Your Name: ________________________

PHY203
Final Exam
Wed., 5/7/14

Part 1

Solutions

1. From the edge of the top of a cliff of height 150 m, a ball is thrown straight up in the air at an initial speed of v_o=25.0 m/s. (Ignore air resistance.)
a. At the highest point the ball reaches, find the magnitude of the acceleration and direction (up, down, or no direction) of the ball.

9.81 m/s^2
down **5**

b. At the highest point the ball reaches, find the magnitude of the velocity and direction (up, down, or no direction) of the ball.

0, no direction **5**

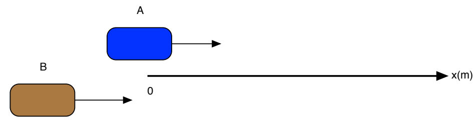
c. To find the time it takes for the ball to reach its highest point, which of the kinematic equations will work best? (Pick A,B, or C.) Briefly explain why.

B : The y component of velocity is 0 at the highest point. Equation B uses this and gives the time.

10

d. Find the time it takes the ball to reach its highest point.

$0 = 25.0\ m/s + (-9.81\ m/s^2)(t)$ **10**
$t = 2.55\ s$



2. Two trains are traveling on parallel tracks. At a time of t=0 train A is at rest and begins to accelerate at 2.50 m/s^2 to the right. At t=2.00 s train B passes the x=0 point traveling to the right with a speed of 15.0 m/s and an acceleration of 3.00 m/s^2.

a. Using the coordinate system depicted above and assuming that the center of train A is at x=0 at t=0, as depicted in the figure write an equation of motion (x vs. t) for train A:

$x_A = 0 + 0 + 1/2(2.50\ m/s^2)(t)^2$ **10**

$= (1.25\ m/s^2)(t)^2$

b. Using the coordinate system depicted above and assuming that the center of train B is at x=0 at t=2.00 s, write an equation of motion (x vs. t) for train B:

$x_B = 0 = 0 + (15.0\ m/s)(t-2.00) + 1/2(3.00\ m/s^2)(t-2)^2$ **10**

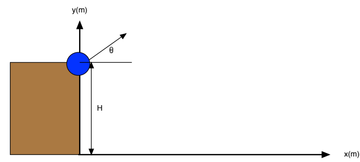
c. Find the time at which the centers of the trains are side-by-side.

$1/2(2.50\ m/s^2)(t)^2 = (15.0\ m/s)(t-2.00) + 1/2(3.00\ m/s^2)(t-2)^2$

10

Solve quadratic eq.

t = 2.49 s



3. A cannon ball is launched from a cliff with an initial speed of 25.0 m/s at an angle of θ=35.0^o with respect to the horizontal direction, as shown above. It hits the ground after 4.50 s (Ignore air resistance.)

a. Write the initial velocity of the ball in vector notation using the coordinate system above.

v_{xo} = (25.0 m/s)(cos35^o**)** **=** 20.5 m/s
v_{yo} = (25.0 m/s)(sin35^o**)** **=** 14.3 m/s **10**

v = (20.5 **i** + 14.3 **j**) m/s

b. Find the horizontal (x) distance the ball lands from the base of the cliff.

x = 0 + (20.5 m/s)(4.50 s) **15**

x = 92.2 m

c. Find the height of the cliff.

$0 = H + (14.3\ \text{m/s})(4.50\ \text{s}) + 1/2(-9.81\ \text{m/s}^2)(4.50\ \text{s})^2$ **15**

H = 35.0 m

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Part 2

Solutions

4. A block with a mass of 2.50 kg is at rest at the origin on a frictionless surface. It is subjected to a pushing force of $\vec{F} = (3.50\hat{i} - 4.00\hat{j})N$

a. Find the acceleration of the block in vector notation.

$$\vec{a} = \frac{\vec{F}}{m} = \frac{(3.50\hat{i} - 4.00\hat{j})}{2.50}$$
$$= (1.40\hat{i} - 1.60\hat{j})m/s^2$$

10

b. Find the velocity of the block in vector notation after the force has been acting on the block for 5.00 s.

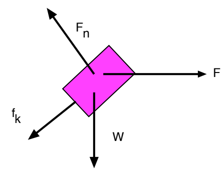
$$\vec{v} = \vec{v}_o + \vec{a}t = 0 + (1.40\hat{i} - 1.60\hat{j})(5.00)$$
$$= (7.00\hat{i} - 8.00\hat{j})m/s$$

10

c. Find the position of the block in vector notation after the force has been acting on the block for 5.00 s.

$$\vec{x} = \vec{x}_o + \vec{v}_o t + \frac{1}{2}\vec{a}t^2 = 0 + 0 + \frac{1}{2}(1.40\hat{i} - 1.60\hat{j})(5.00)^2$$
$$= (17.5\hat{i} - 20.0\hat{j})m$$

10



5. A block with mass 5.00 kg is being pushed with a horizontal force of 150 N such that it slides up the ramp which makes an angle of θ=35° with respect to the horizontal. The coefficients of friction between block and ramp are:
$\mu_s = 0.600 \text{ and } \mu_k = 0.250$.

a. Draw a free-body diagram on the separate block above. **5**

b. Write out Newton's 2nd Law for the block in both directions using the coordinate system in the sketch.

y-direction: $-F_n + mg\cos\theta + F\sin\theta = 0$ **10**

x-direction: $F\cos\theta - mg\sin\theta - \mu_k F_n = ma$ **10**

c. Find the magnitude of the normal force.

$$F_n = mg\cos\theta + F\sin\theta$$
$$= (5.00)(9.81)\cos(35^o) + (150)\sin(35^o)$$
$$= 126N$$

10

d. Find the magnitude of the acceleration of the block.

$$a = \frac{F\cos\theta - mg\sin\theta - \mu_k F_n}{m}$$
$$\frac{150\cos(35^o) - (5.00)(9.81)\sin(35^o) - (0.250)(126)}{5.00}$$
$$= 12.7 m/s^2$$

10

6. A planet XXX has a mass of $9.50x10^{25}$ kg and a radius of $6.00x10^3$ km.

a. Find the acceleration due to gravity on the surface of the planet.

$$a = \frac{GM}{R^2} = \frac{(6.67x10^{-11})(9.50x10^{25})}{(6.00x10^6 m)^2} = 176 m/s^2$$ **15**

b. A person has a mass of 75.0 kg on Earth. Find the mass of the person on the surface of planet XXX.

same = 75.0 kg **5**

c. Find the weight of the person on the surface of planet XXX.

W = mg = (75.0)(176) = $1.32x10^4$ N **5**

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Part 3

Solutions

7. A 7.00 kg block is initially at rest on a horizontal table with the coefficient of kinetic friction between the block and the table of 0.250. At t=0 a rope is attached to the block and to a motor which exerts a pulling force F=55.0 N on the block in the positive x-direction (to the right) and the block starts to slide. Take up as the positive y-direction.

a. Calculate how much work is done by the pulling force after the block has traveled 3.00 m (magnitude and sign).

$$W = F\Delta x = (55.0N)(3.00m) = 165J$$ **5**

b. Calculate the work done by friction as the block is pulled 3.00 m (magnitude and sign).

$$W_f = f_k \Delta s = \mu_k F_n \Delta s$$
$$= (0.250)(7.00kg)(9.81)(3.00m) = -51.5J$$ **10**

c. Using work and energy, find the speed of the block after it has been pulled for 3.00 m.

$$E = \frac{1}{2}mv_f^{\ 2} = W - E_{th}$$
$$\frac{1}{2}(7.00kg)v_f^{\ 2} = 165J - 51.5J$$ **10**
$$v_f = 5.69m/s$$

d. If the pull took 5.00 s, find the power exerted by the motor attached to the rope.

$$P = \frac{W}{t} = \frac{165J}{5.00s} = 33.0W$$ **5**

8. A block of mass 3.50 kg is thrown straight down with an initial speed of 5.50 m/s from the top of a ladder with a height of 2.50 m.

a. Find the gravitational potential energy of the block at the top of the ladder, using the floor at the base of the ladder as y=0.

$$\Delta U = mgh = (3.50kg)(9.81)(2.50m)$$
$$= 85.8J$$

5

b. The block lands on a spring on the ground with uncompressed length of 0.750 m. Using conservation of energy, find the speed of the block just before it hits the top of the spring.

$$E = K_i + U_i = \frac{1}{2}mv_f^{\ 2} + U_f$$
$$v_f^{\ 2} = \frac{2}{m}(K_i + \Delta U) = \frac{2}{3.50kg}(52.9J + 85.8J - 25.7J)$$
$$v_f = 8.03m/s$$

15

d. As the block continues to travel it compresses the spring by a maximum of 0.500 m (down to a compressed length of 0.250 m). Use conservation of energy to find the spring constant of the spring.

$$E = \frac{1}{2}mv^2 + mg(0.750m) = \frac{1}{2}kx^2 + mg(0.750m - x)$$
$$k = \frac{2m}{x^2}(\frac{1}{2}v^2 + gx) = \frac{2(3.50kg)}{(0.500)^2}(\frac{1}{2}(8.04m/s)^2 + g(0.500))$$
$$k = 1.04x10^3 N/m$$

20

9. a. A 3.00 kg block is traveling in the positive x-direction with a speed of 4.50 m/s. Write the momentum of the block in vector notation.

p=(3.00kg)(4.50m/s) = 13.5kgm/s**i** **5**

b. A 5.00 kg block initially at rest is given an impulse of $\vec{I} = (15.0\hat{i} - 25.0\hat{j})Ns$. Find the momentum and velocity of the block after the impulse and write both in vector notation.

$$\vec{p}_f = \Delta\vec{p} = \vec{I} = (15.0\hat{i} - 25.0\hat{j})kgm/s$$

$$\vec{v} = \frac{\vec{p}}{m} = (3.00\hat{i} - 5.00\hat{j})m/s$$

10

d. After the impulse, the 5.00 kg block collides with the 3.00 kg block and they stick together. Find the final velocity of the 2-block combination in vector notation.

$$\vec{p}_i = \vec{p}_f =$$

$$13.5\hat{i}\ kgm/s + (15.0\hat{i} - 25.0\hat{j})kgm/s = (m_1 + m_2)v_f$$

15

$$\vec{v}_f = \frac{(28.5\hat{i} - 25.0\hat{j})kgm/s}{8.00kg} = (3.56\hat{i} - 3.12\hat{j})m/s$$

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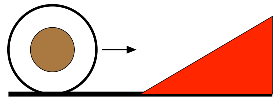
Part 4

Solutions



10. A concentric cylinder is rolling along the ground with a linear speed of 3.50 m/s. The inner cylinder is solid with a mass of 4.00 kg and a radius of 0.500 m. The outer thin cylinder is hollow with a mass of 2.50 kg and a radius of 0.750 m.

a. Find the moment of inertia of the object.

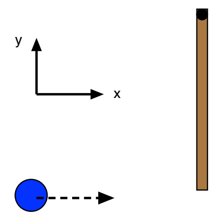
$$I = \frac{1}{2}M_iR_i^{\,2} + M_oR_o^{\,2} = \frac{1}{2}(4.00)(0.500)^2 + (2.50)(0.750)^2 = 1.91\ \text{kgm}^2$$ **10**

b. Find the kinetic energy of the double cylinder.

$$K = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}(6.50)(3.50)^2 + \frac{1}{2}(1.91)\left(\frac{3.50}{0.750}\right)^2 \ \frac{1}{2}I\omega^2$$
$$= 60.6J$$ **10**

c. The object rolls up a ramp inclined at an angle of 40.0° with respect to the horizontal direction. Using Conservation of Energy, find the maximum height the rolling object reaches (<u>measured from the floor to the center of the object</u>) before it starts rolling back down the ramp.

$$K = 60.6 = mgh = (6.50)gh$$
$$h = 0.950m$$
$$0.950 + 0.750 = 1.70m$$ **15**



11. A very small ball of mass 1.25 kg is traveling in the positive x-direction with a speed of 6.00 m/s. It hits a thin rod of mass 5.00 kg and length 3.00 m. The ball sticks to the end of the rod which has an axis through its other end about which it can rotate (but can not translate). Take the positive z-direction as out of the page.

a. Find the angular momentum of the ball before the collision and write it in vector notation.

$L = rp\sin\theta = rmv = (3.00)(1.25)(6.00)$

$= 22.5 kgm/s$ **10**

$\vec{L} = 22.5 kgm/s\ \hat{k}$

b. Find the moment of inertia of the thin rod about its axis.

I = $\frac{1}{3}ML^2 = \frac{1}{3}(5.00)(3.00)^2 = 15.0\ \text{kgm}^2$ **5**

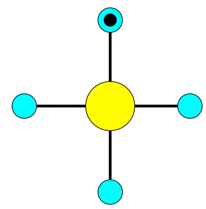
c. Find the moment of inertia of the stuck-together ball/rod combination about the axis of the rod.

I = $15.0 + MR^2 = 15.0 + (1.25)(3.00)^2 = 26.2\ \text{kgm}^2$ **5**

d. Find the angular speed of the ball/rod combination just after the collision.

22.5 = (26.2) ω_f **15**

ω_f = 0.859 rad/s



12. 4 very small balls are attached to a solid disk using thin rods, as shown. The mass of the disk is 4.00 kg; the radius is 0.250 m. The balls are placed a distance of 0.400 m from the center of the disk. The mass of each ball is 0.500 kg. Ignore the mass of the rods.

a. Find the moment of inertia of the system about an axis through the center of the disk and perpendicular to the page.

I = $$\frac{1}{2}M_iR_i^{\,2} + 4M_oR_o^{\,2} = \frac{1}{2}(4.00)(0.250)^2 + 4(0.500)(0.400)^2$$
$$= 0.445 \text{ kgm}^2$$

10

b. A nail is driven through one of the balls, as shown above, and the system is set to small oscillations. Find the moment of inertia about the nail.

I = $$I = I_{CM} + Mh^2 = 0.445 + (6.00)(0.400)^2$$
$$= 1.40 \text{ kgm}^2$$

10

c. Find the period of oscillation of the system.

$$T = 2\pi\sqrt{\frac{I}{MgD}} = 2\pi\sqrt{\frac{1.40}{(6.00)g(0.400)}} =$$
$$= 1.53s$$

10