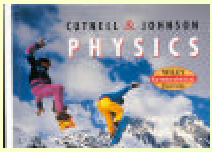
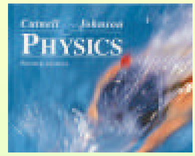




Edition Five

Please refer to

Chapter Five

Sections: 5.1 to 5.6

Chapter 4

Section 4.7

Edition Four

Please refer to

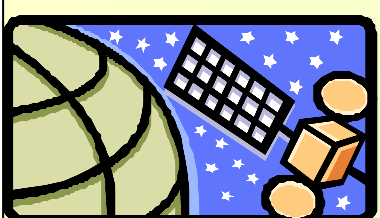
Chapter Five

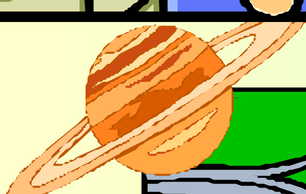
Sections: 5.1 to 5.6

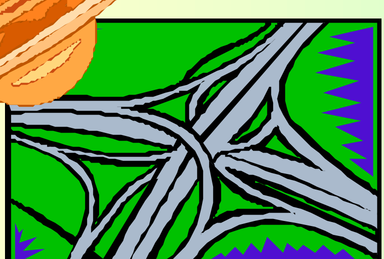
Chapter 4

Section 4.7

CIRCULAR MOTION

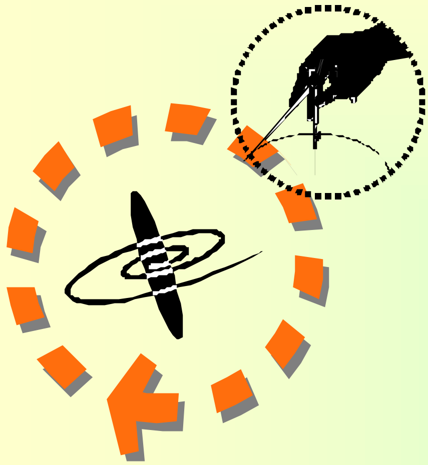




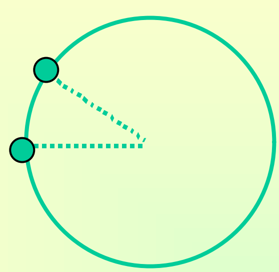


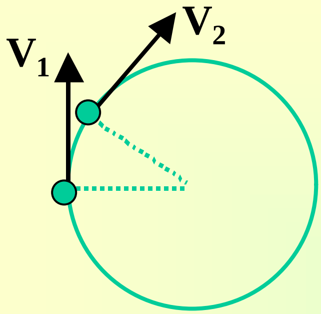
Circular motion…

CIRCULAR MOTION

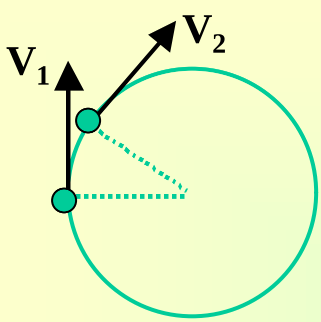


We will study the mechanics (kinematics and dynamics) of a body moving in a circle or a curved path with a constant velocity.



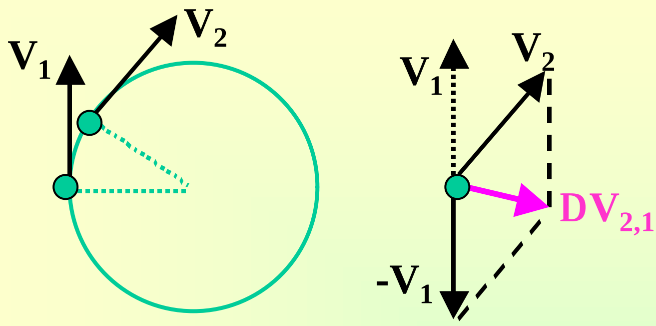


$\mathbf{V}_2$ and $\mathbf{V}_1$ differ in direction but not in magnitude.



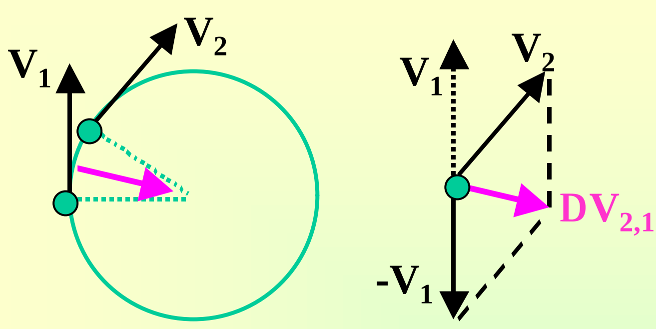
$\mathbf{V}_2$ and $\mathbf{V}_1$ differ in direction but not in magnitude.

What is the difference?



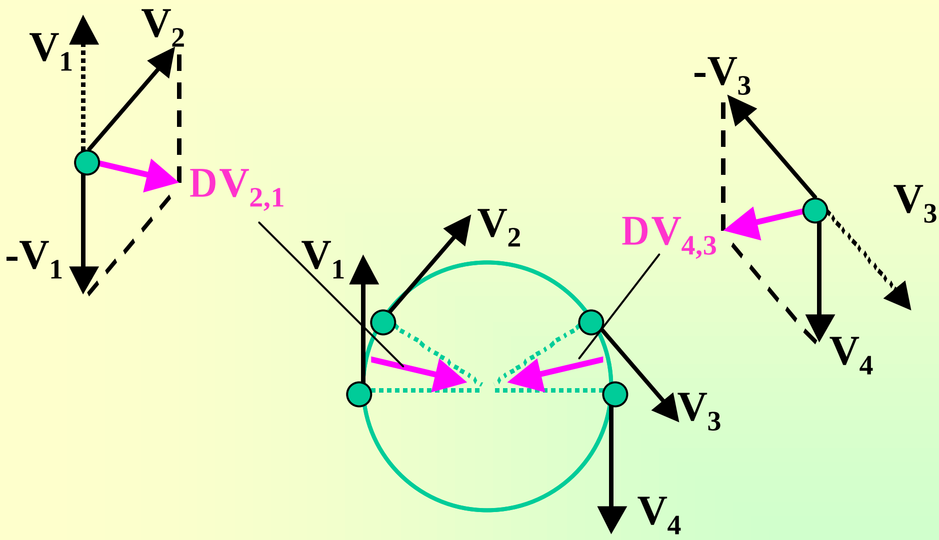
What is the difference?

$DV_{2,1} = V_2 - V_1$



What is the difference?

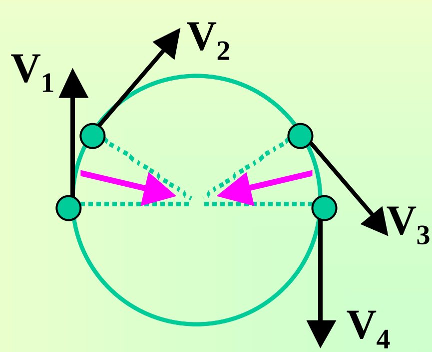
$DV_{2,1} = V_2 - V_1$



CIRCULAR MOTION

For circular motion with a uniform magnitude of velocity, there is an acceleration (DV/t), which is always directed towards the centre of curvature.

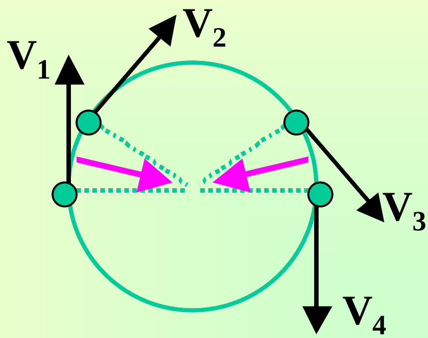
OR ....



CIRCULAR MOTION

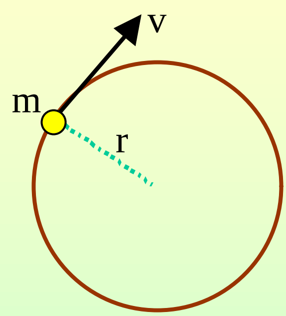
OR ….

When a body moves along a curved path a force acts on the body that is directed towards the centre of curvature. This force is called the Centripetal Force



Centripetal Force, Centripetal Acceleration

When a body moves along a curved path a force acts on the body that is directed towards the centre of curvature. This force is called the Centripetal Force, F_c.



$$F_c = m\,v^2 / r$$

Where

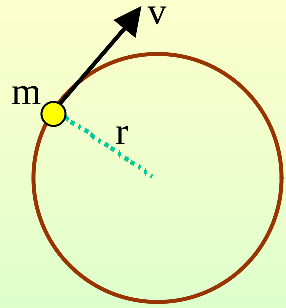
m : body mass

v : magnitude of the velocity

r : radius of curvature

Centripetal Force, Centripetal Acceleration

When a body moves along a curved path a force acts on the body that is directed towards the centre of curvature. This force is called the Centripetal Force, F_c.



$F_c = m\,v^2 / r$

Where

m : body mass

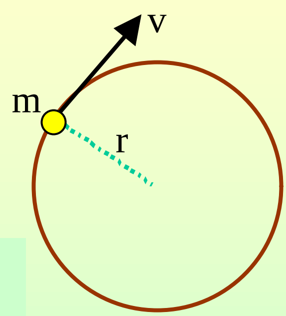
v : magnitude of the velocity

r : radius of curvature

$a_c = v^2 / r$ a_c : Centripetal acceleration

Centripetal Force, Centripetal Acceleration

When a body moves along a curved path a force acts on the body that is directed towards the centre of curvature. This force is called the Centripetal Force, F_c.



$F_c = m\,v^2 / r$

This equation will be in the exam cheat sheet

Where

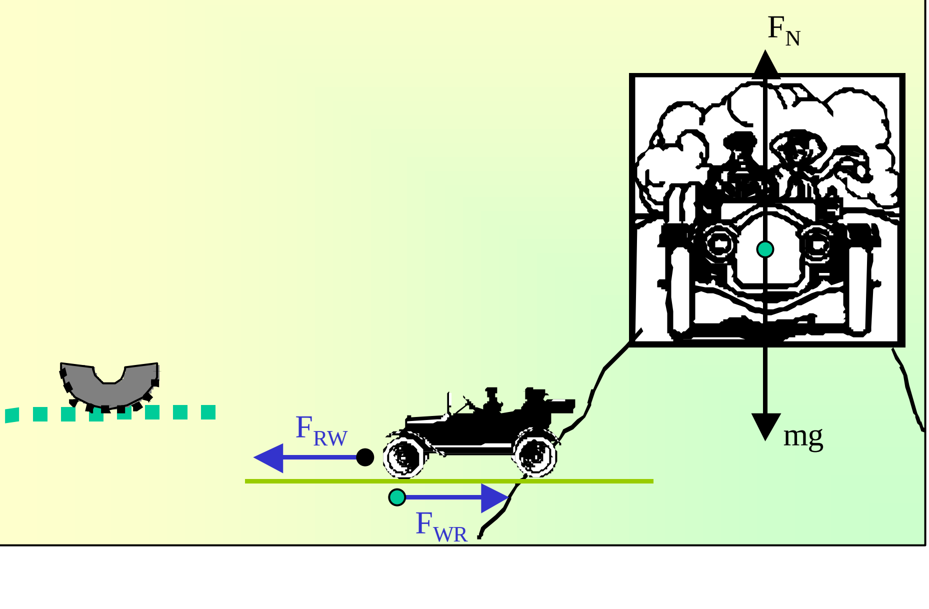
m : body mass

v : magnitude of the velocity

r : radius of curvature

$a_c = v^2 / r$ a_c : Centripetal acceleration

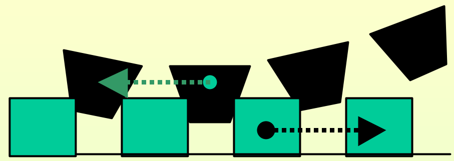
The case of a skidding car

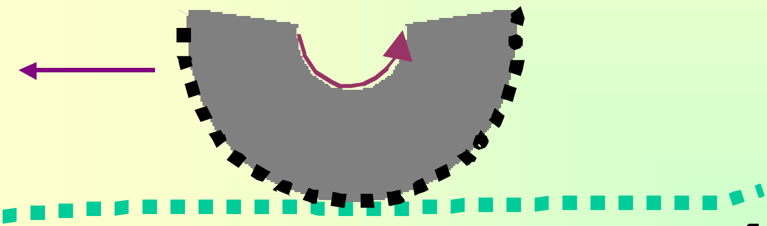


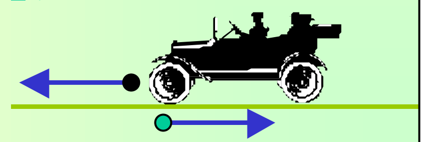
$F_{RW:}$ Force by the road on the wheel.

F_{WR}: Force by the wheel on the road.

The more the F_{WR}, the more the F_{RW}.



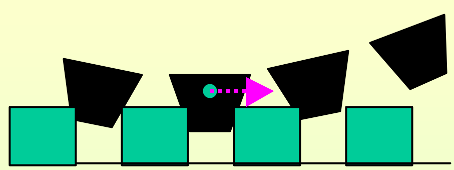


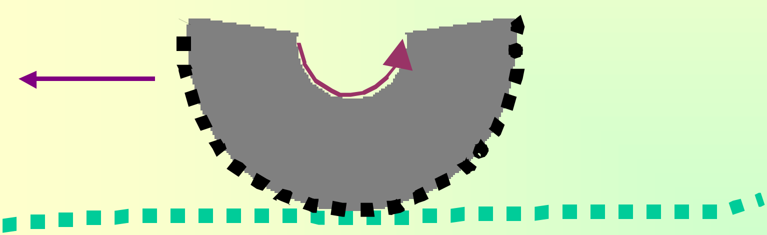


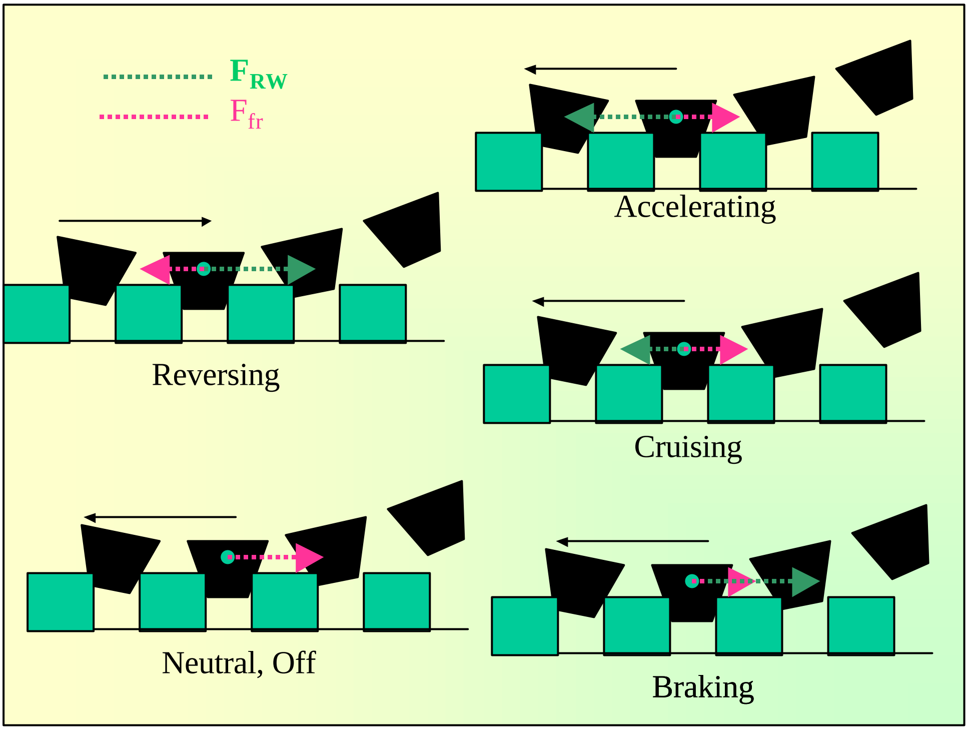
$F_{fr:}$ Frictional force

F_{fr} does not change with car speed.

$F_{fr} = m F_N$



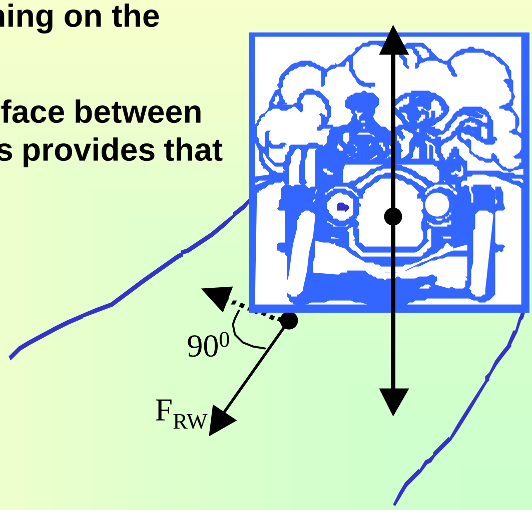




The case of a skidding car

A centripetal force is needed to act on the car to keep the turning on the curved path.

The firm and rough surface between the road and the wheels provides that centripetal force.



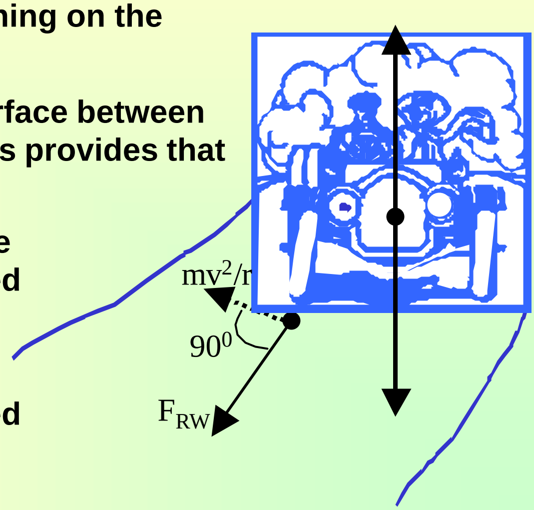
The case of a skidding car

A centripetal force is needed to act on the car to keep the turning on the curved path.

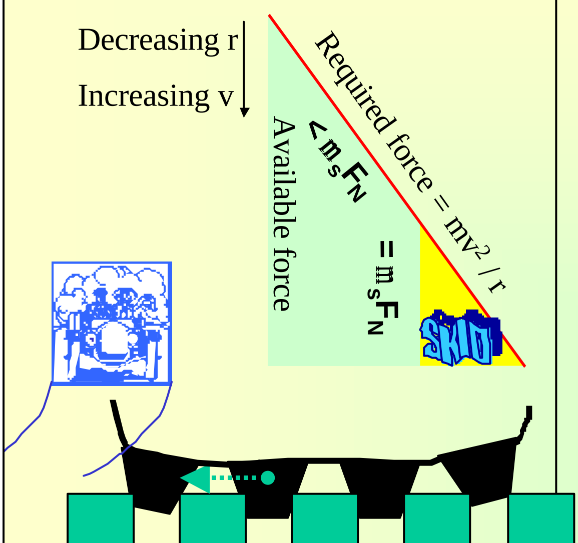
The firm and rough surface between the road and the wheels provides that centripetal force.

The tighter the turn the more the force required to keep the car on the track.

The more the car speed the more the force required.



The case of a skidding car



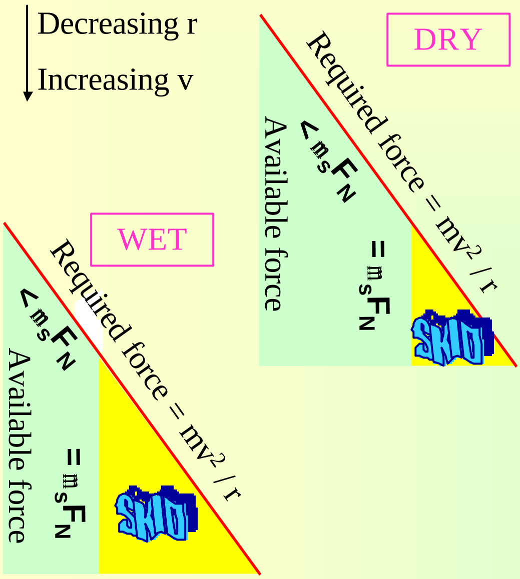
The static friction between the road and the wheels provides the required centripetal force mv^2/r.

The maximum static friction force is = $\mu_s F_N$

A car will skid if

$mv^2/r > \mu_s F_N$

The case of a skidding car

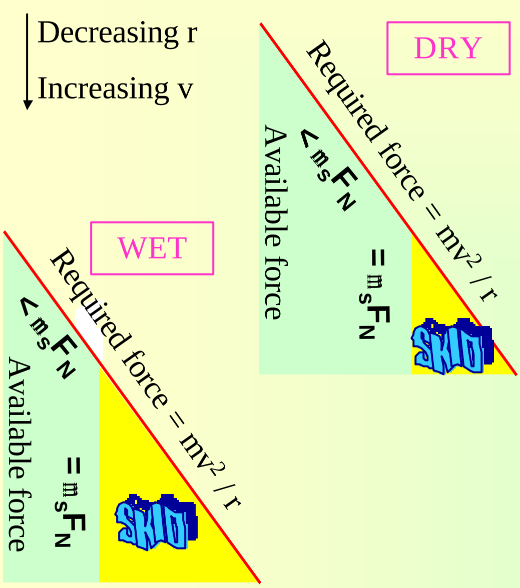


A car will skid if

$mv^2/r > \mu_s F_N$

$\mu_{s\text{-DRY}} > \mu_{s\text{-WET}}$

The case of a skidding car



A car will skid if

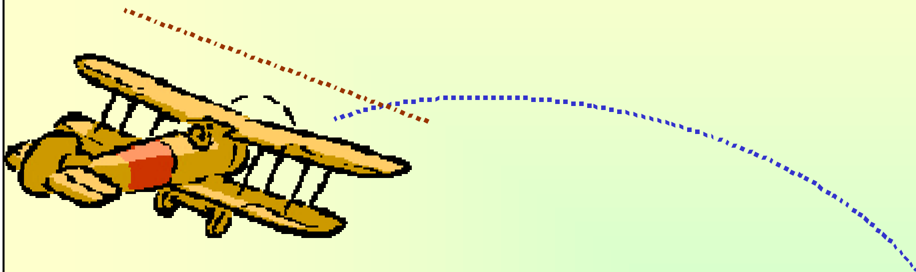
$mv^2/r > \mu_s F_N$

$\mu_{s\text{-DRY}} > \mu_{s\text{-WET}}$

More cars skid during the wet weather, as people do not reduce speed to adjust for lower static friction coefficient.

A turning plane

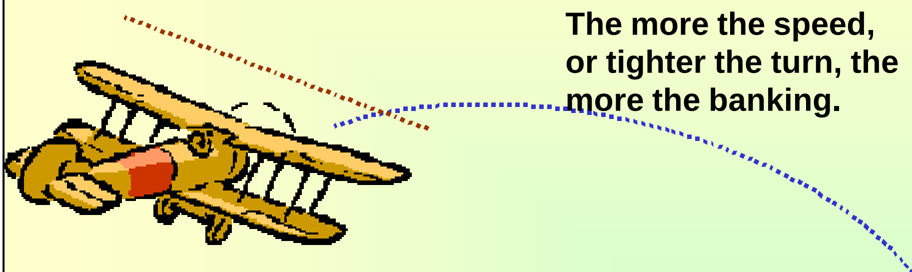
A turning plane banks towards the radius of curvature.



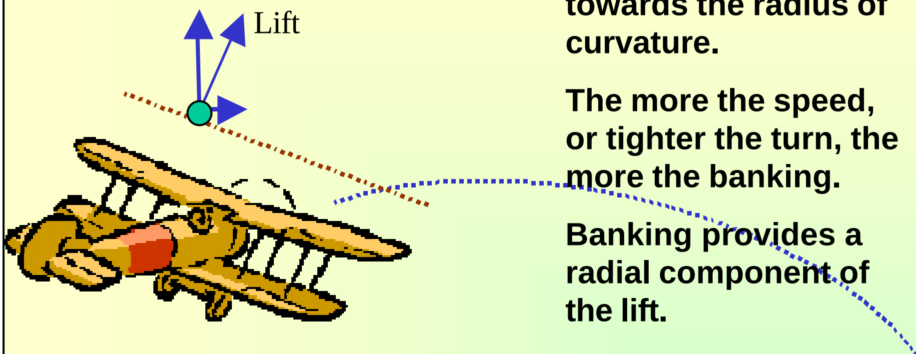
A turning plane

A turning plane banks towards the radius of curvature.

The more the speed, or tighter the turn, the more the banking.



A turning plane

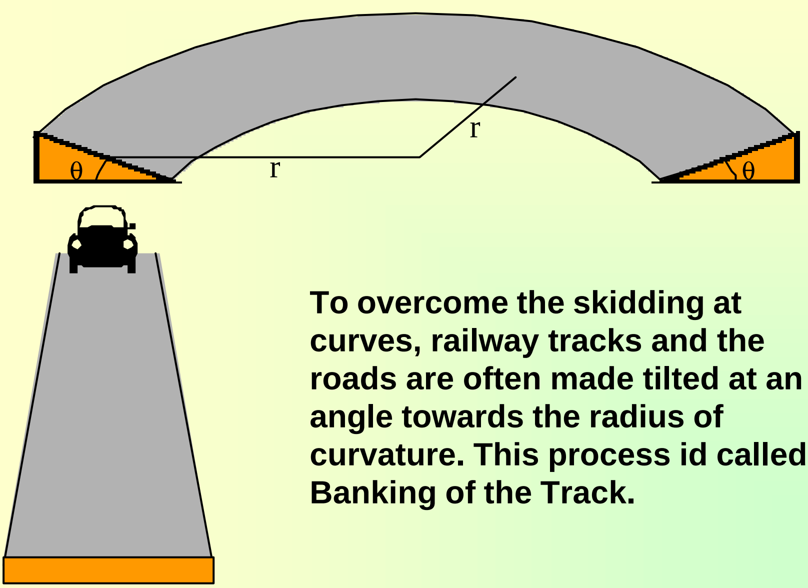


A turning plane banks towards the radius of curvature.

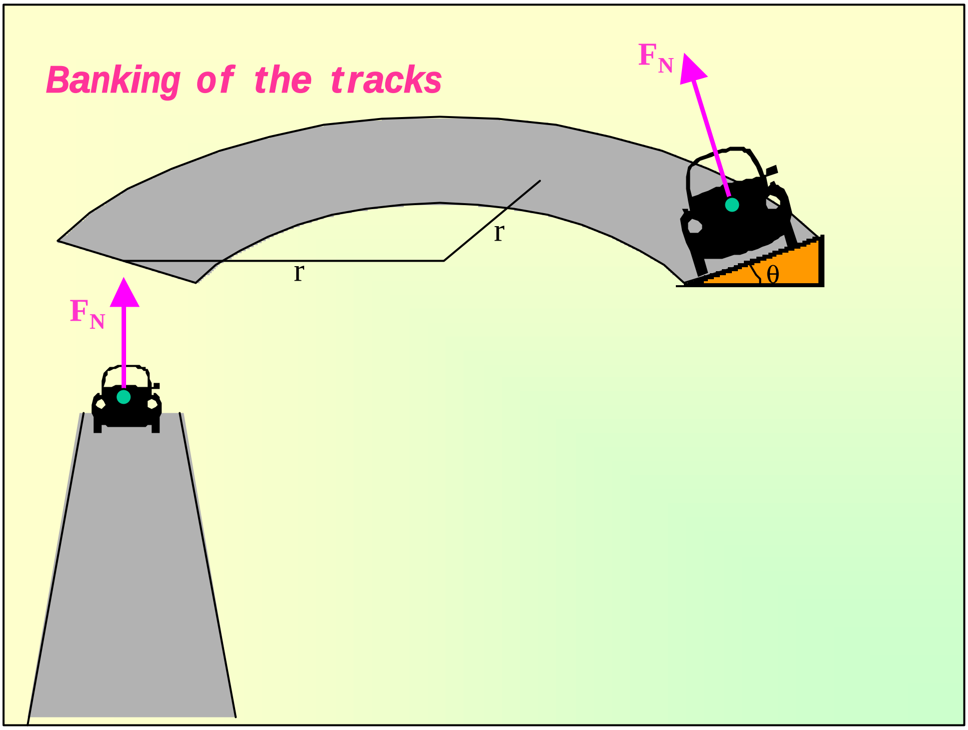
The more the speed, or tighter the turn, the more the banking.

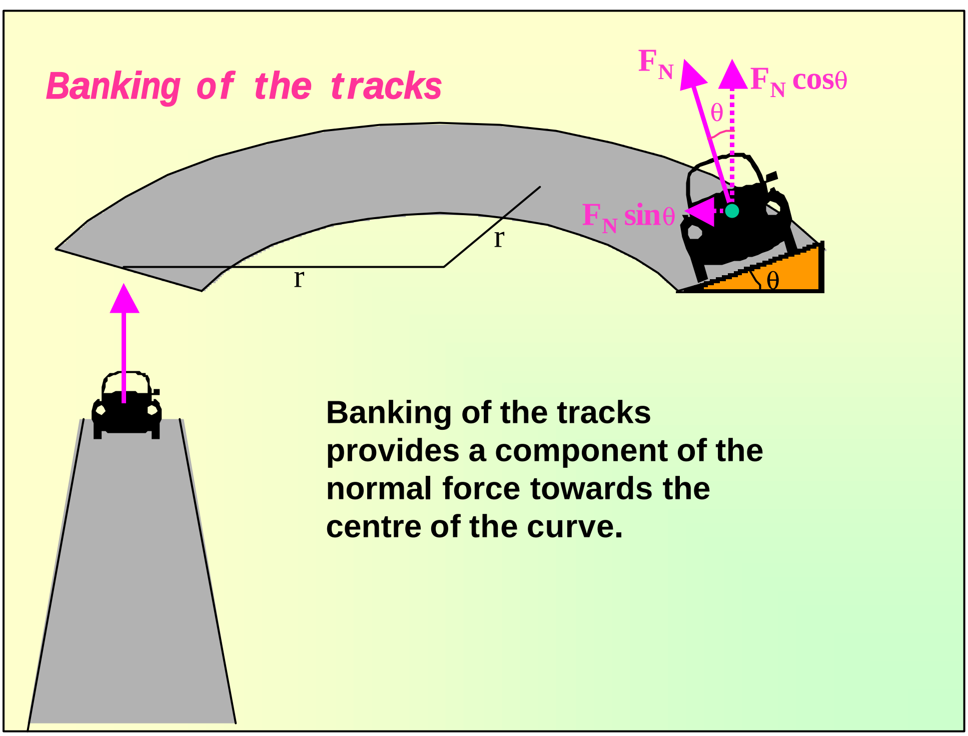
Banking provides a radial component of the lift.

Banking of the tracks

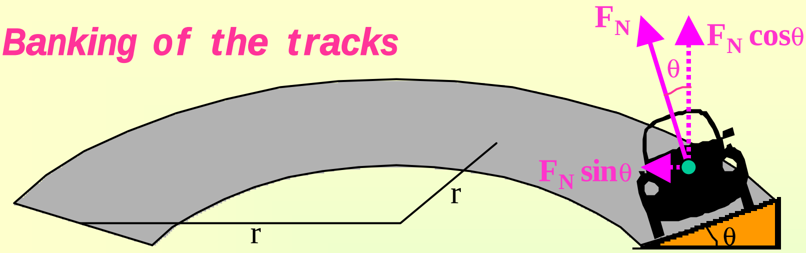


To overcome the skidding at curves, railway tracks and the roads are often made tilted at an angle towards the radius of curvature. This process id called Banking of the Track.


Banking of the tracks
F N
r
r
θ
F N


Banking of the tracks
F N
F N cosθ
θ
F N sinθ
r
r
θ
Banking of the tracks provides a component of the normal force towards the centre of the curve.

Banking of the tracks



Mathematically,

$F_N \sin\theta = mv^2 / r$ --------(1)

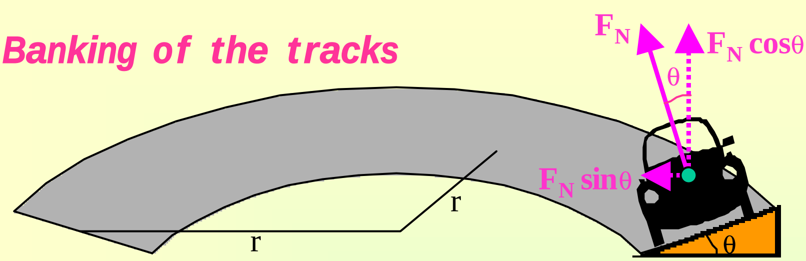
$F_N \cos\theta = mg$ ------- (2)

From (1) / (2)

$\sin\theta / \cos\theta = v^2 / rg$

$\tan\theta = v^2 / rg$

Banking of the tracks



Mathematically,

$F_N \sin\theta = mv^2 / r$ --------(1)

$F_N \cos\theta = mg$ ------- (2)

From (1) / (2)

$\sin\theta / \cos\theta = v^2 / rg$

$\tan\theta = v^2 / rg$

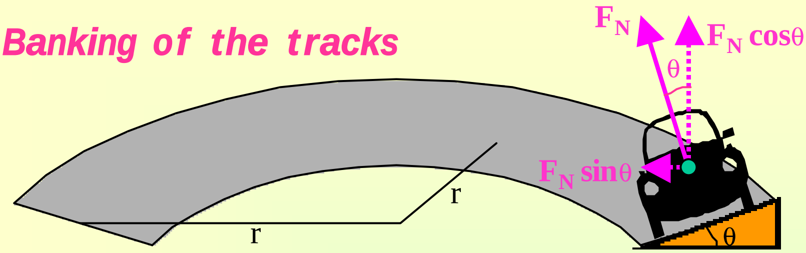
$\theta = \tan^{-1} (v^2 / rg)$

is independent of m.

$v = (rg \tan\theta)^{0.5}$

is all weather, all vehicle safe turning speed.

Banking of the tracks



$$\tan\theta = v^2 / rg$$

θ : banking angle

v : car speed

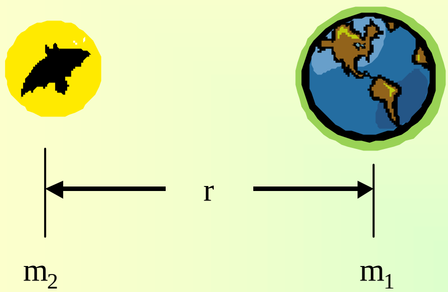
r: radius of curvature

g: acceleration due to gravity

The Gravitational Force

Every object in the universe attracts every other object with a force proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

The Gravitational Force



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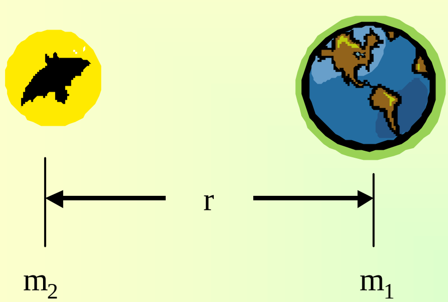
The Gravitational Force

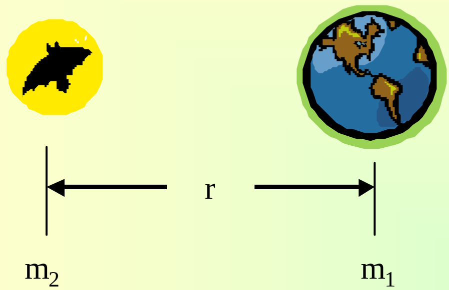


Every object in the universe attracts every other object with a force proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

$F_{12} = G\ (m_1\ m_2\ /\ r^2)$

$G = 6.67 \times 10^{-11}\ Nm^2.kg^{-2}$

The Gravitational Force



$$F_{12} = G\,(m_1 m_2 / r^2)$$

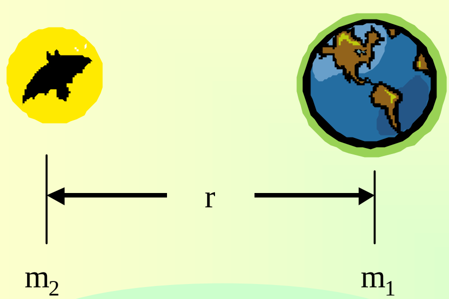
$$G = 6.67 \times 10^{-11}\ Nm^2.kg^{-2}$$

G is the Universal Gravitational Constant

Every object in the universe attracts every other object with a force proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

This statement is called Newton's Law of Universal Gravitation.

The Gravitational Force



Part of the exam cheat sheet

$$F_{12} = G\,(m_1 m_2 / r^2)$$

$$G = 6.67 \times 10^{-11}\ Nm^2.kg^{-2}$$

G is the Universal Gravitational Constant

Every object in the universe attracts every other object with a force proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

This statement is called Newton's Law of Universal Gravitation.

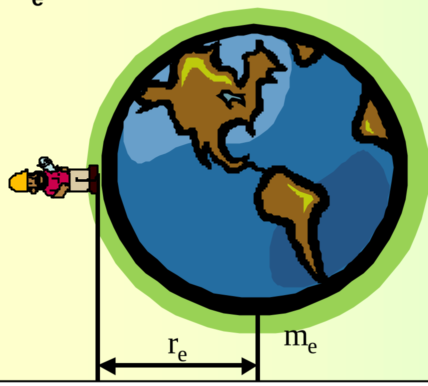
The Gravitational Force

$F_{1.2} = G\ (m_1\ m_2\ /\ r^2)$

$G = 6.67 \times 10^{-11}\ Nm^2.kg^{-2}$

$m_e = 5.98\ 10^{24}$

$r_e = 6.38\ 10^6\ m$



Weight = $\{G\ (m_e\ /\ r_e^2)\}\ m$

Acceleration due to gravity

$g = \{G\ (m_e\ /\ r_e^2)\}$

$g = 9.8\ \ N.kg^{-1}$

The Gravitational Force

$F_{1.2} = G\ (m_1\ m_2\ /\ r^2)$

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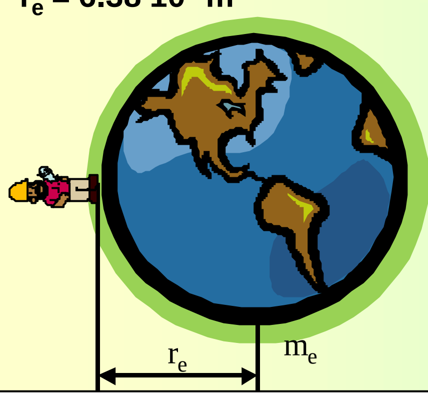


Weight = $\{G\ (m_e\ /\ r_e^2)\}\ m$

Acceleration due to gravity

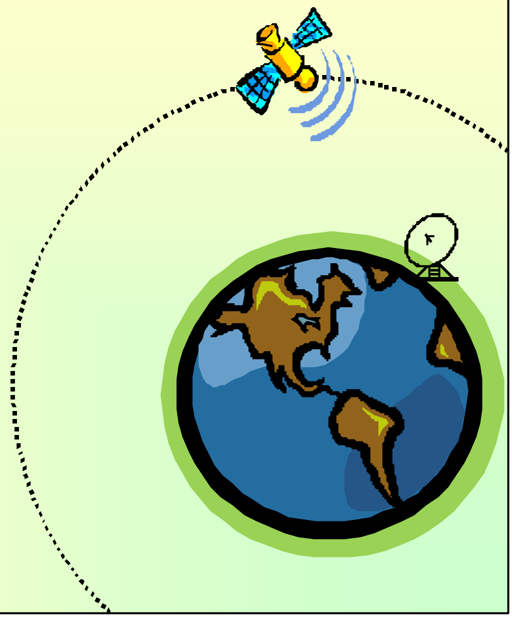
$g = \{G\ (m_e\ /\ r_e^2)\}$

$g = 9.8\ \ N.kg^{-1}$

Acceleration due to gravity will decrease with the height above sea level.

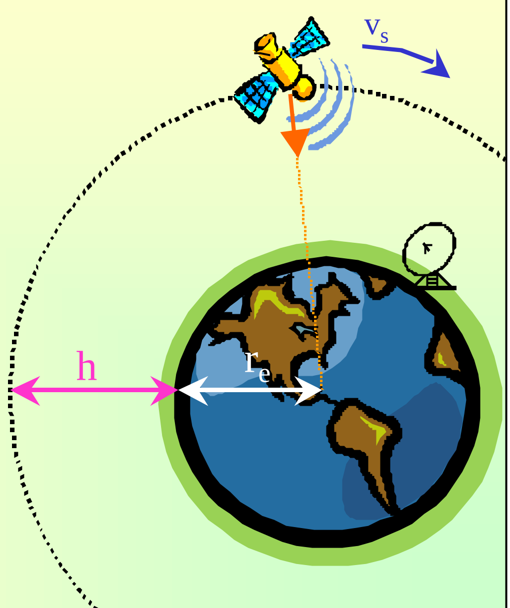
It may be different on different planets, depending upon their masses and radii.

Satellites around the Earth



Satellites around the Earth

For satellites, the gravitational force of Earth is used as the centripetal force.

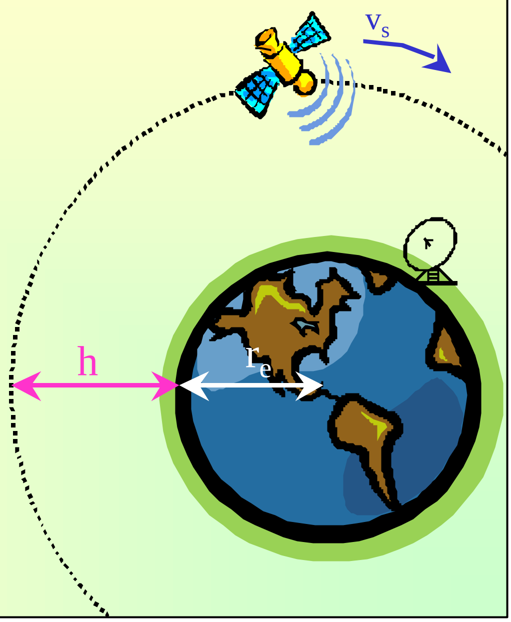


Satellites around the Earth

For satellites, the gravitational force of Earth is used as the centripetal force.

It can be shown that velocity of a satellite at at height ‘h’ above the Earth’s surface, will be given by:

$$v_s^2 = G\, m_e / (h + r_e)$$

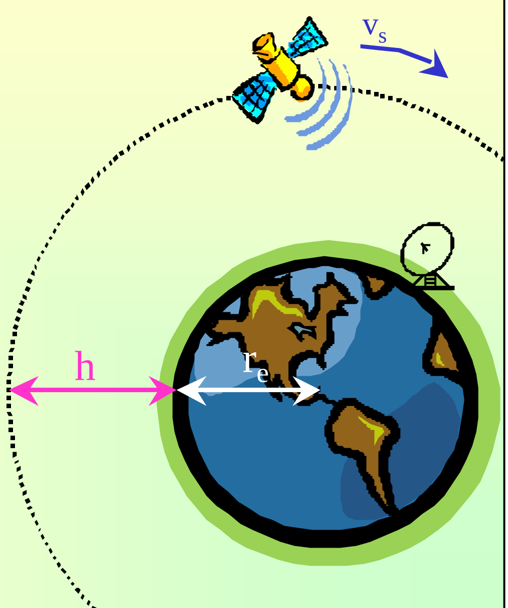


Satellites around the Earth

$$v_s^2 = G\, m_e / (h + r_e)$$

The period of a satellite revolution is given by

$$T_s = 2\pi (h + r_e) / v_s$$



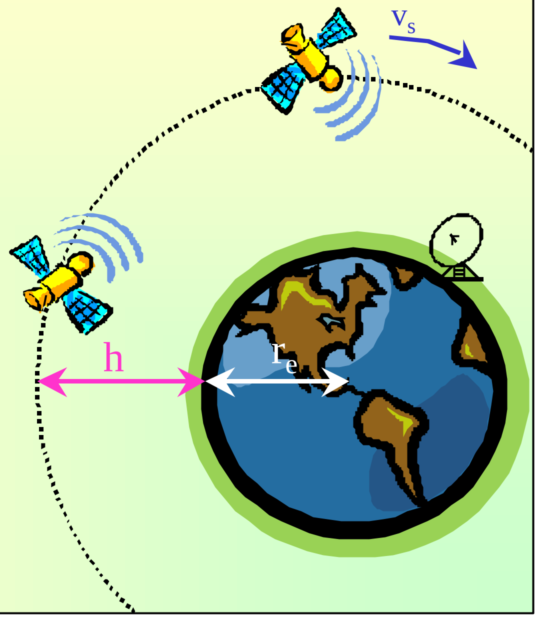
Satellites around the Earth

$$v_s^2 = G\, m_e / (h + r_e)$$

The period of a satellite revolution is given by

$$T_s = 2\pi (h + r_e) / v_s$$

For a (geo) synchronous satellite, the period of revolution is the same as that of the Earth.



Satellites around the Earth

$$v_s^2 = G\, m_e / (h + r_e)$$

The period of a satellite revolution is given by

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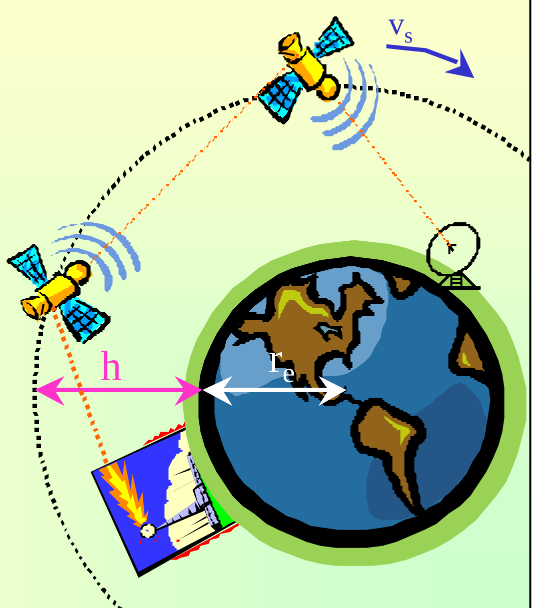

How high will be a synchronous satellite above the Earth surface?

Centrifugal force ?!!!

Problems

Text Book

Chapter Five: Edition 5

10, 18, 23, 30