

SAMPLE TEST 3  
PHYS 111 SPRING 2010

Name: \_\_\_\_\_

By writing my name above, I affirm that this test represents my work only, without aid from outside sources. In all aspects of this course I perform with honor and integrity.

SHOW YOUR WORK ON ALL OF THE PROBLEMS – YOUR APPROACH TO THE PROBLEM IS AS IMPORTANT AS (IF NOT MORE) IMPORTANT THAN) YOUR FINAL ANSWER.

1) Starting with the definition of work, derive the **Work Energy Theorem**.

$$W = \int \vec{F} \cdot d\vec{s}, \quad \vec{F} = F_x \hat{x} + F_y \hat{y} + F_z \hat{z}$$
$$d\vec{s} = dx \hat{x} + dy \hat{y} + dz \hat{z}$$

$$W = \int (F_x \hat{x} + F_y \hat{y} + F_z \hat{z}) \cdot (dx \hat{x} + dy \hat{y} + dz \hat{z})$$

$$\Rightarrow W = \int (F_x dx + F_y dy + F_z dz) \Rightarrow \boxed{W = \int F_x dx + \int F_y dy + \int F_z dz}$$

$$\boxed{W_{\text{net}} = \sum W} = \sum (\int F_x dx + \int F_y dy + \int F_z dz)$$

$$\Rightarrow W_{\text{net}} = \sum \int F_x dx + \sum \int F_y dy + \sum \int F_z dz$$

$$\Rightarrow W_{\text{net}} = \int \sum F_x dx + \int \sum F_y dy + \int \sum F_z dz$$

Now:  $\sum F_x = ma_x$  (NSL) so we can subst.

consider just the  $x$ -axis.

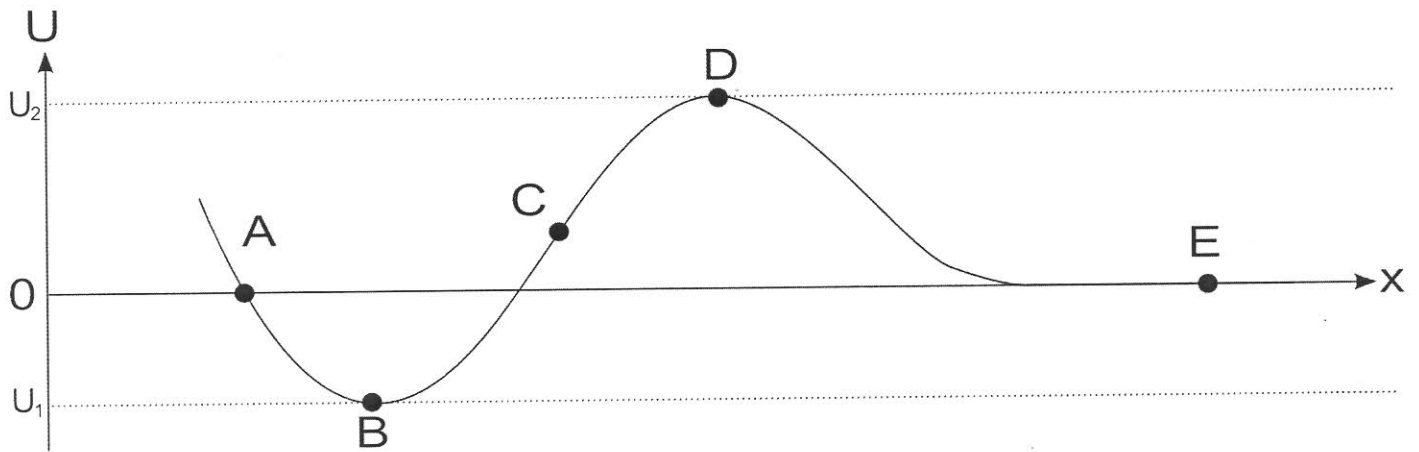
$$\int_{x_0}^x \sum F_x dx = \int_{x_0}^x m a_x dx = \int_{x_0}^x m \frac{dv_x}{dt} dx \stackrel{\text{Change Variable}}{=} \int_{v_{0x}}^{v_x} m \frac{dx}{dt} dv = \int_{v_{0x}}^{v_x} m v dv$$

$$= \frac{1}{2} m v_x^2 - \frac{1}{2} m v_{0x}^2 = \boxed{\Delta K_x}$$

$$\text{So: } \boxed{W_{\text{net}} = \Delta K} \quad \text{QED.}$$

SAMPLE TEST 3  
 PHYS 111 SPRING 2010

2) Conceptual Questions, 4 points each.



1) Refer to the potential energy curve above. Which point(s) represent **stable** equilibrium?

- a) B, D, E
- b) A, B, C, D, E
- c) B
- d) E

2) What is the minimum velocity required by a particle at point A to reach point D?

- a)  $v = \sqrt{\frac{2U_1}{m}}$
- b)  $v = \sqrt{\frac{2U_2}{m}}$
- c)  $v = \sqrt{\frac{2(U_1 + U_2)}{m}}$
- d)  $v = \sqrt{\frac{2(U_1 - U_2)}{m}}$

$$U_I + K_I = U_F$$

$$0 + \frac{1}{2} m v^2 = U_2$$

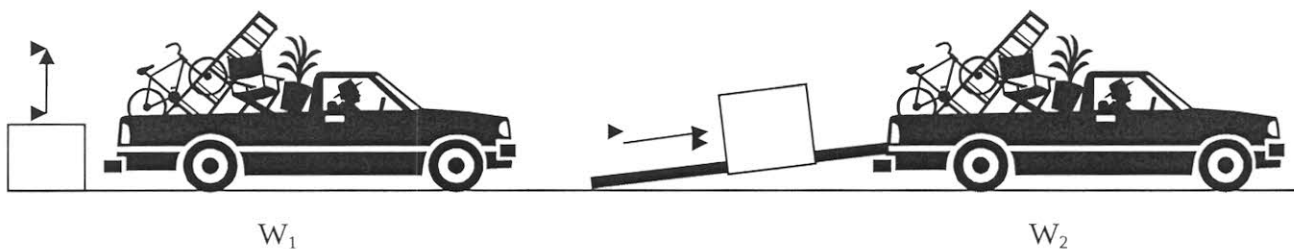
$$v = \left[ \frac{2U_2}{m} \right]^{1/2}$$

3) True or False: A force that is always perpendicular to the velocity of a particle does no work on the particle.

- a) True
- b) False

SAMPLE TEST 3  
 PHYS 111 SPRING 2010

- 4) You want to load a box into the back of a truck. One way is to lift it straight up through a height  $h$ , doing a work  $W_1$ . Alternatively, you can slide the box up a loading ramp a distance  $L$ , doing a work  $W_2$ . Assuming the box slides on the ramp without friction, which of the following is correct?
- $W_1 < W_2$
  - $W_1 = W_2$
  - $W_1 > W_2$



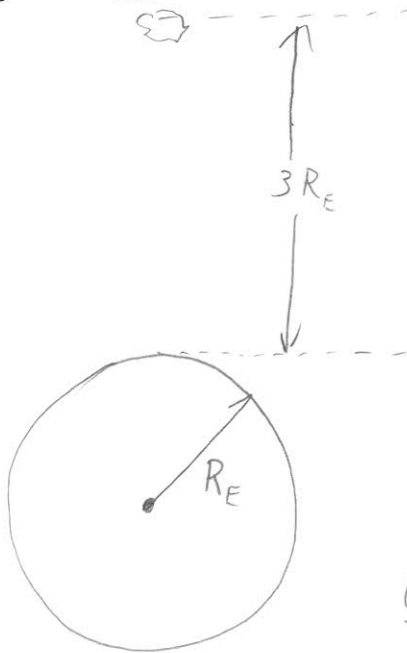
- 5) The Martians have declared war on us and have begun dropping rocks on us from space. If they release a rock from rest from a height of  $3R_{\text{Earth}}$  above the Earth's surface, what will its velocity be when it hits us on the ground?

1)  $v = \sqrt{\frac{4 GM_{\text{Earth}}}{3 R_{\text{Earth}}}}$

2)  $v = \sqrt{\frac{3 GM_{\text{Earth}}}{2 R_{\text{Earth}}}}$

3)  $v = \sqrt{\frac{3 GM_{\text{Earth}}}{4 R_{\text{Earth}}}}$

4)  $v = \sqrt{\frac{GM_{\text{Earth}}}{R_{\text{Earth}}}}$



$U_I = \frac{-GMEm}{4R_E}$       $K_I = 0$

$U_F = \frac{-GMEm}{R_E}$       $K_F = \frac{1}{2}mV^2$

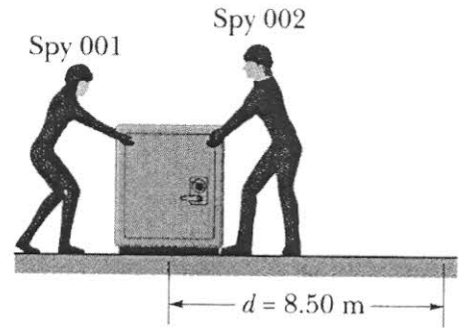
$-\frac{GMEm}{4R_E} = -\frac{GMEm}{R_E} + \frac{1}{2}mV^2$

$\frac{GM_E}{R_E} \left[ 1 - \frac{1}{4} \right] = \frac{1}{2}V^2$

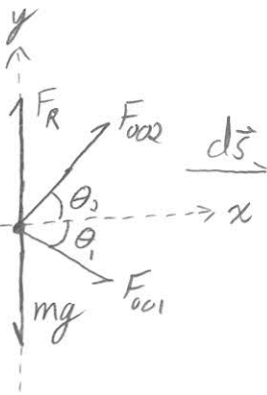
$\Rightarrow V = \left[ \frac{3}{2} \frac{GM_E}{R_E} \right]^{1/2}$

# Energy Problems – Set 2

Two spies slide an initially stationary 225 kg safe 8.50 m along a straight line towards their truck. Spy 001 pushes 12.0 N at an angle of 30 degrees to horizontal. Spy 002 pulls at an angle of 40 degrees from horizontal. The floor is frictionless (they're stealing the safe from an ice rink).



- a) What is the total work done on the safe during the 8.5 m displacement.
- b) During the displacement, what is the work done on the safe by it's own weight and the normal force from the floor?
- c) What is the speed of the safe at the end of the displacement.
- d) After the 8.50 m displacement, the spies stop pushing and let the safe slide across the ice and onto the carpet at the edge of the rink. If the coefficient of friction between the safe and the carpet is = 0.6, use the Work Energy Theorem to find how far does the safe slides.



$$W_{F_R} = 0, \vec{F}_R \perp d\vec{s}$$

$$W_g = 0, \vec{g} \perp d\vec{s}$$

$$W_{F_{001}} = \int_0^d (F_{001} \cos\theta_1 \hat{x} - F_{001} \sin\theta_1 \hat{y}) (dx \hat{x})$$

$$W_{F_{001}} = F_{001} d \cos\theta_1$$

$$W_{F_{002}} = \int_0^d (F_{002} \cos\theta_2 \hat{x} + F_{002} \sin\theta_2 \hat{y}) (dx \hat{x})$$

$$W_{F_{002}} = F_{002} d \cos\theta_2$$

$$W_{net} = (F_{001} \cos\theta_1 + F_{002} \cos\theta_2) d = ((12) \cos(30) + (10) \cos(40)) 8.5$$

$$= 153 \text{ J}$$

continued  
↓

EPJ, P4 - continued.

c) WET

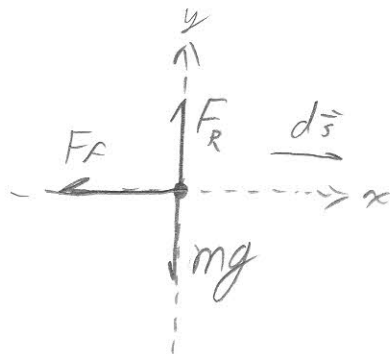
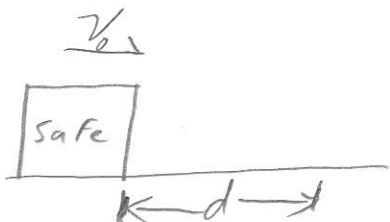
$$W_{\text{net}} = \Delta K$$

$$W_{\text{net}} = \frac{1}{2} m v^2 - \frac{1}{2} m v_0^2$$

$$\Rightarrow v = \left( \frac{2 W_{\text{net}}}{m} \right)^{1/2}$$

$$v = \left( \frac{(2)(153)}{(225)} \right)^{1/2} = 1.2 \text{ m/s}$$

d)



Get  $F_f$  From NSL

$$F_f = \mu_k F_R$$

$$F_R - mg = 0$$

$$\Rightarrow \boxed{F_f = \mu_k mg}$$

$$W_{FR} = 0, F_R \perp d\vec{s}$$

$$W_g = 0, \vec{F}_g \perp d\vec{s}$$

$$W_{F_f} = \int_0^d (-\mu_k mg \hat{x}) \cdot (dx \hat{x}) = -\mu_k mgd$$

WET

$$W_{\text{net}} = \Delta K \Rightarrow -\mu_k mgd = \frac{1}{2} m v^2 - \frac{1}{2} m v_0^2$$

continued ↓

EP2, P4 - continued

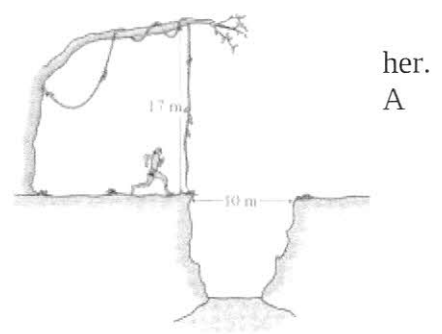
$$+\mu_k mgd = +\frac{1}{2}mv_0^2$$

$$d = \frac{v_0^2}{2\mu_k g} = \frac{(1.2)^2}{(2)(0.7)(9.8)} = 0.1 \text{ m}$$

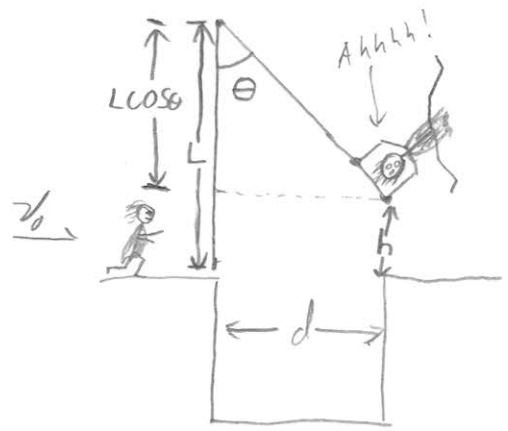
SAMPLE TEST 3  
 PHYS 111 SPRING 2010

Use work-energy techniques to solve the following problem.

Tarzan is late for a date with Jane and is running as fast as he can to meet her. On the way, he has to get over a 10m wide pit of dangerous croc-a-gators. 17m vine is hanging vertically from a tree at one side of the pit. Tarzan is going to run up, grab the vine, swing across, and drop vertically to the ground on the other side.



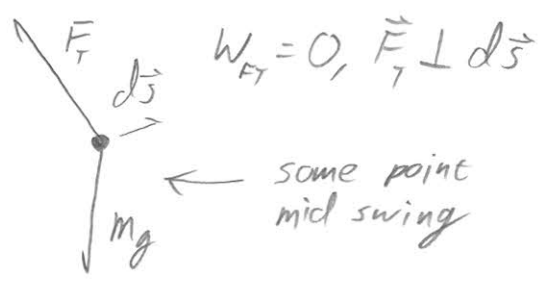
What must his minimum speed be to make it across?



$$h = L - L \cos \theta$$

$$d = L \sin \theta$$

$$y = 0$$



$$U_I = 0$$

$$U_F = mgL(1 - \cos \theta)$$

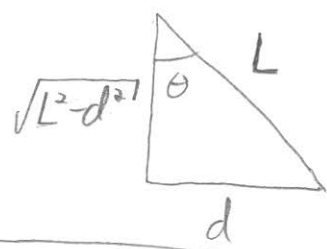
$$K_I = \frac{1}{2} m v_0^2$$

$$K_F = 0 \leftarrow \text{stops to drop vertically}$$

$$W_{NCF} = 0$$

$$\frac{1}{2} m v_0^2 = mgL(1 - \cos \theta)$$

$$v_0 = (2gL(1 - \cos \theta))^{1/2}$$



$$\cos \theta = \frac{\sqrt{L^2 - d^2}}{L}$$

$$v_0 = \left( 2gL \left( 1 - \frac{\sqrt{L^2 - d^2}}{L} \right) \right)^{1/2} = \left( 2g(L - \sqrt{L^2 - d^2}) \right)^{1/2}$$

