Key

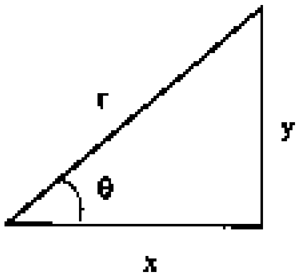
Physics 220 – Exam #2

October 18 **2001**

This exam consists of 12 problems on 7 pages. **Please check that you have them all.**

All of the formulas that you will need are given below. You may also use a calculator.

$\sin\theta = y/r$ $\cos\theta = x/r$ $\tan\theta = y/x$



average speed $= \frac{\text{distance traveled}}{\text{time}}$ $g = 9.8 \text{ m/s}^2$

1 mile = 1.6 km

average velocity $= \bar{v} = \frac{\text{displacement}}{\text{time}}$

instantaneous velocity = slope of position versus time

instantaneous acceleration = slope of velocity versus time

For constant acceleration:
$x = x_0 + v_0 t + \frac{1}{2}at^2$
$v = v_0 + at$
$v^2 = v_0^2 + 2a(x - x_0)$

$\vec{F} = m\vec{a}$
$F_{friction}^{max} = \mu_S N$ (static friction) $F_{friction} = \mu_K N$ (sliding friction)

$F_{gravity} = \frac{Gm_1m_2}{r^2}$ $G = 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$

$a_c = v^2/r$ $KE = \frac{1}{2}mv^2$

$W = F\,d\,\cos\theta$ $PE_{gravity} = mgh$ power = work/Δt

$\vec{p} = m\vec{v}$ Δp = impulse = $F\,\Delta t$

1. A baseball of mass 0.20 kg is hit a long way by Barry Bonds. The ball comes towards home plate (from the pitcher) with a speed of 45 m/s, and leaves his bat with a speed of 60 m/s. If the bat is in contact with the ball for 0.15 s, find the average force of the bat on the ball. Assume that the ball reverses direction when it is hit (i.e., it is hit back towards the unfortunate pitcher).

   (a) 12 N
   (b) 80 N
   [✓ (c) 140 N]
   (d) 33 N
   (e) 21 N

$\longrightarrow +$

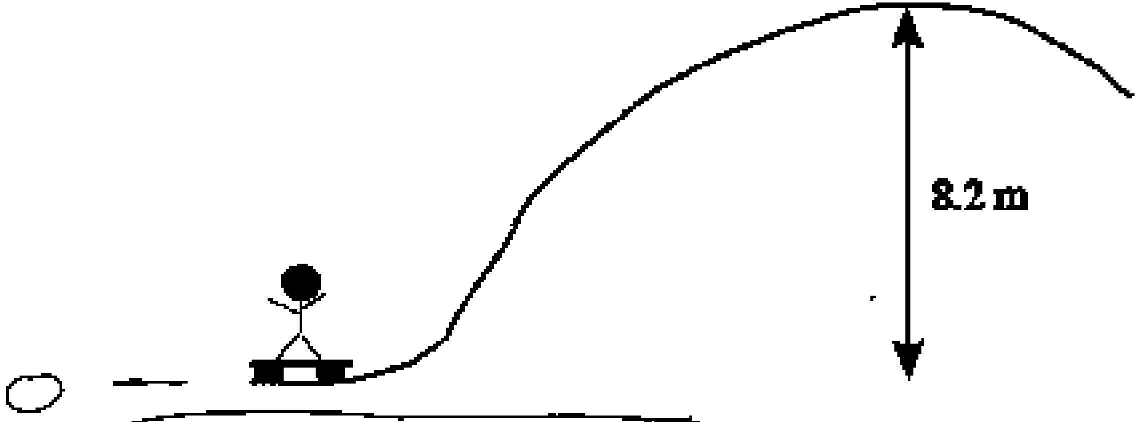
$\longleftarrow \quad v_i = -45\ m/s$

$\longrightarrow \quad v_f = +60\ m/s$

$$F \cdot \Delta t = \Delta p = p_f - p_i = m(v_f - v_i)$$

$$F = \frac{m(v_f - v_i)}{\Delta t} = \frac{0.20(60 - (-45))}{0.15} = \underline{\underline{140N}}$$

2. It is your birthday and you receive a new skateboard. This is not just any skateboard, but a special frictionless model. To test it you arrange to have a speed of 12 m/s on the approach to the ramp shown below. Do you make it to the top of the ramp, and if so what is your speed when you get there?



   [✓ (a) You don't make it to the top.]
   (b) You make it to the top, but your speed is zero when you get there.
   (c) You make it to the top, and your speed is 13 m/s when you get there.
   (d) You make it to the top, and your speed is 4.1 m/s when you get there.
   (e) You make it to the top, and your speed is 1.1 m/s when you get there.

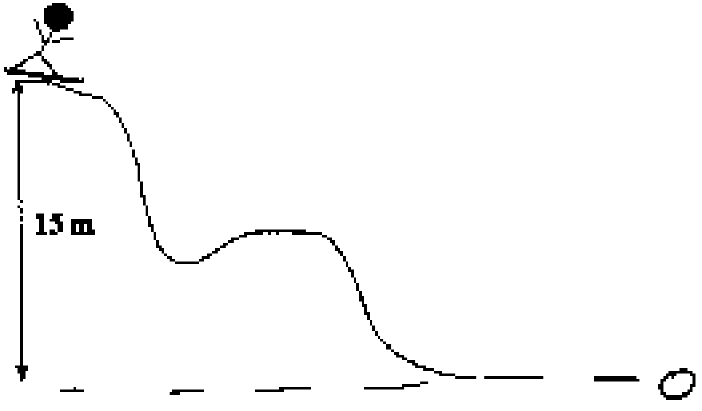
h_f = maximum height

$$KE_i + PE_i = KE_f + PE_f$$

$$\frac{1}{2} m v_i^2 + mg(0) = \frac{1}{2} m \overset{0}{\cancel{v_f}^2} + mgh_f$$

$$h_f = \frac{v_i^2}{2g} = \frac{(12)^2}{2(9.8)} = \underline{\underline{7.3\ m}} \quad < 8.2\ m$$

3. A skier of mass 55 kg starts with an initial speed of 5.5 m/s at the top of a ski slope. When she reaches the bottom of the slope her speed is 9.0 m/s. How much work is done by friction and air drag on the skier?



[✓ (a) -6700 J]
(b) -1400 J
(c) +1400 J
(d) -9500 J
(e) 8100 J

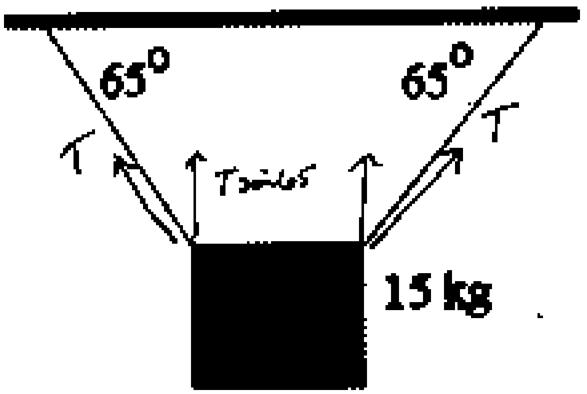
$KE_f + \cancel{PE_f}^{0} = KE_i + PE_i + W_f$

$W_f = KE_f - KE_i - PE_i = \frac{1}{2}m(v_f^2 - v_i^2) - mgh_i$

$= \frac{1}{2}(55)(9.0^2 - 5.5^2) - 55(9.8)\cdot 15$

$= 1395 - 8085 = \underline{\underline{-6690}}$

4. A block of mass 15 kg is suspended from the ceiling by two cables, as shown below. Find the tension in the cable on the left.



Tensions are equal since angles are equal.

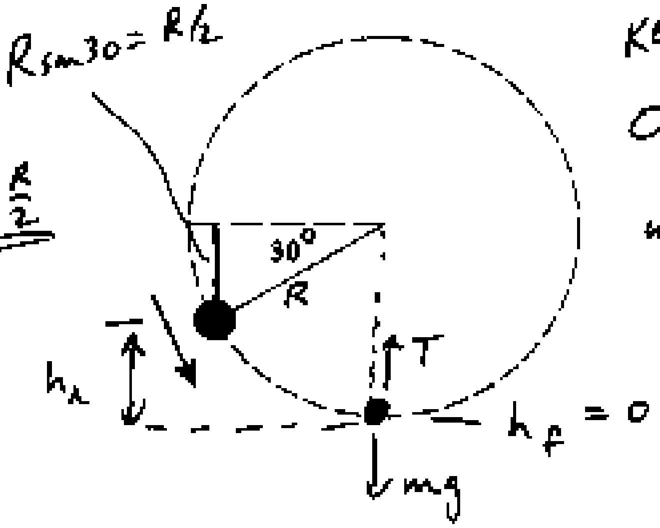
(a) 100 N
(b) 74 N
(c) 160 N
(d) 41 N
[✓ (e) 81 N]

$2T\sin 65 - mg = F = ma = 0$

$T = \frac{mg}{2\sin 65} = \underline{\underline{81N}}$

5. A rock of mass 5.5 kg is tied to a string of length 1.2 m. One end of the string is held fixed, and the rock is released from rest from the location shown below. Find the tension in the string when the rock reaches the lowest point in its circular trajectory.

$h_i = R - \frac{R}{2} = \underline{\underline{\frac{R}{2}}}$



$KE_i + PE_i = KE_f + PE_f$

$0 + mgh_i = \frac{1}{2}mv^2 + 0$

$mv^2 = 2mgh_i$

$= 2mg\frac{R}{2} = \underline{mgR}$

- (a) 160 N
- (b) 65 N
- (c) 80 N
- [✓ (d) 110 N]
- (e) 54 N

$T - mg = \frac{mv^2}{R}$

$T = mg + \frac{mv^2}{R} = mg + \frac{mgR}{\cancel{R}}$

$= 2mg\cancel{R}$

$= 2(5.5)\,9.8$ [illegible])

$= \underline{\underline{108N}}$

6. The earth's orbit around the sun is approximately circular with a radius of 1.5×10^{11} m. Find the orbital speed of the earth.

- (a) 520 m/s
- (b) 3.2×10^7 m/s
- (c) 2.6×10^9 m/s
- (d) 9.4×10^{12} m/s
- [✓ (e) 3.0×10^4 m/s]

$v = \frac{2\pi R}{T} = \frac{2\pi\,(1.5\times10^{11})}{365\cdot24\cdot60\cdot60}$

$= \underline{\underline{3.0\times10^4\ m/s}}$

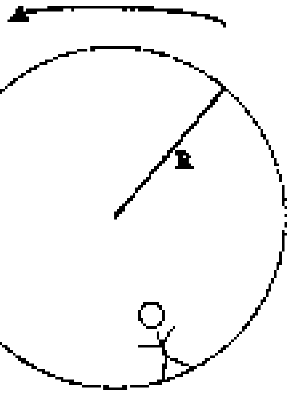
7. A car of mass 1200 kg is moving at a speed of 10 m/s. A bicyclist has a total mass (person plus bicycle) of 80 kg. How fast must the bicyclist be moving to have the same momentum (in magnitude) as the car?

- (a) 12000 m/s
- [✓ (b) 150 m/s]
- (c) 30 m/s
- (d) 450 m/s
- (e) 10 m/s

$$m_{car} v_{car} = m_{bike} v_{bike}$$

$$v_{bike} = \frac{m_{car} v_{car}}{m_{bike}} = \frac{1200(10)}{80} = \underline{\underline{150 \text{ m/s}}} \ (!)$$

8. You work on a space station that produces artificial gravity by rotation. If the station has a radius of 15 m and rotates at 5 revolutions per minute, what is the acceleration due to the artifical gravity on the station?



$$T = \frac{60 s}{5 rev} = 12 s$$

- (a) 9.8 m/s²
- [✓ (b) 4.1 m/s²]
- (c) 590 m/s²
- (d) 20 m/s²
- (e) 7.3 m/s²

$$a = \frac{v^2}{R} = \frac{(2\pi R/T)^2}{R} = \frac{4\pi^2 R}{T^2}$$

$$= \frac{4 \cdot \pi^2 \cdot 15}{(12)^2} = \underline{\underline{4.1 \text{ m/s}^2}}$$

9. An arrow of mass 0.10 kg is fired horizontally. The bow exerts an average force of 85 N on the arrow over a distance of 0.75 m. What is the speed of the arrow when it leaves the bow?

   - (a) 1300 m/s
   - (b) 25 m/s
   - (c) 64 m/s
   - [✓ (d) 35 m/s]
   - (e) 11 m/s

$$\underset{\underset{F \cdot d}{\parallel}}{W} = \Delta KE = \frac{1}{2} m v_f^2 - \frac{1}{2} m \underset{\underset{0}{\uparrow}}{v_i}^2$$

$$v_f = \sqrt{\frac{2 \cdot Fd}{m}} = \sqrt{\frac{2 \cdot 85 \cdot (0.75)}{0.10}}$$

$$= \underline{\underline{36 \ m/s}}$$

10. Superman jumps straight down from a bridge onto a boat of mass 650 kg in which a criminal is fleeing. The initial velocity of the boat (before Superman jumps into it) is 14.0 m/s, and the final velocity is 12.0 m/s. What is Superman's mass?

   - (a) 560 kg
   - (b) 54 kg
   - [✓ (c) 110 kg]
   - (d) 160 kg
   - (e) 85 kg

$$\underset{\uparrow}{p_i} = p_f$$

$$m_{boat} \cdot (14.0) = (m_{boat} + m_s)\ 12.0$$

$$m_{boat}(14.0 - 12.0) = m_s(12.0)$$

$$\frac{m_{boat}(2.0)}{12} = m_s$$

$$\parallel$$

$$\underline{\underline{108 \ kg}}$$

11. A truck is traveling at 15 m/s down a hill when the brakes are applied and all four wheels lock. The hill is an inclined plane that makes an angle of 12° with the horizontal. The coefficient of friction between the tires and the road is 0.45. How far does the truck skid before coming to a stop?

[✓ (a) 49 m]
(b) 11 m
(c) 26 m
(d) 82 m
(e) 15 m

$W_f = -F_f \cdot d$

$= -\mu \cdot N \cdot d$

$= -\mu \cdot mg \cos\theta\ d$

$KE_f + PE_f = KE_i + PE_i + W_f$

$0 + 0 = \frac{1}{2}\cancel{m}v_i^2 + \cancel{m}g\underset{d\sin\theta}{\underset{\uparrow}{h}} - \mu \cancel{m}g \cos\theta\ d$

$d(-g\sin\theta + \mu g\cos\theta) = \frac{1}{2}v_i^2$

$d = \frac{v_i^2/2}{g(\mu\cos\theta - \sin\theta)} = \frac{15^2/2}{9.8(0.45\cdot(.978) - .208)} = \frac{225/2}{9.8(.232)} = \underline{\underline{49\,m}}$

12. A student of mass 75 kg running with a speed of 12 m/s jumps onto a wagon which is initially at rest. The mass of the wagon is 25 kg. What fraction of the initial kinetic energy **remains** after the student jumps onto the wagon? Assume that friction is negligible.

(a) 0.33
(b) 0.40
(c) 0.25
[✓ (d) 0.75]
(e) 1.00

$m_i v_i = m_f v_f$

$v_f = \frac{m_i v_i}{m_f} = \frac{75(12)}{75+100} = 9.0\ m/s$

$KE_f = \frac{1}{2}m_f v_f^2 = \frac{1}{2}(100)\ 9.0^2 = 4050\ J$

$KE_i = \frac{1}{2}m_i v_i^2 = \frac{1}{2}(75)(12)^2 = 5400$

$\frac{KE_f}{KE_i} = \frac{4050}{5400} = \underline{\underline{0.75}}$

The End