

key Level I Physics Pd 3

Circular Motion

AT circular motion (14)

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

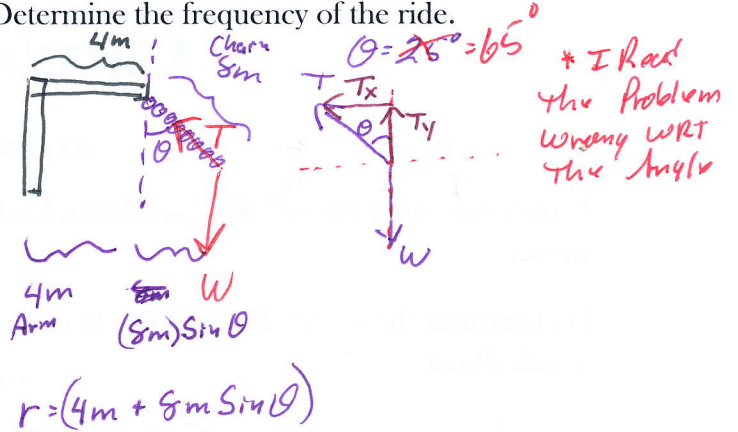
1) Determine the speed of a car if the 42 cm (radius) wheels spin at 9 revs/s. Express your answer in miles/hour.

Car Speed Is the Same As the linear Speed of the Outer Edge of the Car Wheel.

$$v = 2\pi r f = 2\pi (0.42\text{m})(9\text{ Rev/s}) = 23.7\text{ m/s}$$

$$\left(23.7\frac{\text{m}}{\text{s}}\right)\left(\frac{1\text{mi}}{1600\text{m}}\right)\left(\frac{3600\text{s}}{1\text{hr}}\right) = \text{53 mi/hr}$$

2) Please consider a "swing ride" where the seats hang from chains supported by an arm of radius 4m. The chains are 8 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.



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

$$T \cos \theta = W$$

$$T \cos \theta = mg$$

$$T = \frac{mg}{\cos \theta}$$

$$\Sigma F_x = T_x = m a_c$$

$$T \sin \theta = \frac{m v^2}{r}$$

$$\left(\frac{mg}{\cos \theta} \right) \sin \theta = \frac{m (4\pi^2 r^2 f^2)}{r}$$

$$mg \tan \theta = m 4\pi^2 f^2 r$$

$$g \tan \theta = 4\pi^2 f^2 r$$

$$g \tan \theta = 4\pi^2 f^2 (\text{Arm} + \text{Chain} \sin \theta)$$

$$\sqrt{\frac{g \tan \theta}{4\pi^2 (\text{Arm} + \text{Chain} \sin \theta)}} = f$$

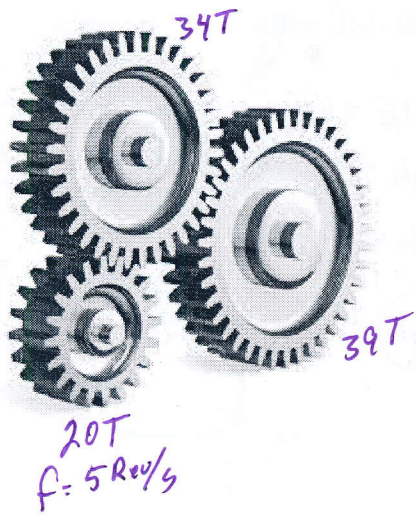
$$\sqrt{\frac{(9.8 \frac{m}{s^2}) \tan(65^\circ)}{4\pi^2 (4m + 8m \sin(65^\circ))}} = f = \cancel{0.25 \text{ Rev/s}} \approx 8 \text{ seconds per Rev}$$

0.22 Rev/s

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

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.



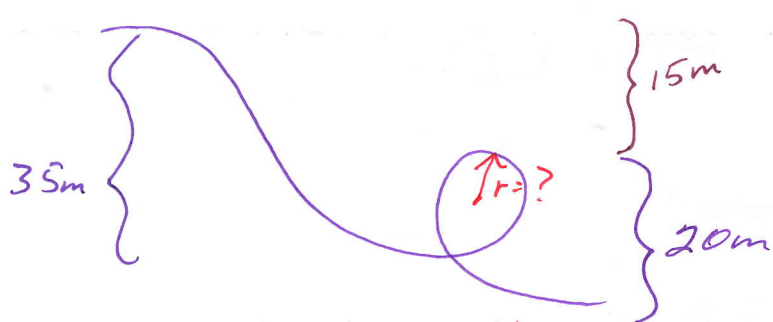
$$\left(\frac{5 \text{ Rev}}{\text{s}}\right) \left(\frac{20\text{T}}{1\text{Rev}}\right) \left(\frac{1\text{Rev}}{34\text{T}}\right) \left(\frac{39\text{T}}{1\text{Rev}}\right)$$

Little gear $\Rightarrow 100\text{T/s}$

Linear Speed Is the Same For All

$$\left(\frac{100\text{T}}{\text{s}}\right) \left(\frac{1\text{Rev}}{39\text{T}}\right) = 2.56 \text{ Rev/s}$$

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 top of the loop so the rides feel 4g, as though they feel heavier in their seats.



$$PE = KE$$

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

$$gh = \frac{1}{2}v^2$$

$$2gh = v^2$$

Forces At Top of Loop



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

$$N = 4mg \text{ [4 Times "normal" Weight]}$$

$$W + N = ma$$

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

$$mg + 4mg = \frac{m2gh}{r}$$

$$g + 4g = \frac{2gh}{r}$$

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

$$5 = \frac{2h}{r}$$

$$r = \frac{2h}{5}$$

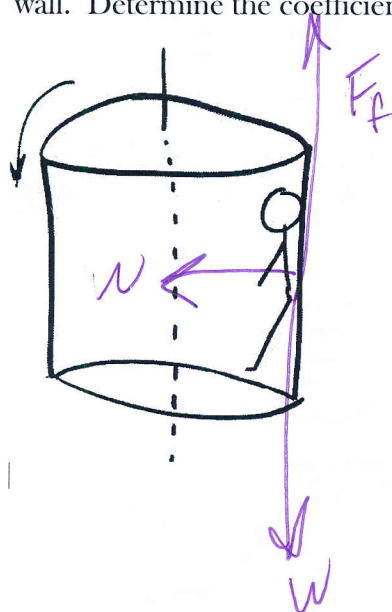
$$r = \frac{2(15m)}{5}$$

$$r = 6m$$

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5) 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 .75 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.



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

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

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

$$\frac{9.8 \text{ m/s}^2}{4\pi^2 (2.5 \text{ m}) (.75 \text{ Rev/s})^2} = \mu \approx 0.177$$

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

$$\mu N - W = 0$$

$$\mu N = W$$

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

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

$$T = (15 \text{ hr}) \left(\frac{3600 \text{ s}}{1 \text{ hr}} \right) = 54000 \text{ s}$$

$$F_c = F_g$$

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

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

$$\frac{4\pi^2 r^3}{T^2} = \frac{Gmm}{r}$$

$$r^3 = \frac{GmmT^2}{4\pi^2}$$

$$r = \sqrt[3]{\frac{(6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}) (0.0735 \times 10^{24} \text{ kg}) (54000 \text{ s})^2}{4\pi^2}}$$

$r = 7.13 \times 10^6 \text{ m}$ from the centre

$$r = 7.13 \times 10^6 \text{ m} - 1.74 \times 10^6 \text{ m} = 5.39 \times 10^6 \text{ m}$$

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7) Determine the linear speed of a Hershey bar (16oz) if it were to orbit you (65 kg) just past an arm's length 0.8 m if you were deep in space just floating (express your answer in cm/hr)...far from the effects of any other gravitational field.

$$F_c = F_g$$

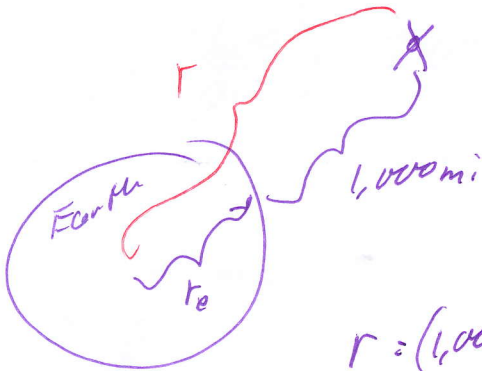
$$\frac{mv^2}{r} = \frac{Gmm}{r^2}$$

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

$$v = \sqrt{\frac{(6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2})(65 \text{kg})}{(0.8 \text{m})}}$$

$$v = 7.36 \times 10^{-5} \text{ m/s} = 7.36 \times 10^{-3} \text{ cm/s} = .0736 \text{ mm/s}$$

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



$$r = (1,000 \text{ mi}) \left(\frac{1600 \text{ m}}{1 \text{ mi}} \right) + 6.38 \times 10^6 \text{ m}$$

$$r = 7.98 \times 10^6 \text{ m}$$

$$F_g = F_g = mg$$

$g \Rightarrow$ gravitational Field Strength

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

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

$$\frac{(6.67 \times 10^{-11}) (5.98 \times 10^{24})}{(7.98 \times 10^6 \text{ m})^2} = 6.26 \text{ m/s}^2$$

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