University of Science and Technology
Faculty of Engineering
first Year - Semester (1)

physics (1)

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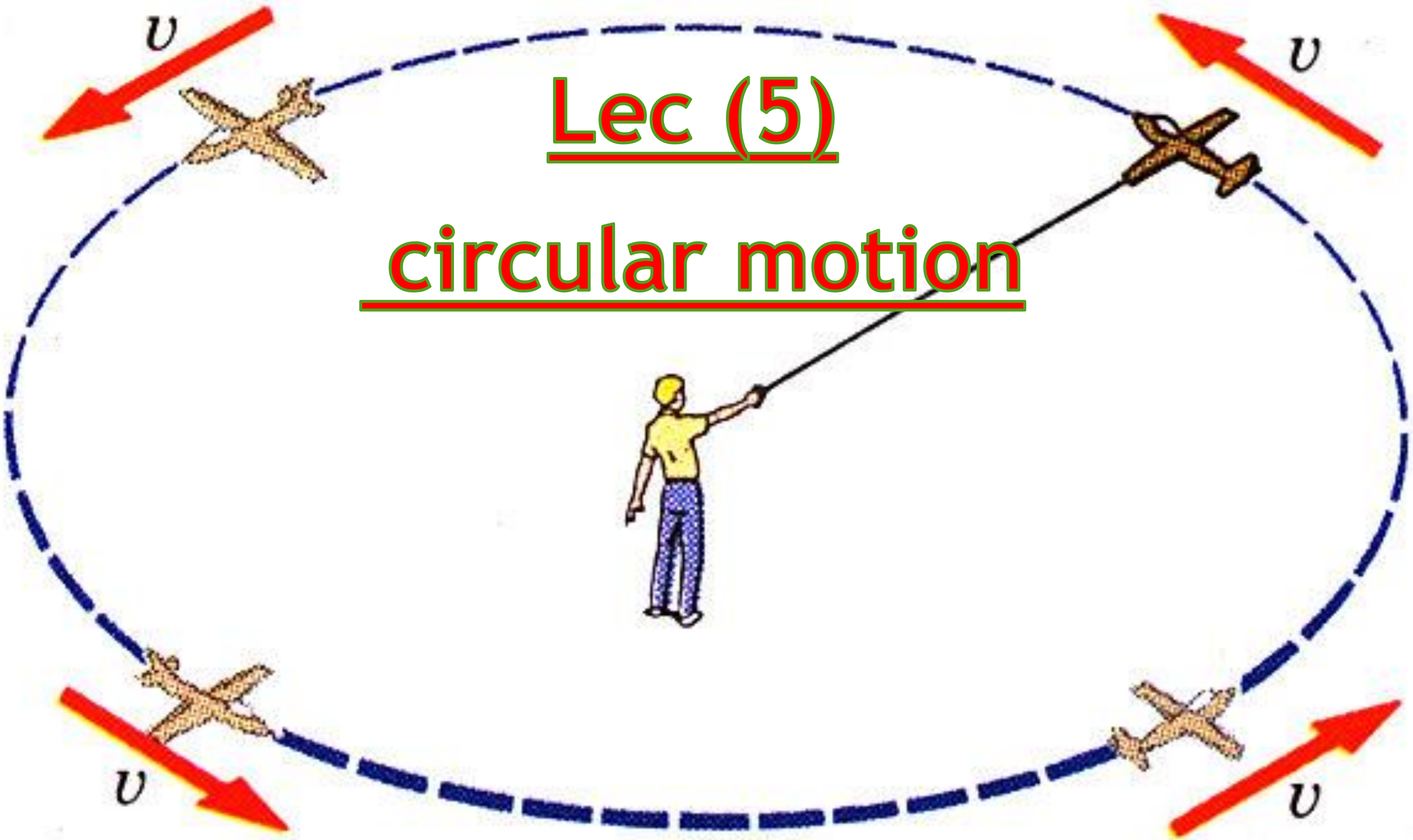
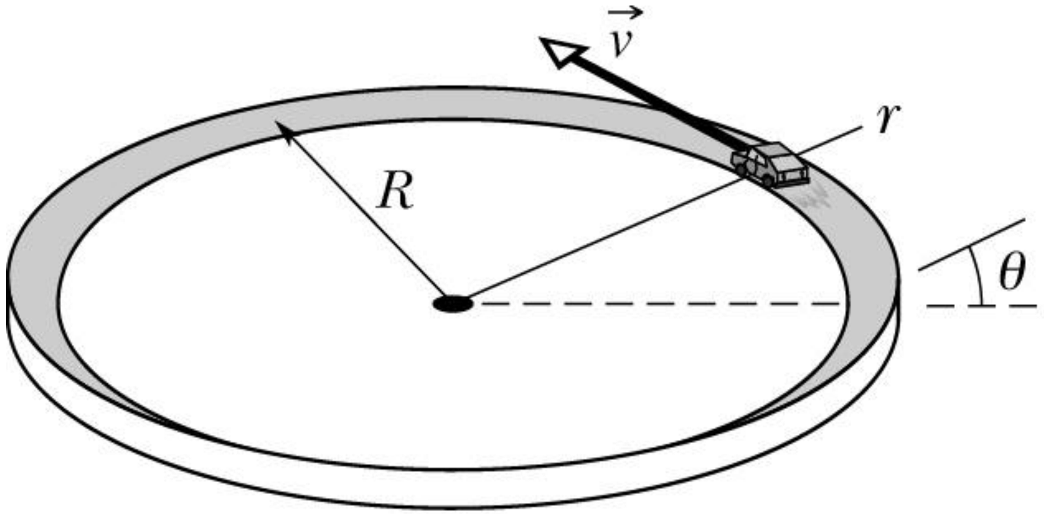
Lec (5)

circular motion



circular motion

- In uniform Circular motion a body travels at a constant speed on acircular path.



arc length =radius x Angle in radians

$$s = r\,\theta$$

$$1 \text{ rev} = 360^{\circ} = 2\pi \text{ rad}$$

*** Angular velocity = angular displacement / time**

$$\omega = \theta / t$$

*** Linear velocity = (angular velocity)(radius of circle)**

$$v = \omega r$$

*** The period (T) of revolution is the time an object takes to complete one revolution**

$$T = 2\pi / \omega$$

$$V = 2\pi r / T$$

* Centripetal acceleration (a)

$$a_c = v^2 / r$$

* Centripetal Force (F)

$$F_c = mv^2 / r$$

* angular acceleration(α)

Angular acceleration = angular velocity change / time

$$\alpha = \omega_f - \omega_0 / t$$

* angular displacement

$$\theta = \omega_0 t + 1/2\alpha t^2$$

$$\omega^2_f = \omega^2_0 + 2\alpha\theta$$

Linear Motion with a Constant (Variables: x and v)	Rotational Motion about a Fixed Axis with α Constant (Variables: θ and ω)	
$v = v_i + at$	$\omega = \omega_i + \alpha t$	[7.7]
$\Delta x = v_i t + \frac{1}{2} a t^2$	$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$	[7.8]
$v^2 = v_i^2 + 2a\Delta x$	$\omega^2 = \omega_i^2 + 2\alpha\Delta\theta$	[7.9]

$$a = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = \frac{r^2\omega^2}{r} = r\omega^2$$

$$F = ma = mr\omega^2$$

Linear

Quantity	unit
Displacement (x)	m
Velocity (v)	m/s
Acceleration (a)	m/sec²
Mass (m)	Kg
Force (F)	Kg * m/s or N

Angular

Quantity	unit
Angular displacement (Θ)	Rad
Angular velocity (ω)	Rad/sec
Angular acceleration (α)	Rad/sec²
Moment of inertia (I)	Kg * m²
Torque (t)	N*m

Law of gravitation

$$F_g = G\frac{m_1 m_2}{r^2}$$

G **= universal gravitational constant**

$= 6.67 \times 10^{-11}\ m^3\ kg^{-1}\ s^{-2}$

***m_1* and *m_2* = masses of interacting bodies**

r **= distance between their centres**

SOLVED PROBLEM (1) :

(a) Express 6 rev in radians.

(b) How many revolutions are equivalent to 10 rad?

(*a*) $$\theta = (8°)\left(\frac{2\pi \text{ rad}}{360°}\right) = 0.14 \text{ rad}$$

(*b*) $$\theta = (2.5 \text{ rad})\left(\frac{360°}{2\pi \text{ rad}}\right) = 143 \text{ rad}$$

SOLVED PROBLEM (2) :

A 1000-kg car rounds a turn of radius 30 m at a velocity of 9 m/s. (*a*) How much centripetal force is required?

$$F_c = \frac{mv^2}{r} = \frac{(1000 \text{ kg})(9 \text{ m/s})^2}{30 \text{ m}} = 2700 \text{ N}$$

SOLVED PROBLEM (3) :

An engine requires 5 s to go from its idling speed of 600 rev/min to 1200 rev/min. (*a*) What is its angular acceleration? (*b*) How many revolutions does it make in this period?

(*a*) The initial and final angular velocities of the engine are, respectively,

$$\omega_0 = (600 \text{ rev/min})\left(\frac{2\pi \text{ rad/rev}}{60 \text{ s/min}}\right) = 63 \text{ rad/s}$$

$$\omega_f = (1200 \text{ rev/min})\left(\frac{2\pi \text{ rad/rev}}{60 \text{ s/min}}\right) = 126 \text{ rad/s}$$

and so its angular acceleration is

$$\alpha = \frac{\omega_f - \omega_0}{t} = \frac{126 \text{ rad/s} - 63 \text{ rad/s}}{5 \text{ s}} = 12.6 \text{ rad/s}^2$$

(*b*) The angle through which the engine turns is

$$\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2 = (63 \text{ rad/s})(5 \text{ s}) + (\tfrac{1}{2})(12.6 \text{ rad/s}^2)(5 \text{ s})^2$$
$$= 472.5 \text{ rad}$$

Since there are 2π rad in 1 rev,

$$\theta = \frac{472.5 \text{ rad}}{2\pi \text{ rad/rev}} = 75.2 \text{ rev}$$

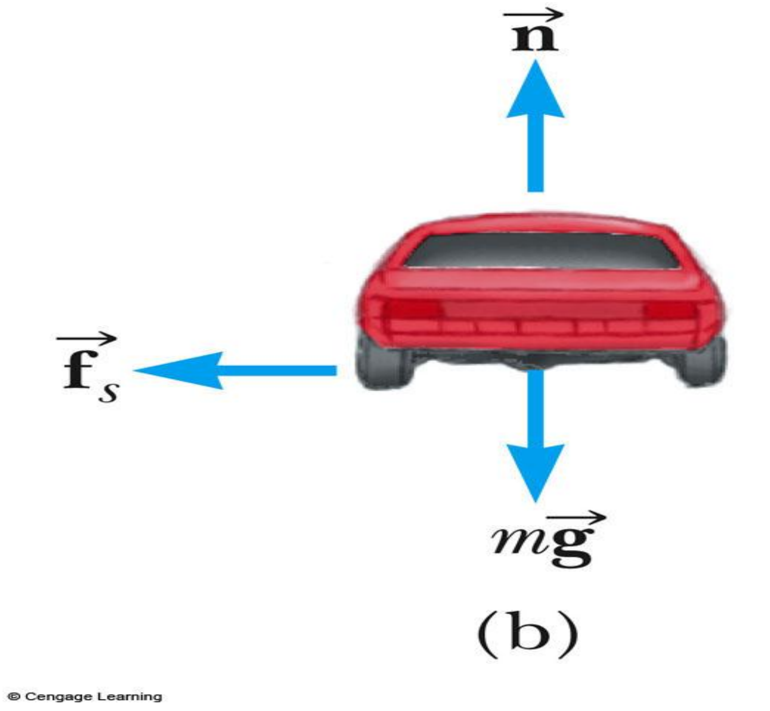
Centripetal Acceleration

$$\boxed{a_c = \frac{v^2}{r} \quad \textbf{(centripetal acceleration)}}$$

$$\boxed{v = \frac{2\pi r}{T} \quad \textbf{(tangential velocity)}}$$

Level Curves

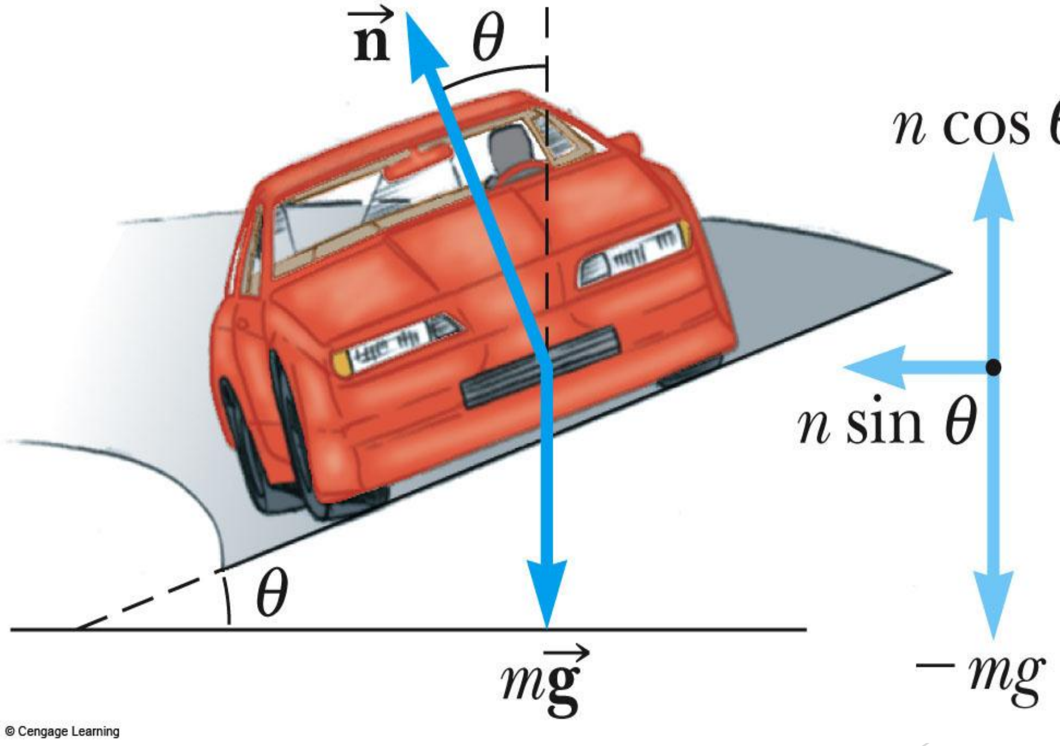
- Friction is the force that produces the centripetal acceleration
- Can find the frictional force, μ, or v



$$V = \sqrt{\mu r g}$$

Banked Curves

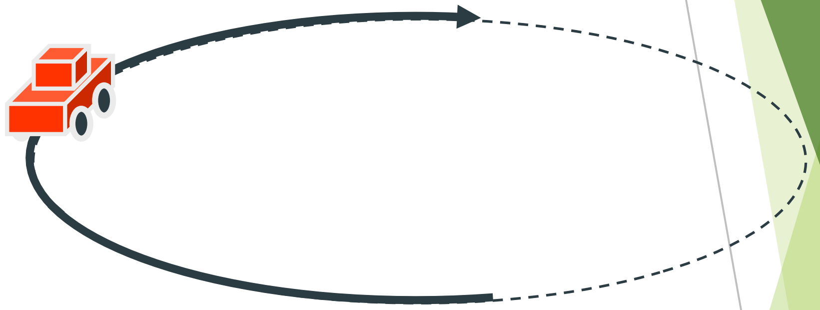
- A component of the normal force adds to the frictional force to allow higher speeds



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

$$or\ a_c = g\tan\theta$$

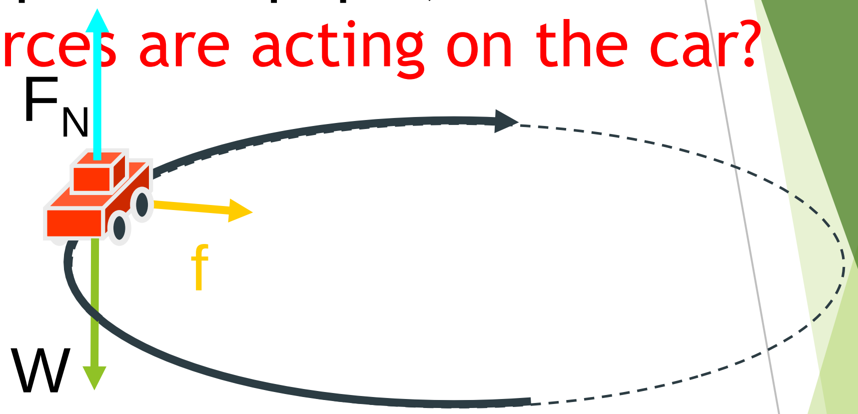
Consider the following situation: You are driving a car with constant speed around a horizontal circular track. On a piece of paper, draw a Free Body Diagram (FBD) for the car. How many forces are acting on the car?



A) 1
B) 2
C) 3
D) 4

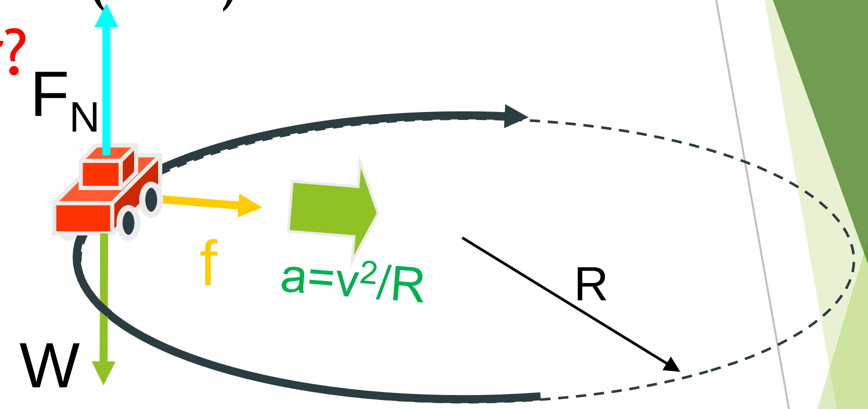
Consider the following situation: You are driving a car with constant speed around a horizontal circular track. On a piece of paper, draw a Free Body Diagram (FBD) for the car. How many forces are acting on the car?

A) 1
B) 2
C) 3
D) 4



Consider the following situation: You are driving a car with constant speed around a horizontal circular track. On a piece of paper, draw a Free Body Diagram (FBD) for the car. How many forces are acting on the car?

A) 1 0%
B) 2 28%
C) 3 44% ← correct
D) 4 28%

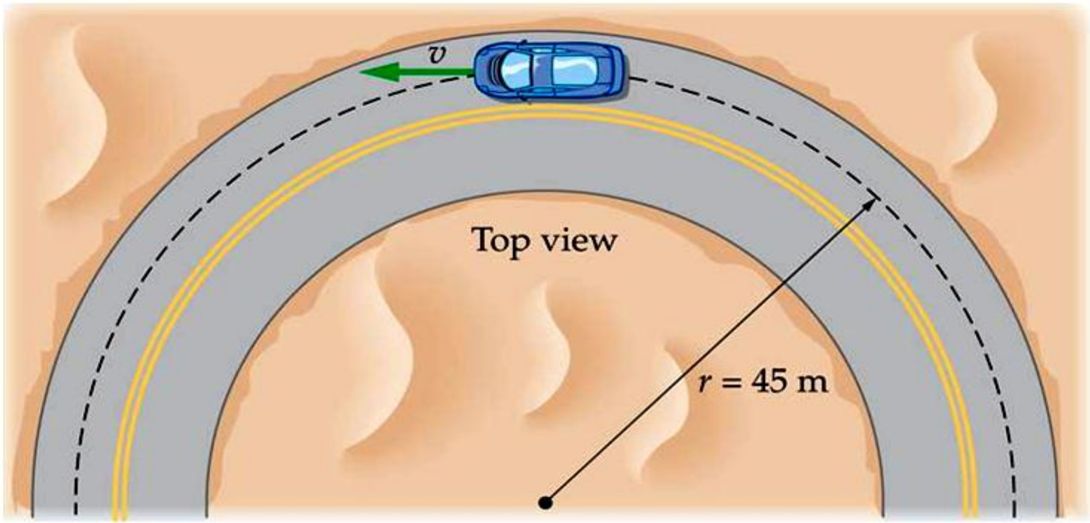


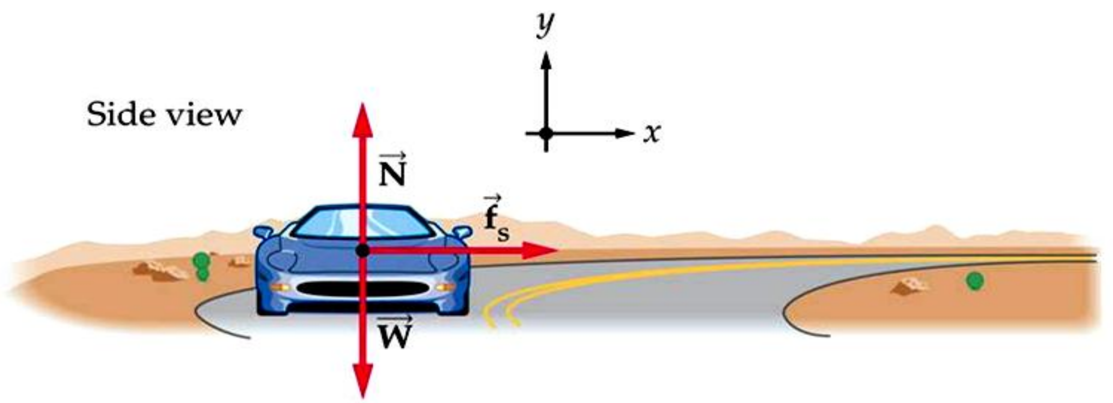
$\Sigma \mathbf{F} = m\mathbf{a} = mv^2/R$

"Gravity, Normal Force, Friction"

"Fn = Normal Force, W = Weight,

the force of gravity, f = centripetal force."





A 1,200 kg car rounds a corner of radius r = 45.0 m. If the coefficient of friction between the tires and the road is μ_s = 0.82, what is the maximum speed the car can have on the curve without skidding?

$$\sum F_x = f_s$$

$$F_{netx} = \mu_s N$$

$$F_{net} = \mu_s mg$$

$$\sum \vec{F}_y = 0$$

$$N = w$$

$$N = mg$$

$$\therefore \quad \mu_s \cancel{m} g = \cancel{m}\frac{v^2}{r}$$

$$F_{net} = m\frac{v^2}{r}$$

$$v = \sqrt{\mu_s r g} = \sqrt{(0.82)(45.0\ \mathrm{m})(9.81\ \mathrm{m/s^2})} \boxed{= 19.0\ \mathrm{m/s}}$$

Question: How does this result depend on the mass of the car?