Circular Motion

Question1

A particle is acted upon by a force of constant magnitude such that its velocity and acceleration are always perpendicular to each other, then its

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Options:

A.

linear momentum is constant

B.

kinetic energy is constant

C.

velocity is constant

D.

acceleration is constant

Answer: B

Solution:

We know that force ($\mathbf{F}$) is directly proportional to acceleration (a) by Newton's second law ($\mathbf{F} = m\mathbf{a}$). Therefore, if the force is always perpendicular to the velocity, then the acceleration is also always perpendicular to the velocity. The work done by a force is given by $W = \int \mathbf{F} \cdot d\mathbf{s}$, where $d\mathbf{s}$ is the displacement.

Since, $\mathbf{F}$ is perpendicular to $\mathbf{v}$ and $d\mathbf{s}$ is in the direction of $\mathbf{v}$, the dot product $\mathbf{F} \cdot d\mathbf{s} = 0$. This means the work done by the force is zero.

According to the work-energy theorem, the net work done on a particle equals the change in its kinetic energy (ΔKE). Since the work done is zero, the change in kinetic energy is zero, meaning the kinetic energy remains constant.

Question2

An aircraft executes a horizontal loop of radius 9 km at a constant speed of $540 \mathrm{kmh}^{-1}$. The wings of the aircraft are banked at an angle of (Acceleration due to gravity $= 10 \mathrm{~ms}^{-2}$)

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Options:

A. $\operatorname{cosec}^{-1}(4)$

B. $\cot^{-1}(4)$

C. $\tan^{-1}(4)$

D. $\sec^{-1}(4)$

Answer: B

Solution:

Given,
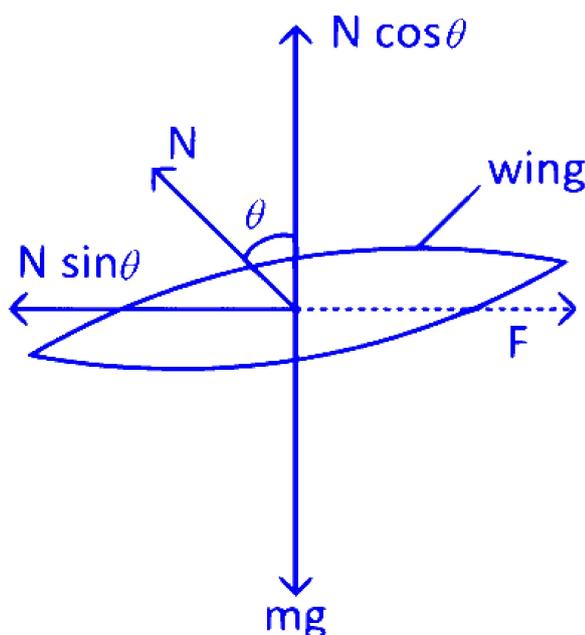
Radius, $r = 9$ km $= 9 \times 10^3$ m

Speed, $u = 540$ km/h $= 150$ m/s

Angle, $\theta = ?$

$g = 10$ m/s^2

Here, $F = \frac{mu^2}{r}$

$m =$ mass of plane

$mg = N \cos \theta$

and due to centripetal force

$N \sin \theta = \frac{mu^2}{r}$

From Eqs. (i) and (ii)

$\tan \theta = \dfrac{u^2}{rg}$

$\qquad = \dfrac{(150)^2}{9 \times 10^3 \times 10} = \dfrac{225}{900}$

$\tan \theta = \dfrac{1}{4}$

$\cot \theta = 4$

$\qquad \theta = \cot^{-1}(4)$

Question3

A 20 ton truck is travelling along a curved path of radius 240 m . If the centre of gravity of the truck above the ground is 2 m and the distance between its wheels is 1.5 m , the maximum speed of the truck with which it can travel without toppling over is(Acceleration due to gravity $= 10 \text{ ms}^{-2}$)

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Options:

A. 43 ms^{-1}

B. 40 ms^{-1}

C. 38 ms^{-1}

D. 30 ms^{-1}

Answer: D

Solution:

Given, $m = 20 \text{ T} = 20 \times 10^3 \text{ kg}$

$r = 240 \text{ m}$

distance between wheels, $d = 1.5 \text{ m}$

Centre of gravity above ground, $h = 2 \text{ m}$

Equating torque by gravity and torque by centrifugal force about outer wheel, we get

$$\frac{mv_{\max}^2}{r} \times h = mg\frac{d}{2}$$

$$\Rightarrow \quad v_{\max} = \sqrt{\frac{grd}{2h}}$$

$$= \sqrt{\frac{10 \times 240 \times 1.5}{2 \times 2}}$$

$$= \sqrt{900} = 30 \text{ m/s}$$

Question4

A car is moving on circular track banked at an angle of $45°$. If the maximum permissible speed of the car to avoid slipping is twice the optimum speed of the car to avoid the wear and tear of the tyres, then the coefficient of static friction between the wheels of the car and the road is

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Options:

A. 0.3

B. 0.5

C. 0.4

D. 0.6

Answer: D

Solution:

As we know,

$v_{\max} = \sqrt{\frac{rg(\tan\theta + \mu)}{1 - \mu\tan\theta}}$ $\quad \dots$ (i)

For optimum speed,

$v_{\mathrm{opt}} = \sqrt{rg\tan\theta}$

where $\theta = 45°$

$$v_{\text{opt}} = \sqrt{\text{rg}\tan 45°}$$

$$v_{\text{opt}} = \sqrt{rg} \quad \dots \text{(ii)}$$

From Eq. (i),

$$(v_{\text{max}})^2 = \frac{(v_{\text{opt}})^2(\tan\theta + \mu)}{1 - \mu\tan\theta}$$

$$(2v_{\text{opt}})^2 = \frac{(v_{\text{opt}})^2(\tan\theta + \mu)}{1 - \mu\tan\theta}$$

$$\Rightarrow 4(1 - \mu) = 1 + \mu$$

$$4 - 4\mu = 1 + \mu \Rightarrow 3 = 5\mu$$

$$\mu = 0.6$$

The coefficient of static friction between the wheels of the car and the road is 0.6 .

Question5

The angular speed of a particle moving in a circular path is doubled. Then, the centripetal acceleration of the particle is

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Options:

A. 4 times the initial centripetal acceleration

B. halved

C. doubled

D. unchanged

Answer: A

Solution:

To understand how the centripetal acceleration changes when the angular speed of a particle moving in a circular path is doubled, let's start by defining the initial conditions:

Assume the initial angular speed of the particle is ω.

The formula for centripetal acceleration is given by:

$$a_c = \omega^2 r$$

Now, if the angular speed is doubled, the new angular speed becomes:

$$\omega' = 2\omega$$

Using the new angular speed, the revised centripetal acceleration is:

$$a'_c = (\omega')^2 r = (2\omega)^2 r = 4\omega^2 r$$

Thus, the new centripetal acceleration is:

$$a'_c = 4a_c$$

This shows that when the angular speed is doubled, the centripetal acceleration becomes four times the initial centripetal acceleration. Therefore, the correct description is that the centripetal acceleration is 4 times the initial centripetal acceleration.