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Sec - K

MECHANICS ASSIGNMENT

Q.1. In the following situations, determine whether the speed or velocity is changing, or neither is changing, or both are changing. A car's cruise control is set to a constant 50 mph.

1) The car is driving on a level straight-away.
→ In straight level road, distance = displacement
∴ Neither is changing.

2) The car rounds a curve.
→ In a curve, displacement changes but the distance remains constant.
So, Velocity is changing.

3) The car drives over a hill.
→ Due to gravity, a retarding force acts, which will decrease both speed and velocity.
∴ Both will change.

4) The car is driving up a hill of constant grade.
→ Given the constant grade, both of the quantities will remain the same.
Hence, Neither are changing.

5) The car is driving on a level-straight away when the driver applies the brakes.
→ Due to decelaration after applying the brakes, Both will change.

Q.2. A fisherman sits in a motor boat at the shore of a river flowing downstream at 4m/s. The fisherman wishes to reach the other side of the river. If the river is 60 m wide and the motor boat has a maximum speed of 3m/s w.r.t. the water, what is the shortest amount of time it could take the fisherman to perform the crossing?

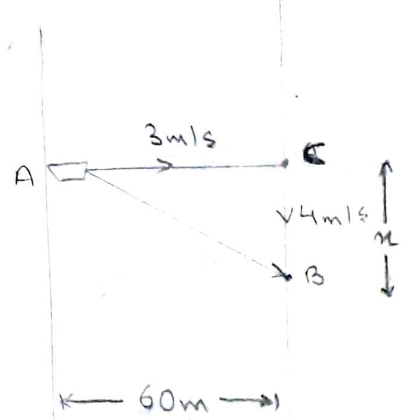
Soln:- Given, Velocity of river, $V_r = 4 m/s$

Velocity of boat, $V_b = 3 m/s$

Width of river, $D = 60 m$

To find, Shortest time required to cross the river. Let it be 't'.

Let CB be 'x' m.



The resultant velocity of the boat,

$$V_{AB} = \sqrt{V_{AC}^2 + V_{CB}^2}$$

$$= \sqrt{3^2 + 4^2}$$

$$= 5 m/s$$

when, $V_{CB} = 0$,

time taken, $T = \frac{60}{3} = 20 s$

and, $CB = x = 20 s \times 4 m/s = 80 m$

So, $AB = \sqrt{AC^2 + CB^2} = \sqrt{60^2 + 80^2} = 100 m$

$\therefore$ Shortest time taken,

$$t = \frac{AB}{V_{AB}} = \frac{100}{5} = 20 s$$

Q.3. A fishing boat wishes to reach the other side of a briskly flowing water. The boat attempts to travel straight across the river, but the strength of the current pushes the boat downstream during the crossing. As a result of the river's current, the velocity of the boat has components in the y-axis as well as the x-direction. If the velocity of the boat relative to shore is a constant $V_b = (5\hat{i} - 2\hat{j})$ m/s and the river is 100 m wide, what is the distance d that the boat is pushed downstream during its crossing?

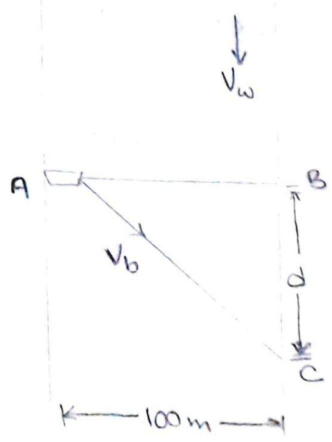
Soln:- Given.

$V_b = (5\hat{i} - 2\hat{j})$ m/s.

$AB = 100$ m

So,

Resultant, $V_r = V_b = \sqrt{5^2 + 2^2} = \sqrt{29}$ m/s



Let, y-component be current of water, $V_w = 2$ m/s $= V_y$

and, x-component be horizontal speed of boat, $V_x = 5$ m/s.

Now,

When, $V_y = 0$,

Time taken, $T = \frac{100}{5} = 20$ s

∴ Distance $BC = 20\text{s} \times V_y$

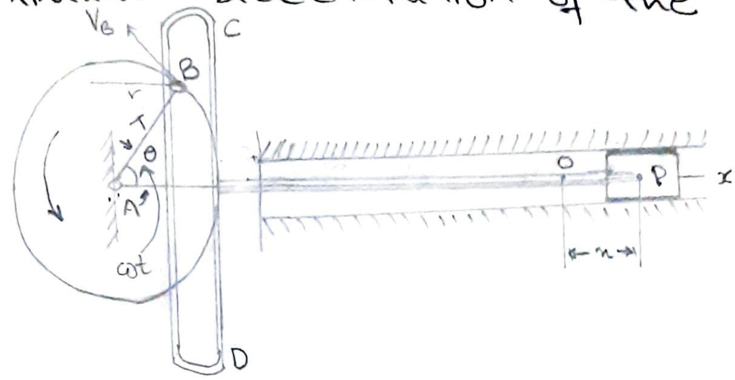
or, $d = 20\text{s} \times 2$ m/s

$d = 40$ m

∴ The pushed distance of boat (d) is 40 m.

Q.4. If the crank of the engine shown in fig. A rotates $\omega = 4\pi$ radians/sec and the crank radius $r = 10$ in., find the maximum velocity and maximum acceleration of the piston.

Sol^n:-



Here,

$r = 10$ in

$\omega = 4\pi$ radian

So,

$V_B = \omega r$

$= 10 \times 4\pi$

$= 40\pi$ in/s

Piston will move only in horizontal direction.

$\therefore V_p = V_B \cos\theta$

$= 40\pi \cos\theta$ in/sec

$= 40\pi \cos(\omega t)$ in/s

$\therefore V_{P_{max}} = 40\pi$ in/s $\quad$ ($\because$ at max, $\cos(\omega t) = 1$)

Now,

Acceleration, $a_p = \dfrac{dV_p}{dt} = -40\pi \times \omega \sin\omega t$

$= -40\pi \times 4\pi \sin\omega t$

$= -160\pi^2 \sin\omega t$ in/s^2

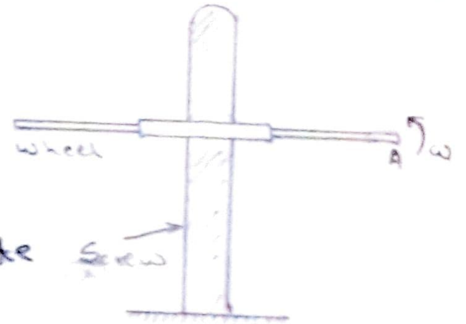
$\therefore a_{P_{max}} = -160\pi^2$ in/s^2 ($\because$ at max, $\sin\omega t = 1$)

$\therefore V_{P_{max}} = 40\pi$ in/s and $a_{P_{max}} = 160\pi^2$ in/s^2

Q.5. A wheel of radius 0.5 m is turned to advance up on a right-handed screw of pitch 1 cm as shown in figure. At an instant when the wheel is turning at a rotational speed of 2 rad/s, determine the velocity and acceleration of the hand held at A. If the wheel was accelerated rotationally at 0.6 rad/s², what would be the velocity and acceleration of the hand?

Soln:- Given, $R = 0.5 m$

$\omega = 2$ rad/s



Pitch = 1cm = 0.01 m

This is the case of cylindrical coordinate

At point A, we have,

$$V_A = V_R e_R + V_\theta e_\theta + V_z e_z \qquad -(i)$$

$$= 0 \times e_R + \omega R e_\theta + \frac{P}{t} e_z$$

$$= 2 \times 0.5\, e_\theta + \frac{0.01}{2\pi/2} e_z$$

$$\therefore V_A = (e_\theta + 0.0032 e_z) \text{ m/s}$$

$$a = (\ddot{R} - R\dot{\theta}^2) e_R + (R\ddot{\theta} - 2\dot{R}\dot{\theta}) e_\theta + \ddot{z} e_z \qquad -(ii)$$

(as R and z are constants)

$$= (0 - 0.5 \times 2^2) e_R + (0.5 \times 0 + 2 \times 0 \times 2) e_\theta + 0 \times e_z$$

$$= -2 e_R \text{ m/s}^2 \quad \text{(inwards)}$$

for second case,

$R = 0.5 m$, $\omega = \dot{\theta} = 2$ rad/s,

and $\alpha = \ddot{\theta} = 0.6$ rad/s²

from (i), $\therefore V = e_\theta + 0.3 e_z$ m/s

from (ii), $a = (0 - 0.5 \times 2^2) e_R + (0.5 \times 0.6 + 2 \times 0 \times 2) e_\theta + 0.00\ldots$

$\therefore a = -2e_r + 0.3 e_\theta + 0.0019 e_z$ rad/s²