Mastering Physics Assignment 2

Is available on Mastering Physics website

Seven practice problems + six for credit on material from chapter 3

Due Wednesday, October 10 at 11 pm
Penalty of 25% per day late
Assignment available for practice until end of year

On Campus Machines
Use Firefox if problems with Internet Explorer!

GENERAL PHYSICS I: PHYS 10

Schedule - Fall 2007
(lecture schedule is approximate)

	W	3	12	Chapter 5	Uniform circular motion	(chapters 1, 2, 3)
	F	5	13			
6	M	8	Thanksgiving Day			Experiment 2: Measurement of g by free fall
	W	10	14	Chapter 5	Uniform circular motion	
	F	12	15	Chapter 6	Work and energy	
7	M	15	16			Tutorial and Test 2 (chapters 4, 5)
	W	17	17			
	F	19	18	Chapter 7	Impulse and momentum	
8	M	22	19			No lab or tutorial
	Tue	23	MID-TERM TEST, Ch 1-5, Tuesday, October 23, 7-9 pm			
	W	24	20	Chapter 7	Impulse and momentum	
	F	26	21	Chapter 8,		

Experiment 2: Measurement of g by free fall
Week of October 15: Tutorial and test 2: ch. 4, 5
Tuesday, October 23, 7-9 pm, midterm: ch. 1-5
(20 multiple-choice questions)

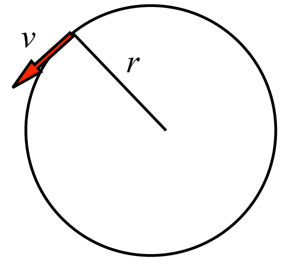
Chapter 5: Uniform Circular Motion

- Motion at constant speed in a circle
- Centripetal acceleration
- Banked curves
- Orbital motion
- Weightlessness, artificial gravity
- Vertical circular motion

Uniform Circular Motion

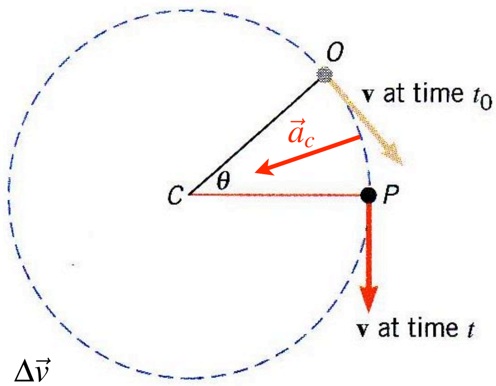
- An object is travelling at constant speed in a circular path.
- The velocity is changing because the direction of the speed is changing and so **the object is accelerated**.
- The period, T, of the motion is the time to go once around the circle.
- For an object travelling at speed v around a circle of radius r –

$$T = \frac{\text{circumference}}{\text{speed}} = \frac{2\pi r}{v}$$



Centripetal Acceleration

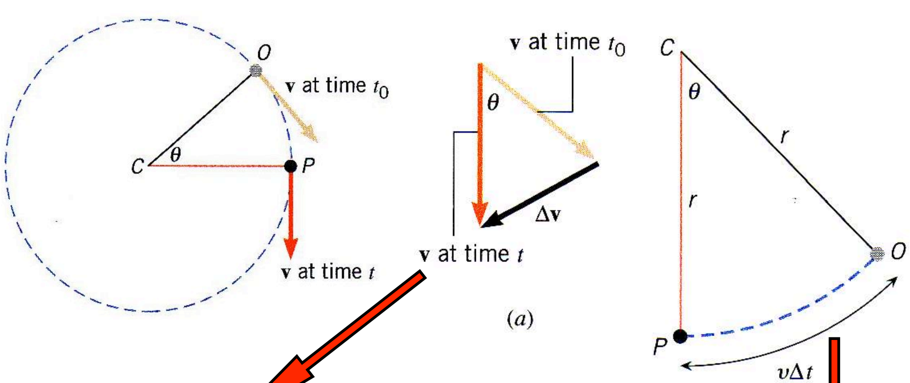
The object is accelerated toward the centre of the circle – this is the centripetal acceleration.



Centripetal acceleration, $\vec{a}_c = \dfrac{\Delta \vec{v}}{\Delta t}$

Work out the change in velocity in a short time interval...

Centripetal Acceleration



$\dfrac{\Delta v}{v} = \theta$ radians, if time interval Δt is short

Object travels $v\Delta t$ in time Δt

$\dfrac{v\Delta t}{r} = \theta$ radians

So, $\theta = \dfrac{\Delta v}{v} = \dfrac{v\Delta t}{r}$ $\qquad a_c = \dfrac{\Delta v}{\Delta t} = \dfrac{v^2}{r}$ = centripetal acceleration

A car is driven at a constant speed of 34 m/s (122 km/h).

What is the centripetal acceleration in the two turns?

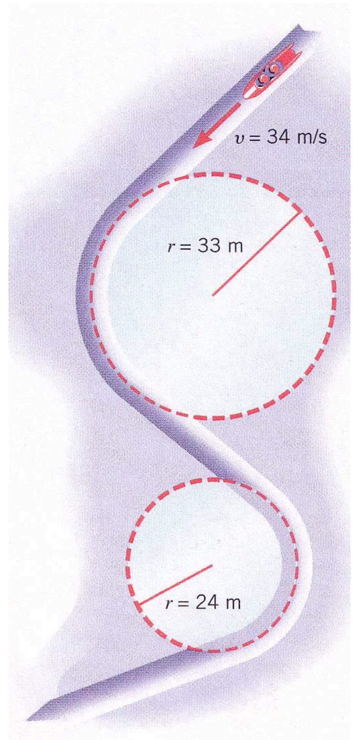
First turn: $r = 33$ m

$$\text{Centripetal acceleration, } a_c = \frac{v^2}{r} = \frac{34^2}{33}$$

$$a_c = 35.0 \text{ m/s}^2 = 3.6 \times g = 3.6g$$

Second turn, $r = 24$ m

$$a_c = \frac{34^2}{24} = 48.2 \text{ m/s}^2 = 4.9g$$



5.7/6: Lettuce drier: spin a container containing the lettuce, water is forced out through holes in the sides of the container.

Radius = 12 cm, rotated at 2 revolutions/second. What is the centripetal acceleration of the wall of the container?

$$\text{Centripetal acceleration, } a_c = \frac{v^2}{r}$$

What is v?

$$v = 2 \times 2\pi r \text{ m/s} = 1.51 \text{ m/s}$$

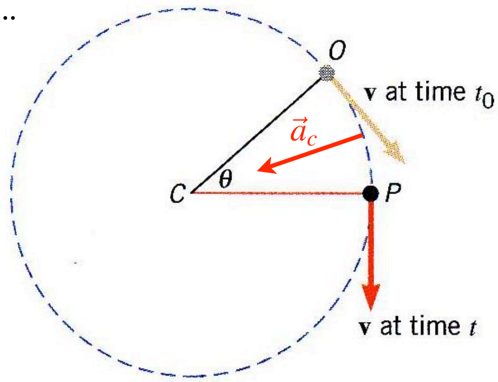
$$a_c = \frac{1.51^2}{0.12} = 18.9 \text{ m/s}^2 = 1.9g$$

Centripetal Force

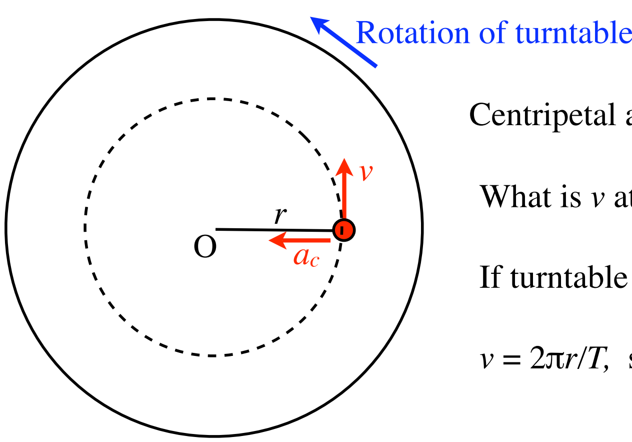
- the force that causes the centripetal acceleration
- acts toward the centre of the circular path – in the direction of the acceleration
- generated by tension in a string, gravity (planetary motion), friction (driving around a curve)...

As F = ma, centripetal force is:

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



5.C11: A penny is placed on a rotating turntable. Where on the turntable does the penny require the largest centripetal force to remain in place? Centripetal force is supplied by friction between the penny and turntable.



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

Centripetal acceleration, $a_c = \frac{v^2}{r}$

What is v at radius r?

If turntable rotates once in T seconds

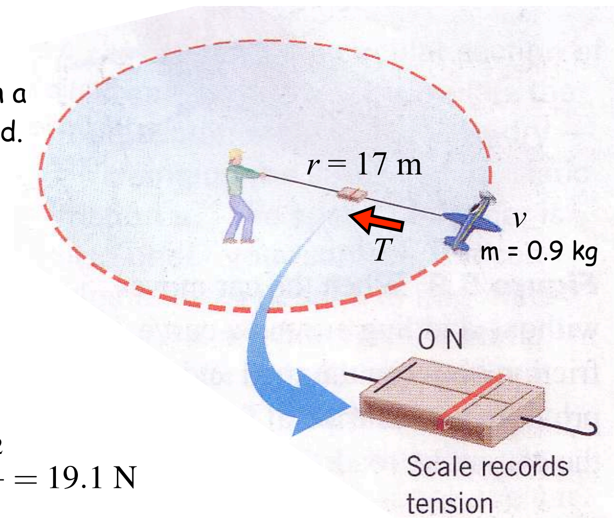
$v = 2\pi r/T$, so $v \propto r$

and $a_c = v^2/r \propto r^2/r = r$

The greatest centripetal acceleration is at the outer edge of the turntable

A 0.9 kg model airplane moves at constant speed in a circle parallel to the ground.

Find the tension in the guideline if r = 17 m and
a) v = 19 m/s and
b) v = 38 m/s.



a) Speed = 19 m/s,

$$T = F_c = \frac{mv^2}{r} = \frac{0.9 \times 19^2}{17} = 19.1 \text{ N}$$

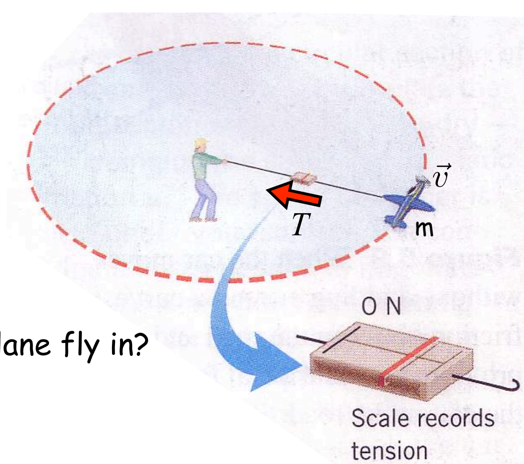
b) Speed = 38 m/s,

$$T = F_c = \frac{mv^2}{r} = \frac{0.9 \times 38^2}{17} = 76.4 \text{ N}$$

A 0.6 kg and a 1.2 kg airplane fly at the same speed using the same type of guideline.

The smallest circle the 0.6 kg plane can fly in without the line breaking is 3.5 m

How small a circle can the 1.2 kg plane fly in?



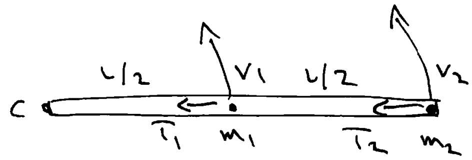
Tension in the line is $T = \frac{mv^2}{r}$

0.6 kg plane: $T = \frac{0.6v^2}{(3.5 \text{ m})}$

1.2 kg plane: $T = \frac{1.2v^2}{r}$

If the tensions are equal: $\frac{0.6v^2}{3.5} = \frac{1.2v^2}{r} \quad \rightarrow r = 3.5 \times 1.2/0.6 = 7 \text{ m}$

5.19/53: A rigid massless rod is rotated about one end in a horizontal circle. There is a mass m_1 attached to the centre of the rod and a mass m_2 attached to the end. The inner section of the rod sustains 3 times the tension as the outer section. Find m_2/m_1.



$T_1 = 3T_2$

$$T_2 = \frac{m_2 v_2^2}{L}$$

$$T_1 = \frac{m_1 v_1^2}{L/2} + T_2 = 3T_2$$

$$\therefore \frac{m_1 v_1^2}{L/2} = 2\frac{m_2 v_2^2}{L}$$

What is v_2 in terms of v_1 ?

$v_2 = 2v_1$ (2x radius)

$$\therefore 2m_1 = 2m_2(2)^2$$

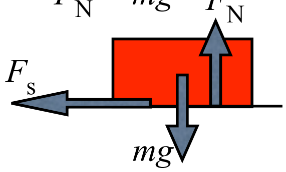
$$m_1 = 4m_2$$

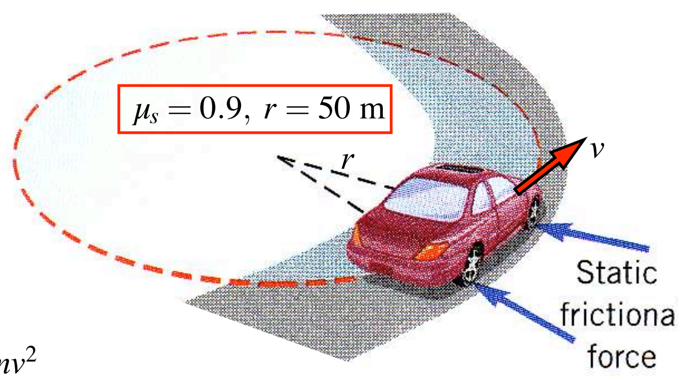
$$\frac{m_2}{m_1} = \frac{1}{4}$$

How fast can you go around a curve?

Forces on the car:

$F_N = mg$





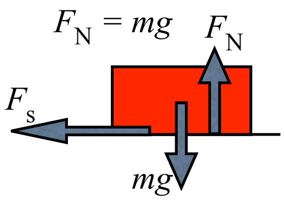
$$\text{Centripetal force } = \frac{mv^2}{r}$$

Provided by static friction force, $F_s = \mu_s F_N = \mu_s mg$

So, $\frac{mv^2}{r} = \mu_s mg \rightarrow v = \sqrt{\mu_s rg} = \sqrt{0.9 \times 50 \times 9.8} = 21$ m/s (76 km/h)

On ice $\mu_s = 0.1 \rightarrow v = 7$ m/s (25 km/h)

5.14/-: Car A uses tires with coefficient of static friction 1.1 with the road on an unbanked curve. The maximum speed at which car A can go around this curve is 25 m/s. Car B has tires with friction coefficient 0.85. What is the maximum speed at which car B can negotiate the curve?



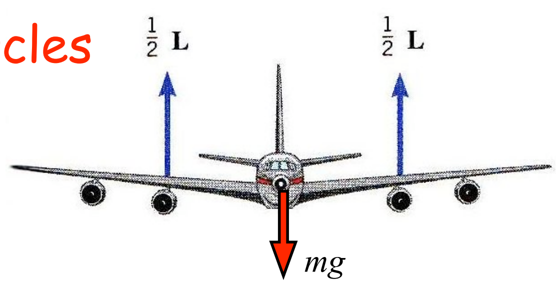
A: $\mu_s = 1.1$, $v_A = 25$ m/s
B: $\mu_s = 0.85$, $v_B = ?$

From previous page, $v = \sqrt{\mu_s r g}$, proportional to $\sqrt{\mu_s}$

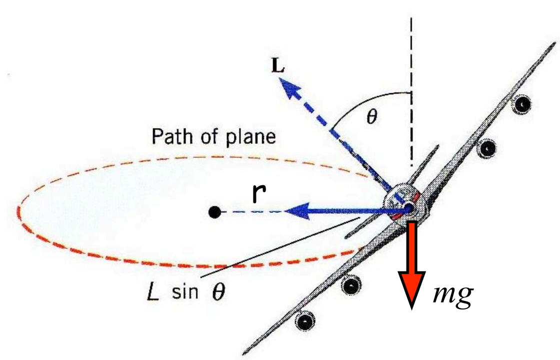
$$\text{Therefore, } \frac{v_B}{v_A} = \sqrt{\frac{0.85}{1.1}} = 0.879$$

$$\text{so, } v_B = 0.879 \times 25 = 22 \text{ m/s}$$

Flying around in circles



Lift: L/2 + L/2 = mg



Plane banking to turn in a horizontal circular path of radius r:

$$L \sin\theta = \frac{mv^2}{r}$$

$$L \cos\theta = mg$$

$$\tan\theta = \frac{v^2}{rg}$$

→ angle of banking needed to make the turn without gaining or losing height

$$\tan\theta = \frac{v^2}{rg}$$ → angle of banking needed to make the turn without gaining or losing height

Example: $v = 100$ m/s (360 km/h), $r = 3{,}000$ m

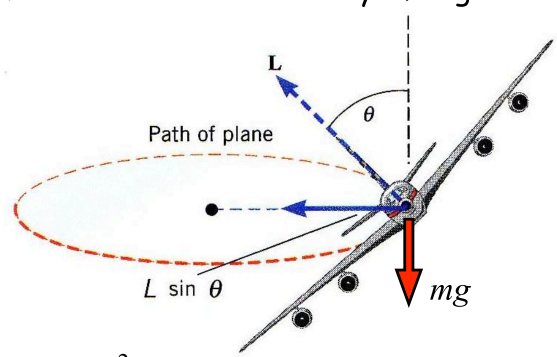
$a_c = v^2/r = 3.33$ m/s^2

$\tan\theta = a_c/g = 0.340$, → $\theta = 19^0$

5.25: A jet (m = 200,000 kg), flying at 123 m/s, banks to make a horizontal turn of radius 3810 m. Calculate the necessary lifting force.

$$L\sin\theta = \frac{mv^2}{r}$$

$$L\cos\theta = mg$$



Trigonometry:

$$\sin^2\theta + \cos^2\theta = 1$$

So, $(L\sin\theta)^2 + (L\cos\theta)^2 = L^2 = (\frac{mv^2}{r})^2 + (mg)^2$

$$\rightarrow\ L = m\sqrt{\left(\frac{v^2}{r}\right)^2 + g^2}$$

$L = 2.11 \times 10^6$ N

Seating for PHYS 1020 Term Test, 2007
Tuesday, October 23, 7-9 pm

Student numbers		Room
From	**To**	
6504394	**6842355**	**200 Fletcher-Argue**
6842547	**6852067**	**200 Armes**
6852080	**6852939**	**206 Tier**
6852942	**6855233**	**306 Tier**
6855256	**7607350**	**223 Wallace**

GENERAL PHYSICS I: PHYS 10

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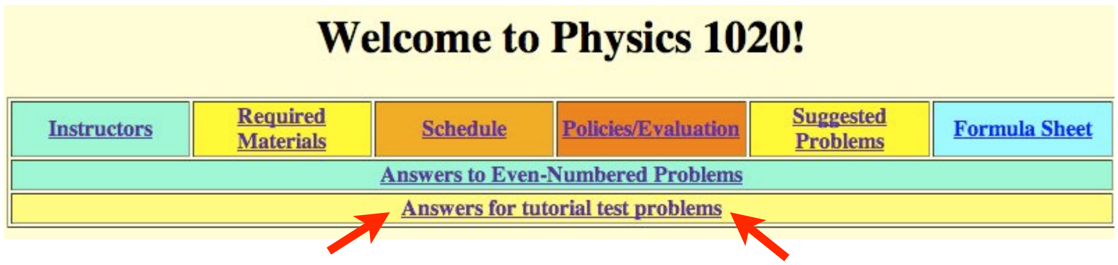
Week of October 15: Tutorial and test 2: ch. 4, 5

Tuesday, October 23, 7-9 pm, midterm: ch. 1-5
(20 multiple-choice questions)

Answers for Tutorial Tests

A link to answers for the tests can be found on the PHYS 1020 home page:



...but only for test 1 so far!

Things Centripetal

or, flying off in all directions

Acceleration toward centre of a circular path of radius r:

$$a_c = v^2/r$$

Force needed to maintain the centripetal acceleration = centripetal force:

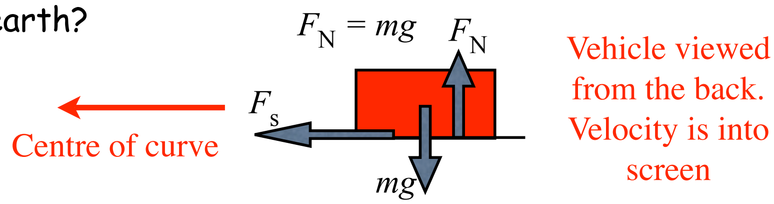
$$F_c = ma_c = mv^2/r$$

Force provided by tension in a string, friction, horizontal component of airplane's lift, gravity...

NB centrifugal force is the force you feel toward the outside of a curve when going around a corner. It's not really a force, but a consequence of Newton's first law that says that things travel at constant velocity (so, in a straight line) unless a force is applied.

Clickers!

5.C6: Other things being equal, would it be easier to drive at high speed (no skidding) around an unbanked horizontal curve on the moon than to drive around the same curve on the earth?

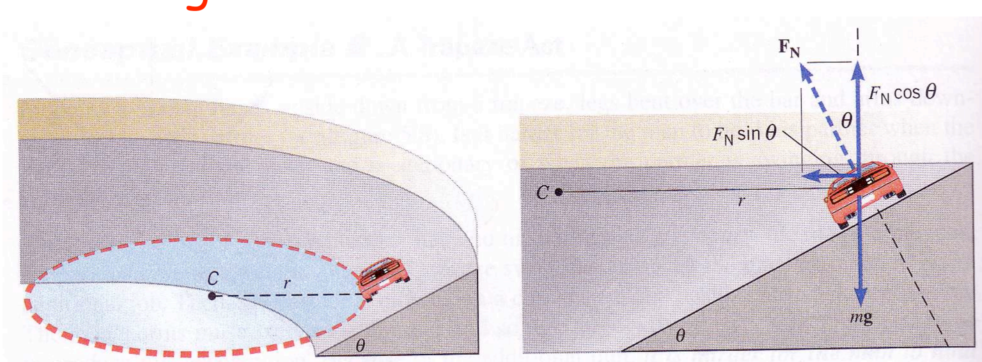


A) Yes, easier on the moon, B) No, more difficult on moon

C) Just the same D) Who knows?

The centripetal acceleration is provided by friction.
The friction force is proportional to the normal force.
The normal force is equal to the weight of the car.
On the moon, the acceleration due to gravity, g_{moon}, is ≈ g/6 ...

Driving around in circles – banked road



No friction!!

As for plane but with lift force replaced by normal force:

$$F_N \sin\theta = \frac{mv^2}{r}$$

$$F_N \cos\theta = mg$$

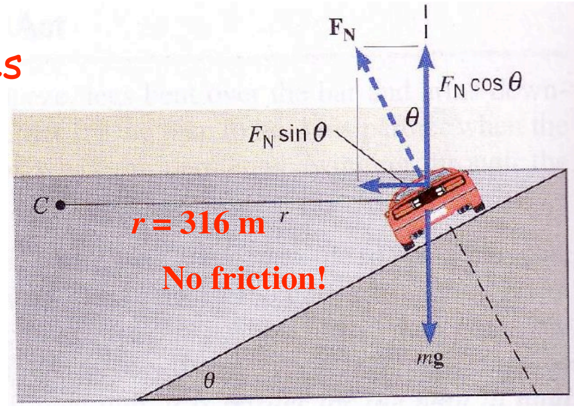
$$\rightarrow \tan\theta = \frac{mv^2}{r} \times \frac{1}{mg} = \frac{v^2}{rg}$$

→ best angle of banking (same as for plane)

Driving around in circles – banked curve

If you drive slowly, you slide **down** the slope.

If you drive fast, you skid **up** the slope.



If θ = 31^0 and r = 316 m, and there is no friction, what is the best speed to drive around the banked curve?

$$\tan\theta = \frac{v^2}{rg}, \text{ so } v = \sqrt{rg\tan\theta}$$

$$v = \sqrt{316 \times 9.8 \tan 31^\circ} = 43.1 \text{ m/s } = 155 \text{ km/h}$$

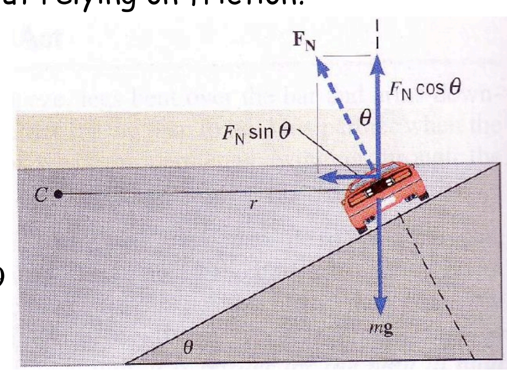
5.20/-: Two banked curves have the same radius. Curve A is banked at 13^0, curve B at 19^0. A car can travel around curve A without relying on friction at a speed of 18 m/s. At what speed can this car travel around curve B without relying on friction?

From previous page: $v = \sqrt{rg\tan\theta}$

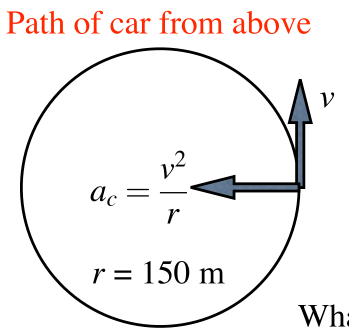
That is, $v \propto \sqrt{\tan\theta}$

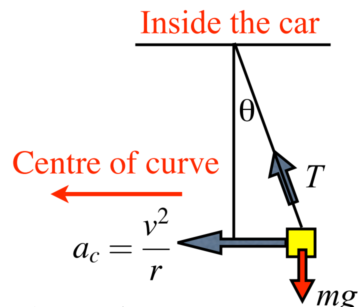
So $\frac{v_A}{v_B} = \sqrt{\frac{\tan\theta_A}{\tan\theta_B}} = \sqrt{\frac{\tan 13^\circ}{\tan 19^\circ}} = 0.819$

Therefore, $v_B = v_A/0.819 = 22$ m/s



5.18: A car travels at 28 m/s around a curve of radius 150 m. A mass is suspended from a string from inside the roof.





What is the angle θ ?

Force toward centre of circular path due to tension in the string:

$$\frac{mv^2}{r} = T\sin\theta \qquad \rightarrow \tan\theta = \frac{v^2}{rg}$$

Forces in the vertical direction: $mg = T\cos\theta$

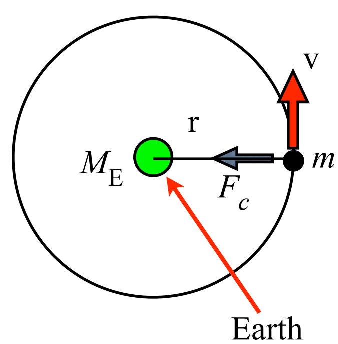
$$\tan\theta = \frac{28^2}{150g} = 0.5333$$

$$\theta = 28.1^\circ$$

Orbiting the Earth

"The secret to flying is to throw yourself at the earth and miss."
Hitch Hiker's Guide to the Galaxy

The centripetal force on the satellite is provided by the gravitational force from the earth.



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

$$\text{So } v = \sqrt{\frac{GM_E}{r}}$$

the smaller the radius, the greater the speed

Synchronous orbit: period = 24 hours

- satellite stays above same part of the earth (above the equator)
- used by communications satellites
- what is the radius of the orbit?

Synchronous Orbit - what is its radius?

The period of an orbit is: $T = \dfrac{\text{circumference of orbit}}{\text{speed of satellite}} \quad = \dfrac{2\pi r}{v}$

What is v?

From previous page, $v = \sqrt{\dfrac{GM_E}{r}}$

So $\boxed{T} = 2\pi r \times \sqrt{\dfrac{r}{GM_E}} \quad = \boxed{2\pi \times r^{3/2}\sqrt{\dfrac{1}{GM_E}}}$

$$r^3 = GM_E\left(\frac{T}{2\pi}\right)^2$$

(Kepler's 3rd law of planetary motion: $T^2 \propto r^3$)

With $T = 24 \times 3600$ s, $r = 4.23 \times 10^7$ m $= 42,300$ km from centre of earth

The speed of the satellite is: $v = \dfrac{2\pi r}{T} = 3070$ m/s $= 11,000$ km/h

5.32/34: The earth orbits the sun once per year at a distance of 1.5×10^{11} m.

Venus orbits the sun at a distance of 1.08×10^{11} m.

What is the length of the year on Venus?

Kepler: $T^2 \propto R^3$,

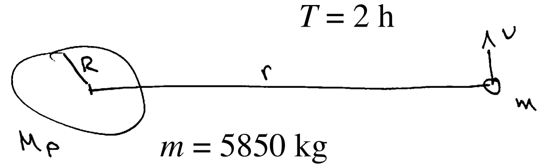
so, $\left(\dfrac{T_V}{T_E}\right)^2 = \left(\dfrac{R_V}{R_E}\right)^3 = \left(\dfrac{1.08}{1.5}\right)^3 = 0.373$

$$T_V = 0.611 T_E$$

The length of the year on Venus is 0.611 Earth years.

5.33: A satellite has a mass of 5850 kg and is in a circular orbit 4.1×10^5 m above the surface of a planet. The period of the orbit is 2 hours. The radius of the planet is 4.15×10^6 m. What is the weight of the satellite when it is at rest on the planet's surface?

$T = 2$ h



What is g at $r = R$?
Need the mass M_p of the planet.

$m = 5850$ kg
$R = 4.15 \times 10^6$ m
$r = 4.1 \times 10^5 + R = 4.56 \times 10^6$ m

The speed of the satellite in orbit is $v = 2\pi r/T$

Centripetal force, $F_c = \boxed{\dfrac{mv^2}{r} = \dfrac{GmM_p}{r^2}} \rightarrow GM_p = v^2 r = \left[\dfrac{2\pi}{T}\right]^2 r^3$

Then, weight on planet's surface, $mg_p = \dfrac{GmM_p}{R^2} = \dfrac{m}{R^2}\left[\dfrac{2\pi}{T}\right]^2 r^3$

$$\text{Weight} = \frac{5850}{(4.15 \times 10^6)^2}\left[\frac{2\pi}{2 \times 3600}\right]^2 \times (4.56 \times 10^6)^3 = 2.45 \times 10^4 \text{ N}$$

($g_p = 4.2$ m/s^2)

Free Fall, Weightlessness

An orbiting satellite is in free fall – there's nothing to hold it up.

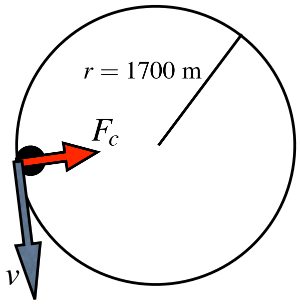
Only its forward speed lets it "miss the earth" (Hitch Hiker's Guide!) and keep orbiting.

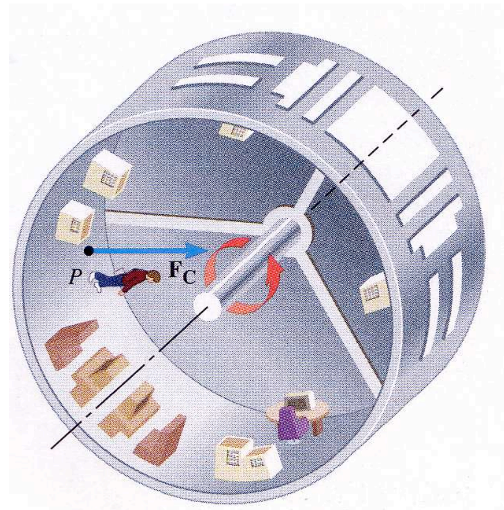
Everything in the satellite is accelerated toward the centre of the earth at the same rate.

An object exerts no force on the bathroom scales as the scales are also being accelerated toward the centre of the earth.

Artificial Gravity

A space station is rotating about its axis to provide an artificial gravity.





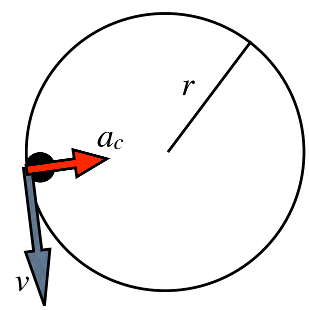
$F_c = \frac{mv^2}{r}$ – make this equal to the person's weight on earth, mg

$$\frac{mv^2}{r} = mg \rightarrow v = \sqrt{rg} = \sqrt{1700 \times 9.8} = 129 \text{ m/s}$$

($2\pi r/v = 83$ seconds per revolution)

Artificial Gravity

5.28/-: Problems of motion sickness start to appear in a rotating environment when the rotation rate is greater than 2 revolutions/minute.



Find the minimum radius of the station to allow an artificial gravity of one gee (a_c = 9.8 m/s^2) while avoiding motion sickness.

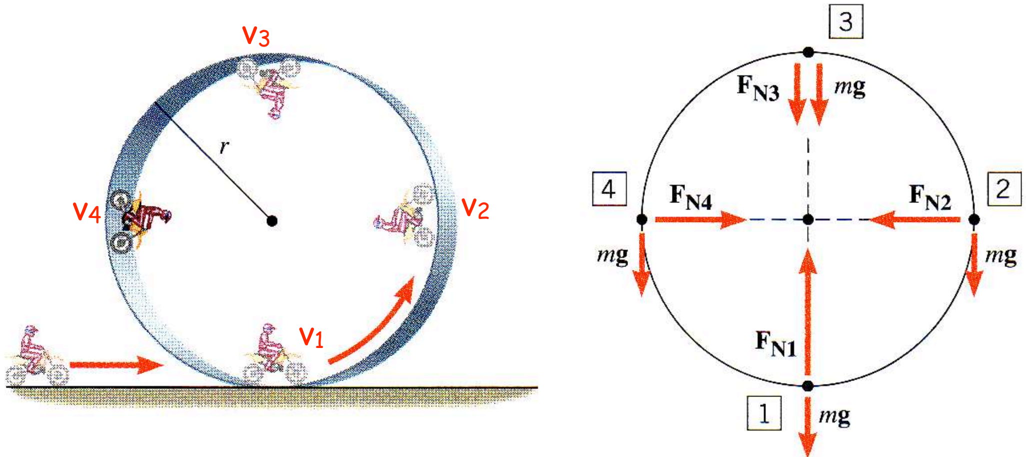
From previous slide, get $a_c = g$ artificial gravity when: $v = \sqrt{rg}$

Period of rotation, $T = \frac{2\pi r}{v} = \frac{2\pi r}{\sqrt{rg}} = 2\pi\sqrt{\frac{r}{g}}$

So, $r = \left[\frac{T}{2\pi}\right]^2 g = 223 \text{ m}$ (for $T = 30$ s)

The minimum radius of the space station is 223 m

Vertical Circular Motion

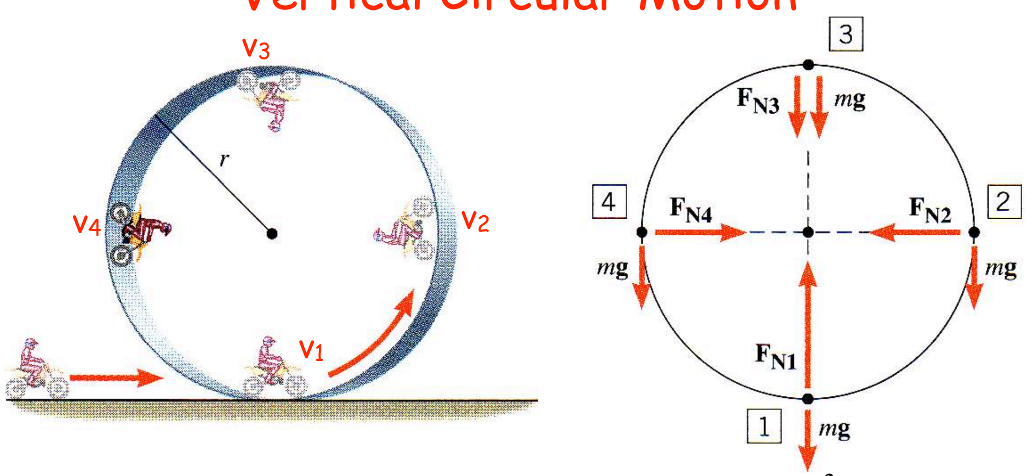


At (1): Net force toward centre of circle $= F_{N1} - mg \;= \dfrac{mv_1^2}{r}$

$$F_{N1} = mg + \frac{mv_1^2}{r} \qquad \text{(greater than the weight)}$$

At (2): Force toward centre of circle $= F_{N2} = \dfrac{mv_2^2}{r}$

Vertical Circular Motion



At (3): Net force toward centre of circle $= F_{N3} + mg \;= \dfrac{mv_3^2}{r}$

$$F_{N3} = \frac{mv_3^2}{r} - mg \qquad \text{Falls off if } F_{N3} = 0, \text{ i.e. } v_3 \le \sqrt{rg}$$

At (4): as for (2)

Chapter 5: Uniform Circular Motion

- Period of circular motion: $T = 2\pi r/v$
- Centripetal acceleration: $a_c = v^2/r$
- Centripetal force: $F_c = ma_c = mv^2/r$
- For motion in a horizontal circle,
  - equilibrium in the vertical direction, vertical forces cancel
  - use Newton's second law to relate net horizontal force to the centripetal acceleration