Homework Set #7

1) A centrifuge is a device in which a small container of material is rotated at high speed on a circular path. Such a device is used in medical laboratories, for instance, to cause the more dense red blood cells to settle through the less dense blood serum and collect in the bottom of the container. Suppose a centrifuge acceleration of a sample is 6250 times as large as the acceleration due to gravity. How many revolutions ***per minute*** is the sample making if it is located at a radius of 5.00 cm from the axis of rotation?

2) A penny is place on the outer edge of a disk (radius = 0.150m) that rotates about an axis that is perpendicular to the plane of the disk at its center. The period of rotation is 1.80 seconds. Find the minimum coefficient of static friction necessary to allow the penny to rotate along with the disk.

3) Two newly discovered planets follow circular orbits around a star in a distant part of the galaxy. The orbital speeds of the planets are determined to be 43.3 km/s and 58.6 km/s. The slower planet's orbital period is 7.6 years. a) What is the mass of the star and b) what is the orbital period of the faster planet, in years?

4) The hammer throw is a track and field event in which a 7.3 kg ball (the hammer) is whirled around in a circle several times and released. It then moves upward on the familiar curving path of projectile motion and eventually returns to the earth some distance away. The world record for this distance is 86.75m, achieved in 1986 by Yuri Sedykh. Ignore air resistance and the fact that the ball is release above the ground rather that at ground level. Furthermore, assume that the ball is whirled in a circle of 1.8 m and its velocity at the instant of release is directed 41° above the horizontal. Find the magnitude of the centripetal force acting on the ball just prior to the moment of release. (Hint: recall that you can find the velocity of release from the angle of release and the range.)

1) $a_c = 6250\,g = (6250)(9.8\ m/s^2) = 61250\ m/s^2$

$a_c = \frac{v^2}{r} \Rightarrow v = \sqrt{r a_c} = \sqrt{(0.05m)\,61250\ m/s^2}$

$v = 55.3\ m/s$

But $v = \frac{2\pi r}{T} \Rightarrow T = \frac{2\pi r}{v} = \frac{2\pi(0.05\ m)}{(55.3\ m/s)}$

$T = 5.677 \times 10^{-3}\,s \left(\frac{1\ m}{60\ s}\right)$

$= 9.462 \times 10^{-5}\ min$

$\#\text{ of Rev/min} = \frac{1}{T} = 10569\ rev/min.$

b) Now, invert equation

$$T = \frac{2\pi M G}{V^3} \Rightarrow T = \frac{C}{V^3}$$

$$\frac{T_2 = \frac{C}{V_2^3}}{T_1 = \frac{C}{V_1^3}} \Rightarrow \frac{T_2}{T_1} = \frac{V_1^3}{V_2^3} = \left(\frac{V_1}{V_2}\right)^3$$

$$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^3 = 7.6\,yr \left(\frac{43.3}{58.6}\right)^3$$

$$= 3.1\,yr$$

4) Recall that $\text{Range} = \frac{V_0^2}{g} \sin(2\alpha) \Rightarrow V_0 = \sqrt{\frac{Rg}{\sin(2\alpha)}}$

$R = 86.75\,m$

$\alpha = 41°$

$m = 7.3\,kg$

$$V_0 = \sqrt{\frac{(86.75\,m)(9.8\,m/s^2)}{\sin(82°)}} = 29.3\,m/s$$

Now $F_c = \frac{mv^2}{r}$

$$= \frac{(7.3\,kg)(29.3\,m/s)^2}{1.8\,m}$$

$$\boxed{F_c = 3482\,N}$$

2) For Penny to stay in place, friction must supply F_c

$$F_c = \frac{mv^2}{r} \qquad V = \frac{2\pi r}{T} = \frac{2\pi(0.150\,m)}{1.8\,s}$$

$$= 0.524\ m/s$$

$$F_c = \frac{mv^2}{r} = \mu m g$$

$$\Rightarrow \mu g = \frac{v^2}{r} \quad \text{or} \quad \mu = \frac{v^2}{rg}$$

$$\mu = \frac{(0.524\ m/s)^2}{(0.150\ m)(9.8\ m/s^2)} = 0.187$$

3) For Planet #1

a) $V = 43.3\ km/s$ $\qquad \frac{GM}{r^2} = \frac{v^2}{r} \Rightarrow M = \frac{v^2 r^2}{G r}$

$T = 7.6\ yr = 2.4\times10^8\,s$

$= (7.6\,yr)\left(\frac{365\,day}{1\,yr}\right)\left(\frac{24\,hr}{day}\right)\left(\frac{3600\,s}{1\,hr}\right)$ $\quad$ OR $\quad M = \frac{v^2 r}{G}$

But $V = \frac{2\pi r}{T} \Rightarrow r = \frac{VT}{2\pi}$

Now

$$M = \frac{v^2}{G}\left(\frac{VT}{2\pi}\right) = \frac{V^3 T}{2\pi G}$$

$$= \frac{(43.3\times10^3\ \frac{m}{s})^3 (2.4\times10^8\ s)}{2\pi\ 6.67\times10^{-11}\ N\cdot m^2/kg^2}$$

$$= \frac{(4.33)^3(2.4)\times10^{12}\times10^8}{2\pi\ 6.67\ \times10^{-11}} \quad \frac{m^3}{s^3}\frac{s^2\ kg^2}{kg\,m\ m^2}$$

$$= 4.65\times10^{31}\ kg$$