Physics 125 secs 5 & 8 November 13, 2008 Quiz 10

1. **Gravitational potential energy**. A rocket of mass m = 440. kg is launched from the surface of the earth. The earth's radius is $R = 6.37 \times 10^6$ m, the earth's mass is M = 5.98 x 10^{24} kg, and Newton's constant $G = 6.67 \times 10^{-11}\ \mathrm{Nm^2/kg^2}$. When appropriate, you may use the approximate gravitational force per unit mass g = 9.8 N/kg (near earth's surface.)

a. To 1% accuracy, how much work must be done (against gravity) to raise the rocket by h = 2.00 km = 2.00 x 10^3 m above the earth's surface?

$$W = -W_{grav} = \Delta U_{grav} = mgh = (.44\times10^3\,\mathrm{kg})(9.8\,\mathrm{m/s^2})(2.00\times10^3\,\mathrm{m}) = 8.6\times10^6\,\mathrm{J}$$

b. Explain in words why it takes less than 1000 times this work to raise the rocket to $h' = 1000\,h$. **If force were constant, work would be proportional to h. However, the force of gravity diminishes as h increases, so work is less.**

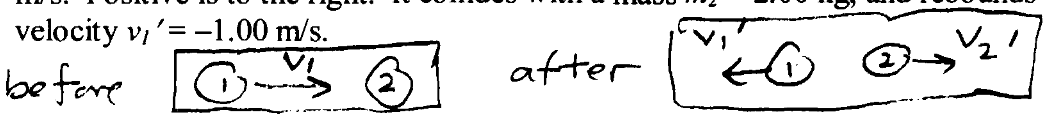
c. How much work must be done against gravity to raise the rocket to $h' = 1000\,h$ = 2.00 x 10^6 m above the earth's surface ?

$$W = \Delta PE_{grav} = -\frac{GMm}{R+h'} + \frac{GMm}{R} = mg\left(-\frac{R^2}{R+h'} + R\right) = mgh'\left(\frac{R}{R+h'}\right) = 8.6\times10^9\,\mathrm{J} \times 6.37/8.37 = 6.6\times10^9\,\mathrm{J}$$

d. Calculate the ratio of the weight of the rocket at height h' to its weight at the earth's surface, h = 0.

$$\frac{W'}{W} = \frac{GmM/(R+h')^2}{GmM/R^2} = \left(\frac{R}{R+h'}\right)^2 = \left(\frac{6.37}{8.37}\right)^2 = 0.60$$

2. **Collision in one dimension.** A mass m_1 = 1.00 kg moves with velocity v_1 = +3.00 m/s. Positive is to the right. It collides with a mass m_2 = 2.00 kg, and rebounds with velocity $v_1{}'$ = –1.00 m/s.



a. What is the velocity $v_2{}'$ of m_2 after the collision?

$$m_1 v_1 = m_1 v_1' + m_2 v_2'\ ;\quad \frac{m_2}{m_1} = 2\ ;\quad v_2' = \tfrac{1}{2}(v_1 - v_1') = \tfrac{1}{2}(3.0\,\tfrac{m}{s} + 1.0\,\tfrac{m}{s}) = 2.00\,\mathrm{m/s}$$

b. How much work did m_2 do on m_1 during this collision?

$$Work_{21} = (\Delta KE)_1 = \tfrac{1}{2}m(v_1'^2 - v_1^2) = \tfrac{1}{2}(1.0\,\mathrm{kg})[(-1\,\mathrm{m/s})^2 - (3\,\mathrm{m/s})^2] = -4.00\,\mathrm{J}$$

c. How much work did m_1 do on m_2 during this collision?

$$Work_{12} = (\Delta KE)_2 = \tfrac{1}{2}m(v_2'^2 - v_2^2) = \tfrac{1}{2}(2.0\,\mathrm{kg})(2.0\,\mathrm{m/s})^2 = +4.00\,\mathrm{J}$$

d. How much total work was done during the collision?

$W_{tot} = 0$ [The collision was elastic!]

3. A block of mass m = 2.6 kg slides on level ground with coefficient of kinetic friction μ = 0.35.

a. How much work does friction do during x = 1.00 m of slide?

$W_f = -\mu mgx$ since $N = mg$ and $\theta = 180^\circ$ $\quad W = -8.9\,\mathrm{J}$

b. How much initial velocity v_0 should the block have, if it is to slide x = 7.0 m before coming to rest?

Friction does $-7 \times 8.9\,\mathrm{J} = -62.4\,\mathrm{J} = \Delta KE = 0 - (KE)_i$

$\tfrac{1}{2}mv^2 = 62.4\,\mathrm{J}$ so $v = 6.9\,\mathrm{m/s}$