Name____________________________

Nov. 2, 2007

Phys 2010, NSCC
Exam #2 — Fall 2007

1.	________________	(8)
2.	________________	(12)
3.	________________	(10)
4.	________________	(16)
5.	________________	(16)
6.	________________	(11)
7.	________________	(6)
8.	________________	(7)
9.	________________	(6)
MC	________________	(10)
Total	________________	(102)

Multiple Choice

Choose the best answer from among the four! (2) each.

1. The units of power are

a) $\mathrm{J} \cdot \mathrm{s}$

$\boxed{\textbf{b)}}$ $\frac{\mathrm{J}}{\mathrm{s}}$

c) $\mathrm{J} \cdot \mathrm{m}$

d) $\frac{\mathrm{J}}{\mathrm{m}}$

2. A mass is attached to the end of a string and whirled in a vertical circle. At the bottom of the swing,

$\boxed{\textbf{a)}}$ The force from the string is upward and the net force is upward.

b) The force from the string is upward and the net force is downward.

c) The force from the string is downward and the net force is upward.

d) The force from the string is downward and the net force is downward.

3. Object B has half the mass and half the speed of object A. In comparison, the kinetic energy of B is

a) The same.

b) $\frac{1}{2}$ as large.

c) $\frac{1}{4}$ as large.

$\boxed{\textbf{d)}}$ $\frac{1}{8}$ as large.

4. The momentum of a system will be conserved if

a) One of the objects is initially at rest.

$\boxed{\textbf{b)}}$ There is no net external force on the objects.

c) The forces between the object don't involve friction–type forces.

d) There are no forces of any kind between the objects.

5. The units of momentum can also be written as

a) $\frac{\mathrm{N}}{\mathrm{m}}$

b) $\mathrm{N} \cdot \mathrm{m}$

c) $\frac{\mathrm{N}}{\mathrm{s}}$

$\boxed{\textbf{d)}}$ $\mathrm{N} \cdot \mathrm{s}$

Problems

Show your work and include the correct units with your answers!

1. The value of g on the surface of the planet Mercury is $3.70\frac{\mathrm{m}}{\mathrm{s}^2}$. The radius of Mercury is 2440 km.

Find the mass of the planet Mercury. Express the result as a multiple (or fraction) of the mass of the earth, which is 5.98×10^{24} kg. (8)

Use formula for acceleration of gravity on planet surface,

$$g = G\frac{M}{R^2} \qquad \Longrightarrow \qquad M = \frac{gR^2}{G}$$

The radius of Mercury is 2.44×10^6 m, so

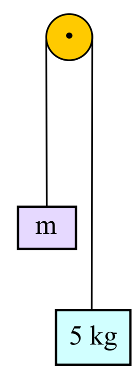
$$M = \frac{(3.70)(2.44 \times 10^6)^2}{(6.67 \times 10^{-11})}\ \mathrm{kg} = 3.30 \times 10^{23}\ \mathrm{kg}$$

In comparison to the mass of the Earth, this is

$$\mathrm{Ratio} = \frac{3.30 \times 10^{23}}{5.98 \times 10^{24}} = 0.055$$

2. The acceleration of the masses in an "Attwood machine" (shown at the right) is measured, with the larger mass being 5.00 kg and the smaller one m. (Masses are joined by a perfect string running over a perfect pulley, they are released and move vertically.)

It is found that the 5.00 kg mass accelerates downward at $4.00\frac{\mathrm{m}}{\mathrm{s}^2}$.



a) What is the tension in the string? (Force diagrams may help!) (6)

Forces on the 5.00 kg mass are mg downward and the tension T upward. It accelerates at $4.00\frac{\mathrm{m}}{\mathrm{s}^2}$ downward, so N's 2nd law gives (summing downward forces)

$$(5.00\ \mathrm{kg})(9.8\tfrac{\mathrm{m}}{\mathrm{s}^2}) - T = ma = (5.00\ \mathrm{kg})(4.00\tfrac{\mathrm{m}}{\mathrm{s}^2})$$

Solve for T. Get:

$$T = (5.00\ \mathrm{kg})(9.8\tfrac{\mathrm{m}}{\mathrm{s}^2}) - (5.00\ \mathrm{kg})(4.00\tfrac{\mathrm{m}}{\mathrm{s}^2}) = 29\ \mathrm{N}$$

b) What is the value of the smaller mass m? (6)

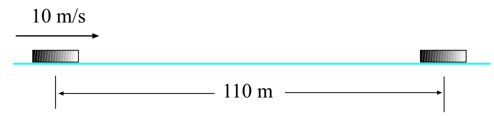
The smaller mass accelerates upward at $a = 4.00\frac{\mathrm{m}}{\mathrm{s}^2}$ and the forces on it are tension T upward and gravity mg downward. N's second law gives:

$$T - mg = ma \qquad \Longrightarrow \qquad T = mg + ma = m(g+a) \qquad \Longrightarrow \qquad m = \frac{T}{(g+a)}$$

Using the answer from (a), this gives

$$m = \frac{(29\ \mathrm{N})}{(9.8\frac{\mathrm{m}}{\mathrm{s}^2} + 4.0\frac{\mathrm{m}}{\mathrm{s}^2})} = 2.10\ \mathrm{kg}$$

3. A hockey puck slides over a large horizontal patch of slightly rough ice. It starts with a speed of $10.0\frac{\mathrm{m}}{\mathrm{s}}$ and slides a distance of 110 m before coming to rest.



a) What was the magnitude of the acceleration of the hockey puck? (5)

Use $v^2 = v_0^2 + 2ax$, solve for a:

$$a_x = \frac{v^2 - v_0^2}{2x} = \frac{0 - (10.0\frac{\mathrm{m}}{\mathrm{s}})^2}{2(110\ \mathrm{m})} = -0.454\frac{\mathrm{m}}{\mathrm{s}^2}$$

The answer is negative, as it should be! So the magnitude of a_x is $\boxed{0.454\frac{\mathrm{m}}{\mathrm{s}^2}}$.

b) Find the coefficient of kinetic friction for the ice and puck. (I didn't give the mass... do you need it? (6)

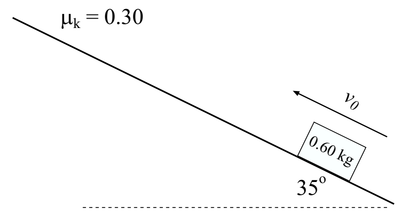
The normal force on the puck is just $F_N = mg$, its weight. The net force on the puck is from friction opposing the motion, so

$$F_x = -f_k = -\mu_k F_N = -\mu_k mg = ma = m(-0.454\frac{\mathrm{m}}{\mathrm{s}^2})$$

We can cancel m to get

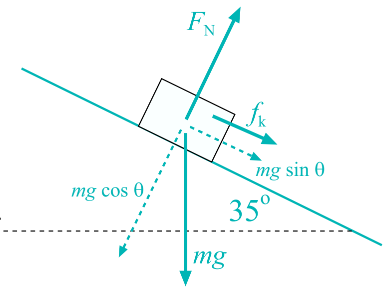
$$\mu_k = \frac{(0.454\frac{\mathrm{m}}{\mathrm{s}^2})}{g} = \frac{(0.454\frac{\mathrm{m}}{\mathrm{s}^2})}{(9.80\frac{\mathrm{m}}{\mathrm{s}^2})} = 0.046$$

4. A 0.600 kg mass is projected up a long (rough) 35° slope, as shown. The coefficient of kinetic friction is $\mu_k = 0.300$.



a) Draw a force diagram showing all the forces acting on the mass as it slides up the slope. (4)

Forces on the block are shown here: Gravity mg points downward and the components are shown here. The force of kinetic friction points down the slope. The normal force F_N is perpendicular to the slope.



b) While the mass is sliding up the slope what is the magnitude of the normal force (from the surface)? (4)

The net force perpendicular to the slope is zero, so

$$F_N = mg\cos\theta = (0.600\ \text{kg})(9.80\tfrac{\text{m}}{\text{s}^2})\cos 35^\circ = 4.82\ \text{N}$$

c) While the mass is sliding up the slope, what is the magnitude of the force of kinetic friction? (3)

$$f_k = \mu_k F_N = (0.300)(4.82\ \text{N}) = 1.44\ \text{N}$$

d) What is the magnitude and direction of the acceleration of the mass? (5)

The net force on the mass has magnitude

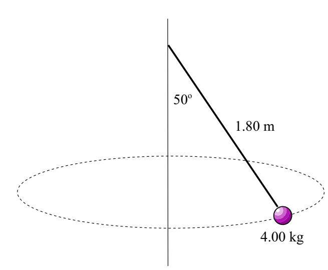
$$|F_x| = mg\sin\theta + f_k = (0.600\ \text{kg})(9.8\tfrac{\text{m}}{\text{s}^2})\sin\theta + 1.44\ \text{N} = 4.81\ \text{N}$$

and it points *down* the slope. (If the x axis goes up the slope then $F_x = -4.81\ \text{N}$.)

The acceleration of the mass is then

$$a_x = F_x/m = \frac{(-4.81\ \text{N})}{(0.600\ \text{kg})} = -8.02\tfrac{\text{m}}{\text{s}^2}$$

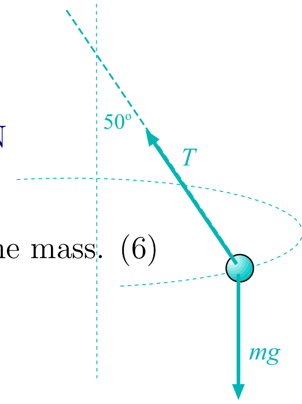
5. A 4.00 kg mass is attached to the end of a 1.80 m string and swings around in a horizontal circle; the string makes an angle of 50.0° with the vertical.



a) What is the radius of the circle in which the mass moves? (2)

$$r = (1.80\ \text{m})\sin 50^\circ = 1.38\ \text{m}$$

b) By balancing the vertical forces, find the tension in the string. (4)



Forces on the mass are shown here. Net vertical force on the mass is zero, so

$$T\cos 50^\circ - mg = 0 \qquad \Longrightarrow \qquad T = \frac{mg}{\cos 50^\circ} = \frac{(4.00\ \mathrm{kg})(9.80\frac{\mathrm{m}}{\mathrm{s}^2})}{\cos 50^\circ} = 61.0\ \mathrm{N}$$

c) Using the inward (centripetal) force on the mass, find the speed of the mass. (6)

The inward force is

$$T\sin 50^\circ = \frac{mv^2}{r} \qquad \Longrightarrow \qquad v^2 = \frac{rT\sin 50^\circ}{m}$$

Substitute:

$$v^2 = \frac{(1.38\ \mathrm{m})(61.0\ \mathrm{N})\sin 50^\circ}{(4.00\ \mathrm{kg})} = 16.1\ \frac{\mathrm{m}^2}{\mathrm{s}^2}$$

Then:

$$v = 4.02\frac{\mathrm{m}}{\mathrm{s}}$$

d) How long it take the mass to make one revolution? (4)

Use $v = \frac{2\pi r}{T}$, then

$$T = \frac{2\pi r}{v} = \frac{2\pi(1.38\ \mathrm{m})}{4.02\frac{\mathrm{m}}{\mathrm{s}}} = 2.16\ \mathrm{s}$$

6. One of the planet Jupiter's moons has an orbit of radius 1.883×10^6 km. The mass of Jupiter is 1.56×10^{27} kg.

a) Find the period of the orbit of the satellite. Express the results in days. (8)

Use

$$4\pi^2 r^3 = GMT^2 \qquad \Longrightarrow \qquad T^2 = \frac{4\pi^2 r^3}{GM}$$

with $r = 1.883 \times 10^9$ m. Then

$$T^2 = \frac{4\pi^2(1.883\times 10^9)^3}{(1.56\times 10^{27})(6.67\times 10^{-11})} = 2.53\times 10^{12}\ \mathrm{s}^2$$

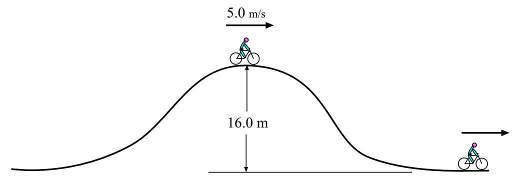
Then:

$$T = 1.59\times 10^6\ \mathrm{s}\left(\frac{1\ \mathrm{hr}}{3600\ \mathrm{s}}\right)\left(\frac{1\ \mathrm{day}}{24\ \mathrm{hr}}\right) = 18.4\ \mathrm{day}$$

b) Find the speed of this moon as it orbits. (3)

$$v = \frac{2\pi r}{T} = \frac{2\pi(1.883\times 10^9\ \mathrm{m})}{(1.59\times 10^6\ \mathrm{s})} = 7.44\times 10^3\frac{\mathrm{m}}{\mathrm{s}}$$

7. A bicyclist has a speed of $5.0\frac{\rm m}{\rm s}$ when he is riding over the the top of a hill; he then coasts to the bottom of the hill, where the elevation is 16.0 m below that of the top. What is his speed when gets there? Ignore all kinds of friction. (6)



If we let the bottom of the hill have "zero height", then applying the conservation of energy, (total energy, $\frac{1}{2}mv^2 + mgy$ the same at top and bottom of hill)

$$mg(16.0\ \mathrm{m}) + \tfrac{1}{2}m(5.0\tfrac{\rm m}{\rm s})^2 = 0 + \tfrac{1}{2}mv^2$$

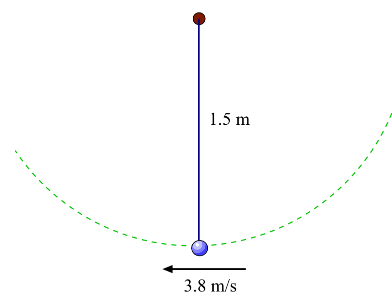
Cancel the m and multiply by 2. Get:

$$2g(16.0\ \mathrm{m}) + (5.00\tfrac{\rm m}{\rm s})^2 = v^2 \qquad \Longrightarrow \qquad v^2 = 338.6\ \tfrac{\rm m^2}{\rm s^2} \qquad \Longrightarrow \qquad v = 18.4\tfrac{\rm m}{\rm s}$$

The speed at the bottom of the hill is $\boxed{18.4\frac{\rm m}{\rm s}}$.

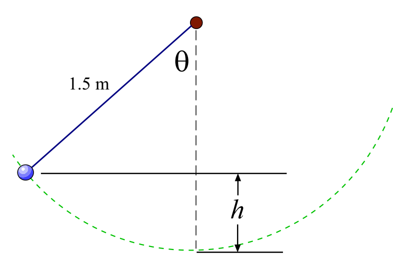
8. A small mass swings at the end of a string of length 1.50 m. When the mass is at the lowest position its speed is $3.80\frac{\rm m}{\rm s}$.

a) Find the maximum height h attained by the mass. (4)



Use conservation of energy, $mgy + \frac{1}{2}mv^2$ is the same at all points; height is zero at the bottom of the swing and the speed is zero when the mass attains height h. This gives:

$$0 + \tfrac{1}{2}m(3.80\tfrac{\rm m}{\rm s})^2 = mgh + 0 \qquad \Longrightarrow \qquad h = \frac{(3.80\frac{\rm m}{\rm s})^2}{2(9.80\frac{\rm m}{\rm s^2})} = 0.737\ \mathrm{m}$$



b) Find the angle θ that the string makes with the vertical when the mass is at its highest position. (3)

When the mass is at its highest point, it is below the center of the circle by a vertical distance

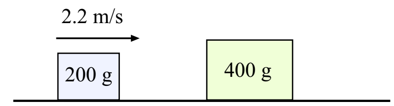
$$x = 1.50\ \mathrm{m} - h = 0.763$$

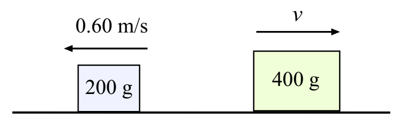
At this the angle which the string makes with the vertical is:

$$\cos\theta = \frac{0.763}{1.5} = 0.509 \qquad \Longrightarrow \qquad \theta = 59.4^\circ$$

9. A 200 g mass and a 400 g mass move on a frictionless track; initially, the 200 g mass slides toward at a speed of $2.2\frac{\mathrm{m}}{\mathrm{s}}$ toward the 400 g mass which is at rest. After the collision, the 200 g mass is moving in the other direction with a speed of $0.600\frac{\mathrm{m}}{\mathrm{s}}$.

What is the speed of the 400 g mass after the collision? (6)





In the collision, momentum is conserved. This gives

$$(0.200\ \mathrm{kg})(2.2\tfrac{\mathrm{m}}{\mathrm{s}}) + 0 = (0.200\ \mathrm{kg})(-0.600\tfrac{\mathrm{m}}{\mathrm{s}}) + (0.400\ \mathrm{kg})v$$

Solve for v:

$$(0.400\ \mathrm{kg})v = (0.200\ \mathrm{kg})(2.2\tfrac{\mathrm{m}}{\mathrm{s}}) + (0.200\ \mathrm{kg})(0.600\tfrac{\mathrm{m}}{\mathrm{s}}) \qquad \Longrightarrow \qquad v = 1.4\tfrac{\mathrm{m}}{\mathrm{s}}$$

You must show all your work and include the right units with your answers!

$$A_x = A\cos\theta \qquad A_y = A\sin\theta \qquad A = \sqrt{A_x^2 + A_y^2} \qquad \tan\theta = A_y/A_x$$

$$v_x = v_{0x} + a_x t \qquad x = v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad v_x^2 = v_{0x}^2 + 2a_x x \qquad x = \tfrac{1}{2}(v_{0x} + v_x)t$$

$$v_y = v_{0y} + a_y t \qquad y = v_{0y}t + \tfrac{1}{2}a_y t^2 \qquad v_y^2 = v_{0y}^2 + 2a_y y \qquad y = \tfrac{1}{2}(v_{0y} + v_y)t$$

$$g = 9.80\tfrac{\mathrm{m}}{\mathrm{s}^2} \qquad R = \frac{2v_0^2 \sin\theta\cos\theta}{g} \qquad \mathbf{F}_{\mathrm{net}} = m\mathbf{a} \qquad \mathrm{Weight} = mg$$

$$F = G\frac{m_1 m_2}{r^2} \qquad G = 6.67\times 10^{-11}\tfrac{\mathrm{N\cdot m^2}}{\mathrm{kg^2}} \qquad g = G\frac{M}{R^2} \qquad f_{\mathrm{s}}^{\mathrm{Max}} = \mu_s F_N \qquad f_{\mathrm{k}} = \mu_{\mathrm{k}} F_N$$

$$v = \frac{2\pi R}{T} \qquad a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad 4\pi^2 r^3 = GMT^2$$

$$W = Fs\cos\theta \qquad W_{\mathrm{total}} = \Delta\mathrm{KE}$$

$$\mathrm{PE}_{\mathrm{grav}} = mgh \qquad \mathrm{KE} = \tfrac{1}{2}mv^2 \qquad E = \mathrm{PE} + \mathrm{KE} \qquad \Delta E = W_{\mathrm{nc}} \qquad P = \frac{W}{t}$$

$$\mathbf{p} = m\mathbf{v} \qquad \text{For isolated system} \quad \mathbf{p}_{\mathrm{Tot}} \quad \text{is conserved}$$

$$\mathbf{J} = \Delta\mathbf{p} \qquad \mathbf{F}_{\mathrm{av}} = \frac{\Delta\mathbf{p}}{\Delta t} \qquad x_{\mathrm{CM}} = \frac{m_1 x_1 + m_2 x_2 + \cdots}{m_1 + m_2 + \cdots}$$