Your Name: ________________________

PHY203
Final Exam
12/15/14

Part 1

Solutions

1. Identical rocks are dropped from the top of a cliff of height 100 m. Find the time, t, at which the rocks are side-by-side.
a. Case1: Rock a is dropped at t = 0; rock b is dropped at t = 2.00 s.
t = 2.00 s.

Never or:

100 m= 0 + 0 + 1/2(9.81 m/s^2)(t)^2 **10**
t = 4.52 s

4.52 s + 2 s = 6.52 s

b. Case 2: Rock a is dropped at t = 0; rock b is thrown straight down at t = 2.00 s with an initial speed of 40.0 m/s.

x_A= 0 + 0 + 1/2(9.81 m/s^2)(t)^2 **10**

x_B = 0 + (40.0 m/s)(t-2) + 1/2(9.81 m/s^2)(t-2)^2 **10**

1/2(9.81 m/s^2)(t)^2 = (40.0 m/s)(t-2) + 1/2(9.81 m/s^2)(t-2)^2

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t = 2.96 s

c. For Case 2, find the distance below the top of the cliff at which the rocks are side-by-side.

x = 1/2(9.81 m/s^2)(2.96)^2 **10**
= 43.0 m

2. A hockey player launches a slap shot at the net from 15.0 m away at an angle with the horizontal of 15^o and with an initial speed of 27.5 m/s. The height of the net is 1.22 m. (Take "up" as the positive y-direction.)

a. Find and write the initial velocity, $\mathbf{v}_i$, of the puck in vector form.

v_{xo} = (27.5 m/s)(cos15^o**)** **=** 26.6 m/s
v_{yo} = (27.5 m/s)(sin15^o**)** **=** 7.12 m/s

v = (26.6 **i** + 7.12 **j** **)**m/s **10**

b. Find the time that it will take for the puck to reach the net.

15.0 m = 0 + (26.6 m/s)(t) **10**

t = 0.564 s

c. Determine whether the puck will enter the net or not-explain briefly why or why not.

at the net, find y:

$$y = 0 + (7.12)(0.564) + \frac{1}{2}(-9.81)(0.564)^2$$
$$= 2.46m$$
15

y is greater than the net height so the puck does not enter the net.

d. If the net *were not in place*, calculate the highest point the puck would reach.

$$0 = (7.12)^2 + 2(-9.81)(\Delta y)$$
$$\Delta y = 2.58m$$
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e. Find and write the velocity of the puck at its highest point in vector form.

v = (26.6 **i** + 0 **)**m/s **5**

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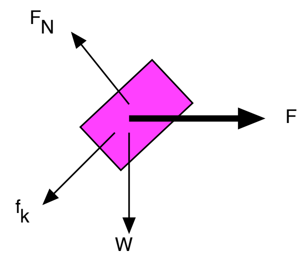
Part 2

Solutions



3. A block with mass m is being pushed with a horizontal force F up a ramp which makes an angle of θ with respect to the horizontal. The coefficient of kinetic friction between block and ramp is μ_k.
a. Draw a free-body diagram on the separate block (to the right) above. Make it clear in what directions forces are pointing.

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

x-direction: $F\cos\theta - \mathrm{mg}\sin\theta - f_k = \mathrm{ma}$ **10**

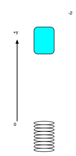
y-direction: $-\mathrm{F_n} + \mathrm{mg}\cos\theta + F\sin\theta = 0$ **10**

Assume these values: m = 5.00 kg, θ=35°, F=75.0 N, and μ_k = 0.250.
c. Find the magnitude of the normal force.

$$\mathrm{F_n} = \mathrm{mg}\cos\theta + F\sin\theta$$
$$= (5.00)(9.81)\cos(35^\circ) + (75.0)\sin(35^\circ)$$ **10**
$$= 83.2\,\mathrm{N}$$

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

$$\mathrm{a} = \frac{F\cos\theta - \mathrm{mg}\sin\theta - \mu_k F_n}{\mathrm{m}}$$
$$= \frac{(75.0)\cos 35^o - (5.00)(9.81)\sin 35^o - (0.250)(83.2)}{5.00}$$ **10**
$$= 2.50 m/s^2$$



4. A 1.50 kg block is initially held at rest at a position of y=5.50 m above the top of a spring (at y=0) with spring constant 0.500 kN/m

a. Now the block is released. Use <u>energy conservation</u> to find the speed of the block when it is at a position of y=1.00 m.

$$E = mgy_o = mgy + \frac{1}{2}mv^2$$

$$v^2 = \frac{2mg(y_o - y)}{m} = \frac{2(1.50)(9.81)(5.50-1.00)}{1.50}$$ **10**

$$v = 9.40 m/s$$

b. Find the lowest point the block reaches (give the y-coordinate; ignore the size of the block).

$$E = mgy_o = mgy + \frac{1}{2}ky^2$$

$$0 = -mgy_0 + mgy + \frac{1}{2}ky^2$$

$$0 = -(1.50)g(5.50) + (1.50)gy + \frac{1}{2}(500)y^2$$ **20**

$$\textit{solve equadratic equation}:$$

$$y = -0.599m$$

c. Find the speed of the block after it has compressed the spring and later is at a position of y = -0.250 m.

$$E = mgy_o = mgy_o + \frac{1}{2}kx^2 + \frac{1}{2}mv^2$$

$$v^2 = \frac{2mg(y_o - y) - kx^2}{m} = \frac{2(1.50)(9.81)(5.75) - (500)(-0.250)^2}{1.50}$$ **20**

$$v = 9.59 m/s$$

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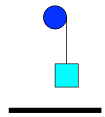
Part 3

Solutions



5. A block with mass 4.00 kg is suspended from a light string that is wrapped around a pulley, as shown. The pulley is a solid disk of mass 5.50 kg and radius 0.850 m. Initially the center of mass of the block is held at a height of 2.50 m above the floor.

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

$$I = \frac{1}{2}(5.50kg)(0.850m)^2 = 1.99kgm^2$$ **10**

b. Use <u>conservation of energy</u> to find the speed of the block just before it hits the floor.

$$(4.00kg)g(2.50m) = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}mv^2 + \frac{1}{2}I(\frac{v}{r})^2$$

$$= \frac{1}{2}v^2(4.00kg + \frac{(1.99kgm^2)}{(0.850m)^2})$$ **20**

$$v = 5.39m/s$$

c. Using <u>forces and torque</u>, find the acceleration of the block while the block is moving.

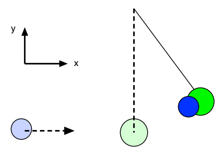
$$block: -T + mg = ma$$

$$pulley: TR = I\alpha = I\frac{a}{R} = \frac{1}{2}MR^2\frac{a}{R}$$

$$Combine: mg = a(m + \frac{1}{2}M)$$ **20**

$$(4.00)g = a(4.00 + \frac{1}{2}5.50)$$

$$a = 5.81m/s^2$$



6. A 3.50 kg ball traveling in the positive x-direction with a speed of 4.00 m/s collides with and sticks to a 4.50 kg ball that is suspended from a string of length 0.750 m. The balls stick together and swing up. (The z-axis is positive out of the paper.)

a. Find the momentum of the 3.50 kg ball before the collision and write it in vector notation.

p=(3.50kg)(4.00m/s) = 14.0kgm/s**i** **10**

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

$$\vec{p}_i = \vec{p}_f = 14.0$$
$$14.0 = (m_1 + m_2)v$$
$$v = \frac{14.0}{8.00kg} = 1.75m/s$$
$$\vec{v} = 1.75m/s\hat{i}$$

10

Same problem but the string is replaced by a rod with mass 3.00 kg (the 4.50 kg ball is now stuck to the end of the rod).

c. Find the angular momentum of the 3.50 kg ball about the rod's pivot point just before the collision and write it in vector notation.

$$\vec{L} = \vec{r}x\vec{p} = (0.750m)(14.0kgm/s)\hat{k} = 10.5kgm^2\hat{k}$$ **10**

d. Find the moment of inertia of the 2-ball-rod system just after the collision.

$$I = [(3.50kg) + (4.50kg)](0.750m)^2 + \frac{1}{3}(3.00kg)(0.750m)^2 = 5.06kgm^2$$ **10**

e. Find the angular speed of the 2-ball-rod system just after the collision.

$$\vec{L}_i = \vec{L}_f = 10.5$$
$$10.5 = I\omega$$
$$\omega = \frac{10.5}{5.06} = 2.07rad/s$$

10

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Part 4

Solutions

7. A planet 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.

$$g = \frac{GM}{R^2} = \frac{(6.67x10^{-11})(9.50x10^{25})}{(6.00x10^{6}m)^2} = 176m/s^2$$ **10**

b. Find the escape speed of a 750 kg rocket launched <u>from a height of 3.50 km</u> above the planet's surface. **15**

$$\frac{1}{2}mv_e{}^2 - \frac{mGM}{R} = 0$$

$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2(6.67x10^{-11})(9.50x10^{25})}{(3.50x10^{3} + 6.00x10^{6}m)}} =$$

$$4.59x10^{4}m/s$$ **15**

A 750 kg shuttle falls back to the surface <u>from a height of 3.50 km</u> above the planet's surface.

c. Find the initial acceleration of the shuttle assuming it started from rest.

$$a = \frac{GM}{d^2} = \frac{(6.67x10^{-11})(9.50x10^{25})}{(6.0035x10^{6}m)^2} = 176m/s^2$$ **10**

d. Find the speed of the shuttle just before it hits the surface of the planet.

$$-\frac{mGM}{R+h} = \frac{1}{2}mv^2 - \frac{mGM}{R}$$

$$-2\frac{GM}{R+h} = v^2 - 2\frac{GM}{R}$$ **15**

$$v = 1.11x10^{4}m/s$$

8. A block of mass 0.750 kg is attached to a spring. The block is stretched and released and oscillates between the positions x= 0.450 m (at t=0) and x=-0.450 m with a period of 1.25 s.

a. Write the equation of motion (position vs. time) of the system.

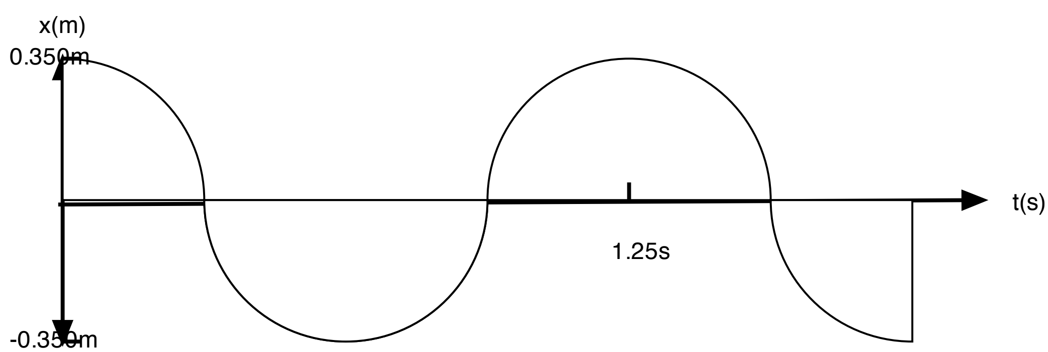
$$f = \frac{1}{T} = \frac{1}{3.00} = 0.333Hz$$

$$\omega = 2\pi f = \frac{2\pi}{T} = \frac{2\pi}{1.25} = 5.03rad/s$$

15

$$x = (0.450m)\cos(5.03t)$$

b. Sketch the position vs. time for the block below. Be sure to include values at key points in the sketch. **15**



c. Find the velocity (magnitude and sign) the first time the block is at x = -0.350m.

$$-0.350 = A\cos(\omega t) = 0.450\cos(5.03t)$$

$$5.03t = \cos^{-1}(-0.350/0.450) = 2.46; t = 0.489s$$

$$v = \frac{dx}{dt} = -\omega A\sin(\omega t) = -(5.03)(0.450)\sin[(5.03)(0.489)]$$

$$= -1.43m/s$$

20