frac{1}{2}v^2\left(8.75 + \frac{1}{2} \cdot 2.50\right)$$
$$= \frac{1}{2}v^2(10.0)$$
$$v = 2.93\ m/s$$