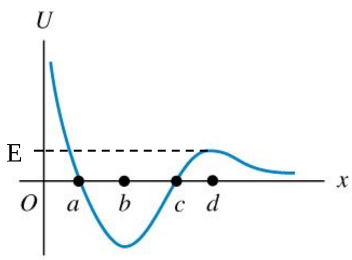
Physics 160-02 Sp. 2017 Exam #3 Name:______________

1) In electrodynamics, a magnetic field produces a force on a moving charged particle that is always perpendicular to the direction the particle is moving. How does this force affect the kinetic energy of the particle? Explain.

Since the force is ALWAYS perpendicular to the direction of motion, it cannot do any work since W = Fdcosθ. Since no work, no transfer of energy, and hence no change in kinetic energy. I does, however, affect the direction of motion - an electron will move in a circle in a magnetic field.

2) A marble moves along the x-axis. The potential-energy function is shown below. Describe the force (magnitude and direction) on the marble at the four labeled points.

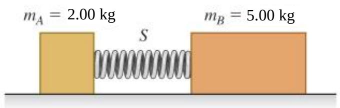


The force is related to the potential by $F_x = -\frac{\partial U}{\partial x}$. The derivative of the potential function is zero at points b and d, so that's where the force is also zero. At point a, the derivative is negative, so the force is positive (and has a relatively large magnitude). At point c, the derivative is positive, so the force is negative (pointing in the negative x-direction) and is a bit less strong than at point a.

3) If the marble above has a total energy E as marked, describe the speed of the marble at the four labeled points.

The kinetic energy of the marble is given by the total energy minus the potential energy, so, at point b, the kinetic energy (and hence, the speed) is the highest and at point d it is zero. At points a and c, the speed is the same.

4) Block A in the figure below has mass 2.00 kg, and block B has mass 5.00 kg. The blocks are forced together, compressing a spring S between them; then the system is released from rest on a level, frictionless surface. The spring, which has negligible mass, is not fastened to either block and drops to the surface after it has expanded. Block B acquires a speed of 1.20 m/s . How much potential energy was stored in the compressed spring?



Since there are no net outside forces, the total momentum of the system must remain constant: $\vec{p}_i = \vec{p}_f$, but since nothing is moving before the blocks are released:

$$0 = \vec{p}_f = m_A v_A + m_B v_B$$

$$0 = 2.00kg \cdot v_A + 5.00kg \cdot 1.2\frac{m}{s} \Rightarrow$$

$$v_A = \left(-6.00\frac{kgm}{s}\right) \Big/ 2.00kg = -3.00\frac{m}{s}$$

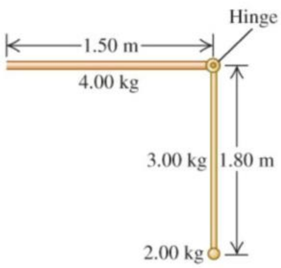
Then, we also know from energy conservation that the spring potential energy was converted to kinetic energy of the two blocks:

$$U_{el} = KE_{Tot} = \frac{1}{2}m_A v_A^2 + \frac{1}{2}m_B v_B^2$$

$$= \frac{1}{2}2.00kg \cdot \left(-3.00\frac{m}{s}\right)^2 + \frac{1}{2}5.00kg \cdot \left(1.20\frac{m}{s}\right)^2$$

$$= 9.00J + 3.60J = 12.60J$$

5) Find the location of the center of mass of the object below. (Take the hinge to be massless, and place the origin at the hinge.)



Taking the location of the hinge to be the origin,

$$x_{CM} = \frac{4.00kg\times(-0.75m)+3.00kg\times(0m)+2.00kg\times(0m)}{9.00kg}$$

$$= -0.33m$$

$$y_{CM} = \frac{4.00kg\times(0m)+3.00kg\times(-0.90m)+2.00kg\times(-1.80m)}{9.00kg}$$

$$= -0.70m$$

6) A rocket is fired straight upward on a windless day. At the peak of its trajectory, it explodes into two parts, one with three times the mass as the other. Both pieces strike the ground at the same time. You find the heavy piece 10m to the East of the launch site. Where should you look for the lighter piece? Assume no air resistance.

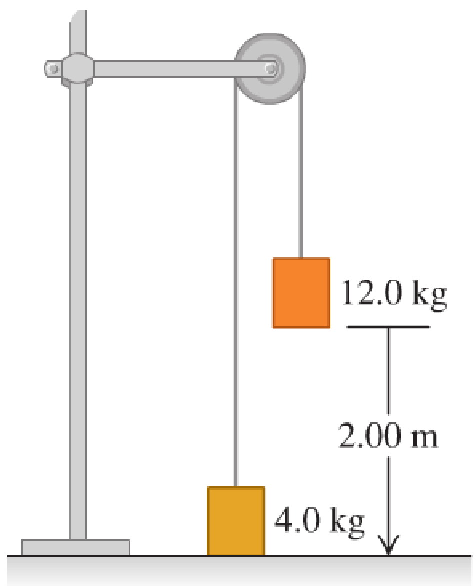
Since the center of mass wouldn't move (no outside forces in the horizontal direction) the center of mass would remain at the launch site. The center of mass is closer to the heavier object, so the lighter object is farther from the launch site. If we put x=0m at the launch site, then we have

$$x_{CM} = 0 = 10m\times 3M + x_{light}\times 1M \Rightarrow$$

$$x_{light} = -30m$$,

or 30m West of the launch site.

7) A system of two paint buckets connected by a lightweight rope (over a massless pulley) is released from rest with the 12.0 kg bucket 2.00 m above the floor. During the time that the 12.0 kg bucket drops to the floor, friction in the pulley removes 10.0 J of energy from the system. What is the speed of the bucket when it hits the floor?



From conservation of energy, the net change in mechanical energy is the work done by friction, so

$$\Delta E_{mech} = W_{f_k} = \Delta K + \Delta U_g + \Delta U_{el}$$

$$-10J = \left(1/2\,mv_f^2 - 1/2\,mv_0^2\right)^{4kg} + \left(1/2\,mv_f^2 - 1/2\,mv_0^2\right)^{12kg} + \left(mgy_f - mgy_0\right)^{4kg} + \left(mgy_f - mgy_0\right)^{12kg}$$

$$-10J = \left(1/2\,mv^2\right)^{4kg} + \left(1/2\,mv^2\right)^{12kg} + \left(mgy - 0\right)^{4kg} + \left(0 - mgy\right)^{12kg} \Rightarrow$$

$$-10J = 1/2\left(12kg + 4kg\right)v^2 + \left(4kg\right)g\left(2m\right) - \left(12kg\right)g\left(2m\right) \Rightarrow$$

$$v^2 = \frac{-10J}{8kg} - \left(\frac{8kg \cdot m}{8kg}\right)\left(9.8\frac{m}{s^2}\right) + \left(\frac{24kg \cdot m}{8kg}\right)\left(9.8\frac{m}{s^2}\right)$$

$$v^2 = 18.4\frac{m^2}{s^2} \Rightarrow$$

$$v = 4.28\frac{m}{s}$$

A bullet of mass 5.0 g is fired horizontally into a 2.0 kg wooden block at rest on a horizontal surface. The coefficient of kinetic friction between block and surface is 0.25. The bullet stops in the block, which slides straight ahead for 2.5 m (without rotation).

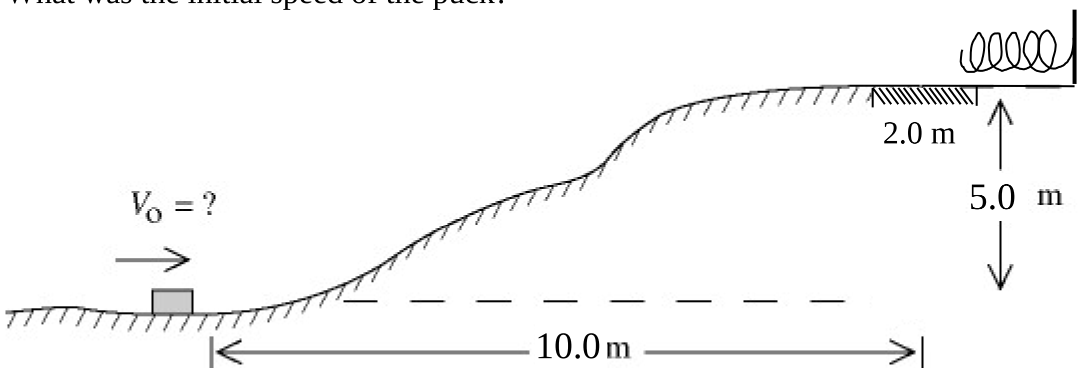
8) What is the speed of the block immediately after the bullet stops in it?

Friction does work on the block to stop it. The magnitude of the frictional force is (eq. 3) $F_f = 0.25*(2.005kg*9.8m/s^2)=4.91N$ and acts on the block for 2.5m, so from eq.2, W=Fd=-4.91N*2.5m=-12.3J. This will represent a change in the kinetic energy (eqs. 7 & 8). So v = sqrt(2*12.3Nm/2.005kg) = 3.50m/s.

9) At what speed is the bullet fired?

Momentum is conserved in the collision, so $mv_{before} = mv_{after}$ or 0.005kg*v=(2.0kg+0.005kg)*3.50m/s so v = 1400m/s.

10) A small hockey puck of mass 1 kg slides without friction over the icy hill shown below. At the top of the hill, it encounters a rough horizontal surface (coefficient of kinetic friction = 0.4) and hits a spring with spring constant k = 400N/m, compressing it by 0.2m before it stops. The total distance it travels over the rough surface is 2.0 m. What was the initial speed of the puck?



From conservation of energy, the net change in mechanical energy is the work done by friction, so

$$\Delta E_{mech} = W_{f_k} = \Delta K + \Delta U_g + \Delta U_{el}$$

$$-F_{f_k} d = \left(1/2\,mv_f^2 - 1/2\,mv_0^2\right) + \left(mgy_f - mgy_0\right) + \left(1/2\,kx_f^2 - 1/2\,kx_0^2\right)$$

$$-\mu_k F_N d = \left(0 - 1/2\,mv_0^2\right) + \left(mgh - 0\right) + \left(1/2\,kx_f^2 - 0\right) \Rightarrow$$

$$-\mu_k mgd = -1/2\,mv_0^2 + mgh + 1/2\,kx_f^2 \Rightarrow$$

$$v_0^2 = 2\mu_k gd + 2gh + \frac{k}{m}x_f^2 = 2(0.4)\left(9.8\frac{m}{s^2}\right)(2m) + 2\left(9.8\frac{m}{s^2}\right)(5m) + \frac{400\frac{N}{m}}{1kg}(0.2m)^2$$

$$v_0^2 = 15.7\frac{m^2}{s^2} + 98\frac{m^2}{s^2} + 16\frac{m^2}{s^2} \Rightarrow$$

$$v_0 = 11.4\frac{m}{s}$$