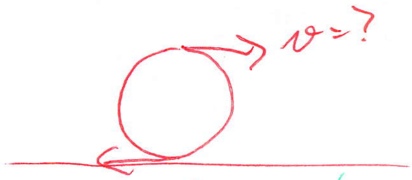
Level I Key Pd 1

Circular Motion

AT circular motion (13)

Directions: Solve the following problems. Each is worth 5 points. Show all work and circle your answer.

1) Determine the speed of a car if the 42 cm (radius) wheels spin at 9 revs/s. Express your answer in miles/hour.



Relative Motion Between the Tire And the Road Is Zero

$v = 2\pi r f$

$v = 2\pi(.42\,m)(9\,Rev/s)$

$v = 23.7\,m/s$

Highway Speed...

$\left(23.7\frac{m}{s}\right)\left(\frac{1\,mi}{1600\,m}\right)\left(\frac{3600\,s}{1\,hr}\right) =$

$53\,mi/hr$

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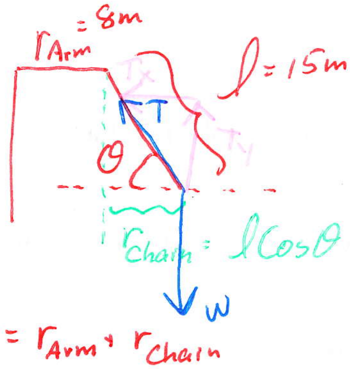
$G = 6.67\times10^{-11}\,Nm^2/kg^2$ $m_e = 5.98\times10^{24}$ $r_e = 6.38\times10^{6}\,m$ $m_m = 0.0735\times10^{24}\,kg$ $r_m = 1.74\times10^{6}\,m$

2) Please consider a "swing ride" where the seats hang from chains supported by an arm of radius 8m. The chains are 15 m long (See the photo below). When the ride is up to full speed, the chains hang with an angle of 25 degrees from horizontal. Determine the frequency of the ride.



$$\Sigma F_y = T_y - W = ma$$
$$T_y - W = 0$$
$$T\sin\theta = mg$$
$$T = \frac{mg}{\sin\theta}$$

$$\Sigma F_x = T_x = -ma_c$$
$$T_x = ma_c$$
$$T\cos\theta = \frac{mv^2}{r}$$
$$\frac{mg\cos\theta}{\sin\theta} = m4\pi^2 r f^2$$

$$\frac{g\cos\theta}{\sin\theta} = 4\pi^2 f^2 (r_{Arm} + r_{Chain})$$

$$\frac{g\cos\theta}{\sin\theta} = 4\pi^2 f^2 (r_{Arm} + l\cos\theta)$$

$$\sqrt{\frac{g\cos\theta}{(\sin\theta)4\pi^2(r_{Arm} + l\cos\theta)}} = f$$

$$\sqrt{\frac{(9.8\frac{m}{s^2})\cos(25^\circ)}{\sin(25^\circ)4\pi^2(8m + 15m\cos(25^\circ))}} = .157 \text{ Hz}$$

-or-

~ 7 sec/Rev

Reasonable... period Not Required... But It Was Easier For Me To Think In "Time"

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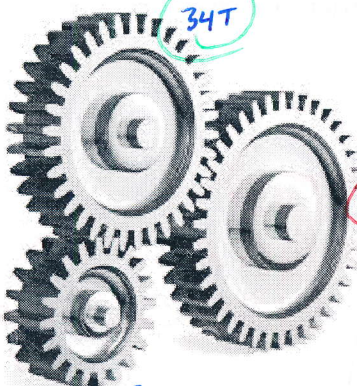
3) Counting around clockwise, and starting with the small gear in the lower left, the small gear has 20 teeth, the upper left has 34 teeth, and the gear in the lower right has 39 teeth. If the small gear turns with a frequency of 5 revs/s, determine the frequency of the 39T gear.



34T

39T

20T

the "number of Teeth" Serves As the Circumference...

Linear Distance ⇒ Teeth

Linear Speed ⇒ $\frac{\text{Teeth}}{\text{Second}}$

Meshing Teeth Have Same Speed (or they would be "Breaking Teeth")

$f = 5\ \text{Rev/s}$

$v = (20T)(5\ \text{Rev/s}) = 100T/s$

$100\frac{T}{s} = (34T)\,f$

$2.94\frac{\text{Rev}}{s} = f$ ... No Need To Do this... All the Gears Have A Linear Speed of 100T/s On the Outer Edge

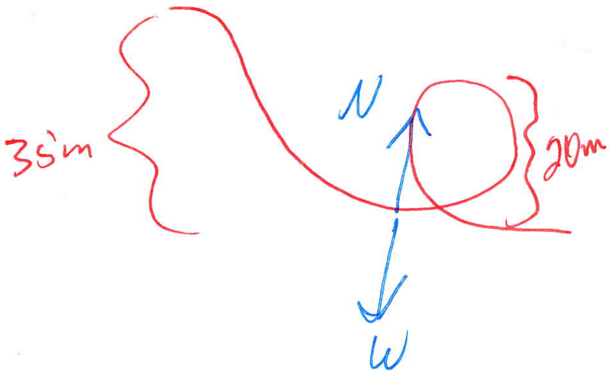
$100\frac{T}{s} = (39T)\,f$

$\frac{100T/s}{39T} = f = 2.56\ \text{Rev/s}$

$G=6.67\times10^{-11}\,Nm^2/kg^2$ $m_e=5.98\times10^{24}$ $r_e=6.38\times10^6 m$ $m_m=0.0735\times10^{24}$ kg $r_m=1.74\times10^6 m$

4

5) A looping roller coaster tops the first main hill at some insignificantly slow speed 35 m above the ground. The track then drops to ground level, through a loop of height 20 m, then back down to the ground. The loop does not have a constant radius. Determine the radius of curvature at the top of the loop so the rides feel 2g, as though they feel heavier in their seats.



(This Diagram Is better...)

$N = 2mg$

$\Sigma F_y = N - w = ma_c$

$N - w = \frac{mv^2}{r}$

$2mg - mg = \frac{m\,2gh}{r}$

$2 - 1 = \frac{2h}{r}$

$1 = \frac{2h}{r}$

$r = 2h$

$r = 70m$

Wrong problem

$PE = KE$

$mgh = \frac{1}{2}mv^2$

$\sqrt{2gh} = v$ (Ahh...)

$2gh = v^2$

$\Sigma F_y = -N - W = -ma_c$

$-2mg - mg = -ma_c$

$2mg + mg = \frac{mv^2}{r}$

$3mg = \frac{mv^2}{r}$

$3mg = \frac{m2gh}{r}$

$3 = \frac{2h}{r}$

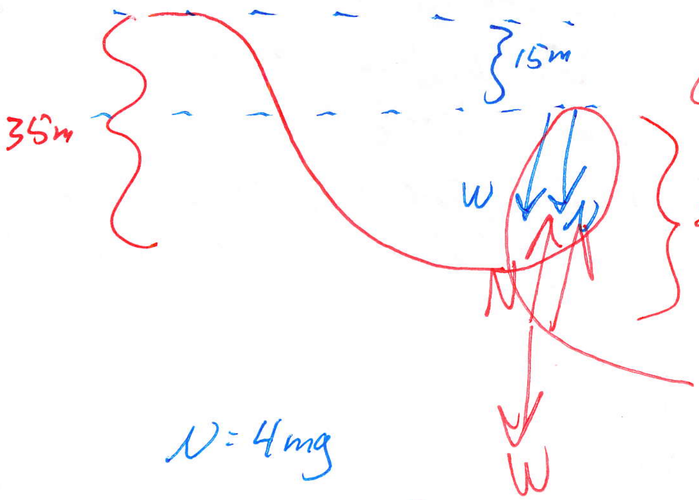
$r = \frac{2h}{3}$

$r = \frac{(2)(15m)}{3}$

$r = 10m$

3

4) A looping roller coaster tops the first main hill at some insignificantly slow speed 35 m above the ground. The track then drops to ground level, through a loop of height 20 m, then back down to the ground. The loop does not have a constant radius. Determine the radius of curvature at the bottom of the loop so the rides feel 4g, as though they feel heavier in their seats.



(Bad Diagram...)

$N = 4mg$

$\Sigma F = -N - \cancel{w} = -ma_c$

$N + w = ma_c$

$N + w = \frac{mv^2}{r}$

$4\cancel{mg} + \cancel{mg} = \frac{\cancel{m}2\cancel{g}h}{r}$

$4 + 1 = \frac{2h}{r}$

$r = \frac{2h}{(4+1)}$

$r = \frac{2(15m)}{(5)} = 6m$

$PE = KE$

$mgh = \frac{1}{2}mv^2$

$2gh = v^2$

$\Sigma F = N - W = ma_c$

$4mg - mg = \frac{mv^2}{r}$

$4\cancel{mg} - \cancel{mg} = \frac{\cancel{m}2\cancel{g}h}{r}$

$r(4 - 1) = 2h$

$r(3) = 2h$

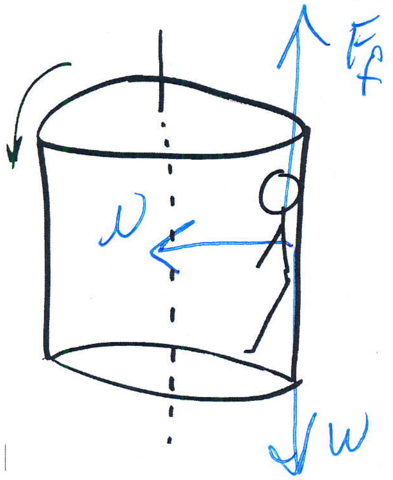
$r = \frac{2h}{3}$

$r = \frac{(2)(35m)}{3}$

$r = 23.3m$

$G=6.67\times10^{-11}Nm^2/kg^2$ $m_e=5.98\times10^{24}$ $r_e=6.38\times10^6m$ $m_m=0.0735\times10^{24}$ kg $r_m=1.74\times10^6m$

6) The "Taz Twister" is a ride at Six Flags. Referring to the hand drawing below, consider a round "room" that spins on a vertical axis. The round room has a radius of 2.5 m. The room spins at a rate of about 1.5 revs/s. Once the room is at speed the floor drops 2 feet while you "stick" to the wall. Determine the coefficient of friction that is needed for you to stay on the wall.



$$\Sigma F_y = F_f - W = 0$$

$$\mu N = mg$$

$$N = \frac{mg}{\mu}$$

$$\Sigma F_x = -N = -ma_c$$

$$N = ma_c$$

$$N = \frac{mv^2}{r}$$

$$\frac{mg}{\mu} = \frac{mv^2}{r}$$

$$\frac{g}{\mu} = \frac{(2\pi r f)^2}{r}$$

$$\frac{g}{\mu} = 4\pi^2 r f^2$$

$$\frac{g}{4\pi^2 r f^2} = \mu = \frac{9.8\,m/s^2}{4\pi^2 (2.5m)(1.5\,Rev/s)^2} = .04$$

7) Determine the altitude above the surface of the moon for a satellite to orbit the moon once every 15 hours.

$$F_c = F_g$$

$$\frac{mv^2}{r} = \frac{Gmm}{r^2}$$

$$v^2 = \frac{Gm}{r}$$

$$\frac{4\pi^2 r^2}{T^2} = \frac{Gm}{r}$$

$$r = \sqrt[3]{\frac{GmT^2}{4\pi^2}}$$

$$r = \sqrt[3]{\frac{(6.67\times10^{-11})(.0735\times10^{24}\,kg)\left[(15\,hrs)(3600\,s/1\,hr)\right]^2}{4\pi^2}}$$

$r = 7.13\times10^6\,m$ from the Center of the moon

$$r_{Alt} = 7.13\times10^6\,m - 1.74\times10^6\,m$$

$r_{Alt} = 5.39\times10^6\,m$ = ~~33,000~~ 3,300 miles

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8) Determine the linear speed needed for a Hershey bar (16oz) to orbit you (65 kg) if you were deep in space just floating (express your answer in cm/hr)...far from the effects of any other gravitational field.

$$F_c = F_g$$

$$\frac{mv^2}{r} = \frac{Gmm}{r^2}$$

$$v^2 = \frac{Gm}{r}$$

$$v = \sqrt{\frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)(65kg)}{1m}}$$

$$v = 6.58\times10^{-5}\,m/s = \cancel{6.58\times10^{-7}}$$

$$\left(6.58\times10^{-5}\frac{m}{s}\right)\left(\frac{3600s}{1hr}\right)\left(\frac{100cm}{1m}\right) = .237\ cm/hr$$

$G=6.67\times10^{-11}Nm^2/kg^2$ $m_e=5.98\times10^{24}$ $r_e=6.38\times10^6m$ $m_m=0.0735\times10^{24}$ kg $r_m=1.74\times10^6m$

9) Determine the gravitational field strength 1,000 miles above the surface of the Earth.

$$mg = \frac{Gmm}{r^2}$$

$$g = \frac{Gm}{r^2} = \frac{\left(6.67\times10^{-11}\frac{Nm^2}{kg^2}\right)\left(5.98\times10^{24}\,kg\right)}{\left(\cancel{1.6\times10^{6}}\ 7.98\times10^{6}\,m\right)^2}$$

$$g = 6.3\,m/s^2$$

$G=6.67\text{x}10^{-11}Nm^2/kg^2$ $m_e=5.98\text{x}10^{24}$ $r_e=6.38\text{x}10^6m$ $m_m=0.0735\text{x}10^{24}$ kg $r_m=1.74\text{x}10^6m$