Your Name: ________________________

PHY203
Final Exam
Mon., 12/16/13

Part 1

Solutions

1. Ball A is dropped from the edge of the top of a cliff of height 250 m. After a delay of 2.00 s, ball B is thrown straight down with some initial speed. (Ignore air resistance.) Take "up" as the positive x-direction with x=0 at the base of the cliff.
a. Find the time at which ball A reaches the bottom of the cliff.

Use kinematic eq. A: **15**

$0 = 250\text{ m} + (0)(t) + 1/2(-9.81\text{ m/s}^2)(t)^2$

$t = 7.14\text{ s}$

b. Find the speed of ball A just before it reaches the bottom of the cliff.

$v_y = 0 + (-9.81\text{ m/s}^2)(7.14\text{ s})$ **10**

speed = +70.0 m/s

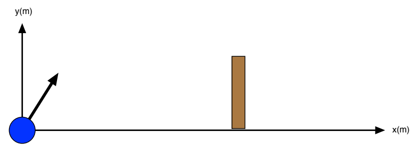
c. Assuming that the two balls reach the bottom of the cliff at the same time, find the initial velocity (magnitude and sign) of ball B.

For ball B:

Use kinematic eq. A: **25**

$0 = 250\text{ m} + (v_B)(5.14\text{ s}) + 1/2(-9.81\text{ m/s}^2)(5.14)^2$

$v_B = -23.4\text{ m/s}$



2. A cannon ball is launched with an *x-component* of initial speed of 22.0 m/s at a 15.0 m high wall that is 55.0 m from the cannon. The ball just grazes the top of the wall *on the way down*. (Ignore air resistance.)

a. Find the time it takes the ball to reach the wall.

Use kinematic eq. A: **15**

55.0 m = 0 + (22.0 m/s)(t) + 0

t = 2.50 s

b. Find the magnitude of the y component of the initial velocity of the ball.

Use kinematic eq. A: **15**

15.0 m = 0+ (v_y)(2.50 s) + 1/2(-9.81 m/s^2)(2.50)^2

v_y = 18.3 m/s

c. Find the y-component of the velocity of the ball when it hits the wall using the above coordinate system.

v_y = 18.3 m/s+ (-9.81 m/s^2)(2.50 s) **15**

v_y = -6.22 m/s

d. Find the magnitude the velocity at that point.

$$v = \sqrt{v_x^{\,2} + v_y^{\,2}} = \sqrt{(22.0m/s)^2 + (-6.22m/s)^2}$$
$$= 22.9m/s$$

5

Alternate

1. Ball A is dropped from the edge of the top of a cliff of height 350 m. After a delay of 3.00 s, ball B is thrown straight down with some initial speed. (Ignore air resistance.) Take "up" as the positive x-direction with x=0 at the base of the cliff.

a. Find the time at which ball A reaches the bottom of the cliff.

Use kinematic eq. A: **15**

$0 = 350\text{ m} + (0)(t) + 1/2(-9.81\text{ m/s}^2)(t)^2$

$t = 8.45\text{ s}$

b. Find the speed of ball A just before it reaches the bottom of the cliff.

$v_y = 0 + (-9.81\text{ m/s}^2)(8.45\text{ s})$ **10**

speed = +82.9 m/s

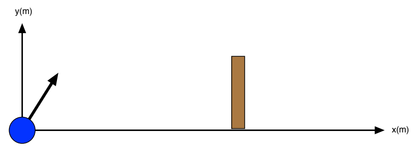
c. Assuming that the two balls reach the bottom of the cliff at the same time, find the initial velocity (magnitude and sign) of ball B.

For ball B:

Use kinematic eq. A: **25**

$0 = 350\text{ m} + (v_B)(5.45\text{ s}) + 1/2(-9.81\text{ m/s}^2)(5.45)^2$

$v_B = -37.5\text{ m/s}$



2. A cannon ball is launched with an *x-component* of initial speed of 20.0 m/s at a 18.0 m high wall that is 65.0 m from the cannon. The ball just grazes the top of the wall *on the way down*. (Ignore air resistance.)
a. Find the time it takes the ball to reach the wall.

Use kinematic eq. A: **15**
65.0 m = 0 + (20.0 m/s)(t) + 0

t = 3.25 s

b. Find the magnitude of the y component of the initial velocity of the ball.

Use kinematic eq. A: **15**
18.0 m = 0+ (v_y)(3.25 s) + 1/2(-9.81 m/s^2)$(3.25)^2$

v_y = 21.5 m/s

c. Find the y-component of the velocity of the ball when it hits the wall using the above coordinate system.

v_y = 21.5 m/s+ (-9.81 m/s^2)(3.25 s) **15**

v_y = -10.4 m/s

d. Find the magnitude the velocity at that point.

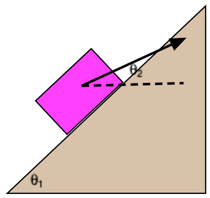
$$v = \sqrt{{v_x}^2 + {v_y}^2} = \sqrt{(20.0 m/s)^2 + (-10.4 m/s)^2}$$
$$= 22.5 m/s$$
5

Your Name: ________________________

PHY203
Final Exam #2
Fri., 5/10/13

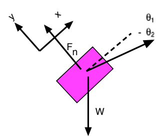
Part 2

Solutions



1. A 3.50 kg block is being pushed up a frictionless ramp by a force of F = 45.0 N.

a. Draw a free-body diagram (sketch and label all the forces on the block). *Include a coordinate system.*



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b. Take $\theta_1 = 50^o$ and $\theta_2 = 30^o$

Write out Newton's 2nd Law for the block for both axes. (*Don't solve the equations yet.*)

y-direction: $F_n - mg\cos\theta_1 - F\sin(\theta_1 - \theta_2) = 0$ **10**

x-direction: $F\cos(\theta_1 - \theta_2) - mg\sin\theta_1 = ma$ **10**

c. Find the magnitude of the acceleration of the block.

$$a = \frac{F\cos(\theta_1 - \theta_2) - mg\sin\theta_1}{m}$$

$$= \frac{(45.0)\cos 20^o - (3.50)(9.81)\sin 50^o}{3.50}$$ **10**

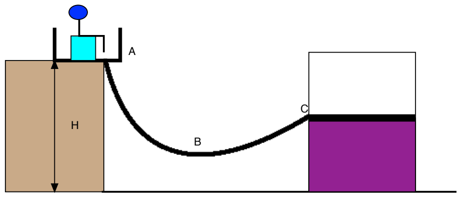
$$= 4.57 m/s^2$$

d. Find the magnitude of the normal force on the block.

$$F_n = mg\cos\theta_1 + F\sin(\theta_1 - \theta_2)$$

$$= (3.5)(9.81)\cos(50^\circ) + (45.0)\sin(20^\circ)$$ **10**

$$= 37.5\,N$$

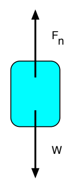


2. A roller coaster is at rest at the top of its track at point A, which is at a height of H_A =150 m. The rollercoaster rolls off the track and descends. The mass of the car is 100 kg; the mass of the rider is 75.0 kg.
a. Find the speed of the rollercoaster at point B, with H_B =60.0 m.

$$E = mgh_A = mgh_{\mathbf{B}} + \frac{1}{2}mv^2$$
$$v^2 = 2g(h_A - h_{\mathbf{B}}) = 2(9.81)(150 - 60.0)$$
$$v = 42.0 m/s$$

10

b. Draw a free-body diagram of a person sitting in the roller coaster when it gets to point B.



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c. Find the magnitude of the force of the chair on the person at point B. Assume at point B that the section of track is part of a circle of radius 35.0 m.

$$F_n - mg = \frac{mv^2}{r}$$
$$F_n = \frac{mv^2}{r} + mg = \frac{(75.0)(42.0)^2}{35.0} + (75.0)(9.81)$$
$$= 4.52x10^3 N$$

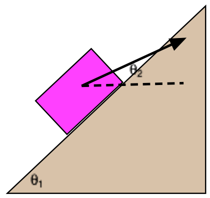
15

d. Find the work that went into friction along the rough section of track from B to C assuming that the speed of the rollercoaster at point C is 25.0 m/s, with H_C =110 m.

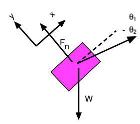
$$E = mgh_A = mgh_C + \frac{1}{2}mv^2 + W_f$$
$$W_f = mg(h_A - h_C) - \frac{1}{2}mv^2$$
$$= (175)(9.81)(150 - 110) - \frac{1}{2}(175)(25.0)^2$$
$$= 1.40x10^4 J$$

20

Alternate



1. A 4.50 kg block is being pushed up a frictionless ramp by a force of F = 55.0 N.
 a. Draw a free-body diagram (sketch and label all the forces on the block). *Include a coordinate system*.



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b. Take $\theta_1 = 50^o$ and $\theta_2 = 30^o$
Write out Newton's 2nd Law for the block for both axes. (*Don't solve the equations yet.*)

y-direction: $F_n - mg\cos\theta_1 - F\sin(\theta_1 - \theta_2) = 0$ **10**

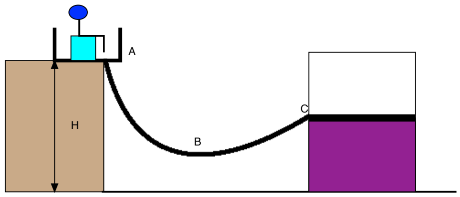
x-direction: $F\cos(\theta_1 - \theta_2) - mg\sin\theta_1 = ma$ **10**

c. Find the magnitude of the acceleration of the block.

$$a = \frac{F\cos(\theta_1 - \theta_2) - mg\sin\theta_1}{m}$$
$$= \frac{(55.0)\cos 20^o - (4.50)(9.81)\sin 50^o}{4.50}$$ **10**
$$= 3.97 m/s^2$$

d. Find the magnitude of the normal force on the block.

$$F_n = mg\cos\theta_1 + F\sin(\theta_1 - \theta_2)$$
$$= (4.5)(9.81)\cos(50^\circ) + (55.0)\sin(20^\circ)$$ **10**
$$= 47.2\,N$$



2. A roller coaster is at rest at the top of its track at point A, which is at a height of H_A =200 m. The rollercoaster rolls off the track and descends. The mass of the car is 100 kg; the mass of the rider is 75.0 kg.

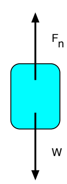
a. Find the speed of the rollercoaster at point B, with H_B =80.0 m.

$$E = mgh_A = mgh_{\mathbf{B}} + \frac{1}{2}mv^2$$

$$v^2 = 2g(h_A - h_{\mathbf{B}}) = 2(9.81)(200 - 80.0)$$ **10**

$$v = 48.5 m/s$$

b. Draw a free-body diagram of a person sitting in the roller coaster when it gets to point B.



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c. Find the magnitude of the force of the chair on the person at point B. Assume at point B that the section of track is part of a circle of radius 45.0 m.

$$F_n - mg = \frac{mv^2}{r}$$

$$F_n = \frac{mv^2}{r} + mg = \frac{(75.0)(48.5)^2}{45.0} + (75.0)(9.81)$$ **15**

$$= 4.66x10^3 N$$

d. Find the work that went into friction along the rough section of track from B to C assuming that the speed of the rollercoaster at point C is 25.0 m/s, with H_C =140 m.

$$E = mgh_A = mgh_C + \frac{1}{2}mv^2 + W_f$$

$$W_f = mg(h_A - h_C) - \frac{1}{2}mv^2$$ **20**

$$= (175)(9.81)(200 - 140) - \frac{1}{2}(175)(25.0)^2$$

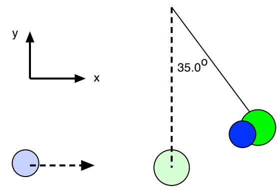
$$= 4.83x10^4 J$$

Your Name: ________________________

PHY203
Final Exam #3
Fri., 5/10/13

Part 3

Solutions



1. A 2.50 kg ball traveling in the positive x-direction collides with and sticks to a 3.50 kg ball that is suspended from a string of length 0.750 m. The balls stick together and swing up to a maximum angle of 35.0°, as shown above.

a. Find the maximum change in height of the 2-ball combination.

$h = L(1-\cos\theta) = (0.750m)(1-\cos 35^0) = 0.136m$ **10**

b. Using conservation of energy, find the speed of the 2-ball combination just after the collision.

$$K_i = mgh$$
$$\frac{1}{2}m(v)^2 = mgh$$ **15**
$$v = \sqrt{2gh} = \sqrt{2g(0.136m)} = 1.63m/s$$

c. Find the momentum of the 2-ball combination just after the collision and write it in vector notation.

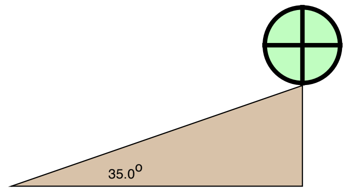
p=(6.00)(1.63) = 9.80kgm/s**i** **10**

d. Find the momentum of the 2.50 kg ball just before the collision and write it in vector notation.

same = 9.80kgm/s**i** **5**

e. Find the speed of the 2.50 kg ball just before the collision.

$$9.80kgm/s = (2.50kg)v$$
$$v = 3.92m/s$$ **10**



2. A wheel which is a rim of mass 1.50 kg and radius 0.650 with 4 spokes of mass 0.500 kg is being held at the top of a ramp which has a length of 2.50 m and an angle of 35°.

a. Find the moment of inertia of the wheel about its axis.

$$I = (1.50kg)(0.650m)^2 + 4(\frac{1}{3}(0.500kg)(0.650m)^2 = 0.915kgm^2$$ **10**

b. Find the change in potential energy of the wheel from the top of the ramp to the floor level.

$$\Delta U = mgh = (3.50)(9.81)(2.50)\sin(35^o) = 49.2J$$ **10**

c. Use conservation of energy to find the speed of the wheel at the bottom of the ramp.

$$\Delta U = 49.2J = K_f$$

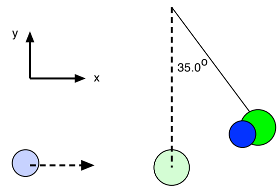
$$49.2J = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 + \frac{1}{2}I(\frac{v}{r})^2$$

$$= \frac{1}{2}v^2(m + I(\frac{1}{r})^2) = \frac{1}{2}v^2(3.50 + (0.916)(\frac{1}{0.650})^2)$$

$$v = 4.17m/s$$

30

Alternate



1. A 3.50 kg ball traveling in the positive x-direction collides with and sticks to a 4.50 kg ball that is suspended from a string of length 0.850 m. The balls stick together and swing up to a maximum angle of 35.0°, as shown above.

a. Find the maximum change in height of the 2-ball combination.

$h = L(1-\cos\theta) = (0.850m)(1-\cos 35^0) = 0.154m$ **10**

b. Using conservation of energy, find the speed of the 2-ball combination just after the collision.

$$K_i = mgh$$
$$\frac{1}{2}m(v)^2 = mgh$$
$$v = \sqrt{2gh} = \sqrt{2g(0.154m)} = 1.74m/s$$

15

c. Find the momentum of the 2-ball combination just after the collision and write it in vector notation.

p=(8.00)(1.74) = 13.9kgm/s**i** **10**

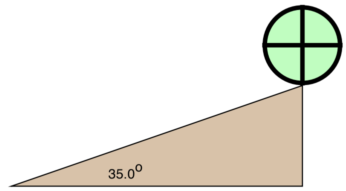
d. Find the momentum of the 2.50 kg ball just before the collision and write it in vector notation.

same = 13.9kgm/s**i** **5**

e. Find the speed of the 2.50 kg ball just before the collision.

$$13.9kgm/s = (3.50kg)v$$
$$v = 3.97m/s$$

10



2. A wheel which is a rim of mass 2.50 kg and radius 0.750 with 4 spokes of mass 0.750 kg is being held at the top of a ramp which has a length of 3.50 m and an angle of 35°.

a. Find the moment of inertia of the wheel about its axis.

$I = (2.50kg)(0.750m)^2 + 4(\frac{1}{3}(0.750kg)(0.750m)^2 = 1.97kgm^2$ **10**

b. Find the change in potential energy of the wheel from the top of the ramp to the floor level.

$\Delta U = mgh = (5.50)(9.81)(3.50)(\sin(35^o) = 108J$ **10**

c. Use conservation of energy to find the speed of the wheel at the bottom of the ramp.

$$\Delta U = 108J = K_f$$
$$108J = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 + \frac{1}{2}I(\frac{v}{r})^2$$
$$= \frac{1}{2}v^2(m + I(\frac{1}{r})^2) = \frac{1}{2}v^2(5.5 + (1.97)(\frac{1}{0.750})^2)$$
$$v = 4.90m/s$$

30

Your Name: __________________________

PHY203
Final Exam #4
Fri., 5/10/13

Part 4

Solutions

1. A planet has a mass of 3.50x10^{26} kg and a radius of 2.00x10^{3} km.
a. Find the magnitude of the force of gravity on a 550 kg satellite at a height of 1.5x10^{3} km above the planet's surface.

$$F = \frac{GmM}{R^2} = \frac{(6.67x10^{-11})(550)(3.50x10^{26})}{(3.50x10^{6}m)^2} = 1.05x10^{6}N$$

10

b. Find the speed of a 550 kg satellite in orbit at that height.

$$F_c = \frac{m\text{v}^2}{r}$$
$$v = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{(1.05x10^{6})(3.50x10^{6}m)}{550}} = 8.17x10^{4}m/s$$

10

c. Find the period of the orbit.

$$T = \frac{2\pi r}{v} = \frac{2\pi(3.50x10^{6}m)}{8.17x10^{4}} = 269s$$

10

d. If the 550 kg satellite falls out of this orbit, find the speed of the satellite when it hits the surface of the planet assuming it started from rest.

$$-\frac{mGM}{R+h} = +\frac{1}{2}mv^2 - \frac{mGM}{R}$$
$$v^2 = \frac{2GM}{R}[1-\frac{1}{1+h/R}]$$
$$= \frac{2(6.67x10^{-11})(3.50x10^{26})}{(2.00x10^{6}m)}[1-\frac{1}{1+(1.50)/(2.00)}]$$
$$v = 1.00x10^{5}m/s$$

20

2. A block is attached to a spring with spring constant 500 N/m. The block is stretched and released. The equation of motion of the block is as follows (with x in meters):

x(t) = (0.550)cos(7.50t)

a. Find the period of the system.

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{7.50} = 0.838s$$ **5**

b. Find the mass of the block.

$$\omega = \sqrt{\frac{k}{m}}$$

10

$$m = \frac{k}{\omega^2} = \frac{500}{(7.50)^2} = 8.89kg$$

c. Find the total energy of the system.

$$E = \frac{1}{2}kA^2 = \frac{1}{2}(500)(0.550)^2 = 75.6J$$ **5**

d. Find the first time at which the block is at a position of x = 0.350 m.

0.350 = (0.550)cos(7.50t) **15**

t = 0.117 s

e. Find (and show work) in what direction the block is traveling at that time.

$$v = \frac{dx}{dt} = -\omega A\sin(\omega t)$$

$$v(0.117) = \frac{dx}{dt} = -(7.50)(0.550)\sin(7.50x0.117)$$ **15**

$$= -3.17m/s$$

so negative x-direction

Alternate

1. A planet has a mass of 4.50x10^{26} kg and a radius of 3.00x10^{3} km.

a. Find the magnitude of the force of gravity on a 650 kg satellite at a height of 2.5x10^{3} km above the planet's surface.

$$F = \frac{GmM}{R^2} = \frac{(6.67x10^{-11})(650)(4.50x10^{26})}{(5.50x10^{6}m)^2} = 6.45x10^{5}N$$ **10**

b. Find the speed of a 650 kg satellite in orbit at that height.

$$F_c = \frac{m\text{v}^2}{r}$$
$$v = \sqrt{\frac{F_c r}{m}} = \sqrt{\frac{(6.45x10^{5})(5.50x10^{6}m)}{650}} = 7.39x10^{4}m/s$$ **10**

c. Find the period of the orbit.

$$T = \frac{2\pi r}{v} = \frac{2\pi(5.50x10^{6}m)}{7.39x10^{4}} = 468s$$ **10**

d. If the 550 kg satellite falls out of this orbit, find the speed of the satellite when it hits the surface of the planet assuming it started from rest.

$$-\frac{mGM}{R+h} = +\frac{1}{2}mv^2 - \frac{mGM}{R}$$
$$v^2 = \frac{2GM}{R}[1 - \frac{1}{1+h/R}]$$
$$= \frac{2(6.67x10^{-11})(4.50x10^{26})}{(3.00x10^{6}m)}[1 - \frac{1}{1+(2.50)/(3.00)}]$$
$$v = 9.54x10^{4}m/s$$ **20**

2. A block is attached to a spring with spring constant 600 N/m. The block is stretched and released. The equation of motion of the block is as follows (with x in meters):

x(t) = (0.650)cos(5.50t)

a. Find the period of the system.

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{5.50} = 1.14s$$ **5**

b. Find the mass of the block.

$$\omega = \sqrt{\frac{k}{m}}$$
$$m = \frac{k}{\omega^2} = \frac{600}{(5.50)^2} = 19.8kg$$ **10**

c. Find the total energy of the system.

$$E = \frac{1}{2}kA^2 = \frac{1}{2}(600)(0.650)^2 = 127J$$ **5**

d. Find the first time at which the block is at a position of x = 0.250 m.

0.250 = (0.650)cos(5.50t) **15**

t = 0.213 s

e. Find (and show work) in what direction the block is traveling at that time.

$$v = \frac{dx}{dt} = -\omega A\sin(\omega t)$$
$$v(0.213) = \frac{dx}{dt} = -(5.50)(0.650)\sin(5.50x0.213)$$ **15**
$$= -3.30m/s$$

so negative x-direction