Motion in 1D and 2D

Date: 27/07/2022

Subject: Physics | Class: Standard XI

Topic : Relative motion | Time: 00:20 hrs

1. A train travels at $60 \mathrm{~m/s}$ to the east with respect to the ground. A businessman on the train runs at $5 \mathrm{~m/s}$ to the west with respect to the train. Find the velocity of the man with respect to the ground.

A. $5 \mathrm{~m/s}$

B. $55 \mathrm{~m/s}$

C. $60 \mathrm{~m/s}$

D. $65 \mathrm{~m/s}$

Assuming east as the positive direction.

Velocity of the train with respect to the ground $(v_T = 60 \mathrm{~m/s})$

Velocity of the man with respect to the train $(v_{MT} = -5 \mathrm{~m/s})$

Let the velocity of the man with respect to the ground $= v_M$

$v_{MT} = v_M - v_T$

$\Rightarrow v_M = v_{MT} + v_T$

$\Rightarrow v_M = -5 + 60 = 55 \mathrm{~m/s}$

Hence, option (B) is the right choice.

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2. Two trains are moving eastward with velocities $10 \mathrm{~ms}^{-1}$ and $15 \mathrm{~ms}^{-1}$ on parallel tracks. Calculate the relative velocity of the slow train w.r.t. the fast train.

- ✔ **A.** $5 \mathrm{~ms}^{-1}$ towards west.
- ✘ **B.** $5 \mathrm{~ms}^{-1}$ towards east.
- ✘ **C.** $25 \mathrm{~ms}^{-1}$ towards west.
- ✘ **D.** $25 \mathrm{~ms}^{-1}$ towards east.

Velocity of slower train, $v_1 = 10 \mathrm{~ms}^{-1}$
Velocity of faster train, $v_2 = 15 \mathrm{~ms}^{-1}$
Relative velocity of slow train w.r.t. the fast train
$v_{12} = v_1 - v_2 = 10 - 15 = -5 \mathrm{~ms}^{-1}$
Negative sign shows that slow train appears to move westward w.r.t fast train with velocity of $5 \mathrm{~ms}^{-1}$

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3. Two cars start off to race with velocities $4 \mathrm{~m/s}$ and $2 \mathrm{~m/s}$ and travel in a straight line with uniform accelerations $1 \mathrm{~m/s^2}$ and $2 \mathrm{~m/s^2}$ respectively. If they reach the final point at the same time instant, then what is the length of the path?

A. $12 \mathrm{~m}$

B. $18 \mathrm{~m}$

C. $24 \mathrm{~m}$ ✓

D. $30 \mathrm{~m}$

Let the two cars be car A and car B.
For car A:

$$s_1 = ut + \frac{1}{2}at^2 \Rightarrow s_1 = 4t + \frac{1}{2} \times 1 \times t^2$$

(using second equation of motion)

For car B:

$$s_2 = ut + \frac{1}{2}at^2 \Rightarrow s_2 = 2t + \frac{1}{2} \times 2 \times t^2$$

(using second equation of motion)

On equating the distance, $s_1 = s_2$

$$\Rightarrow 4t + \frac{1}{2} \times 1 \times t^2 = 2t + \frac{1}{2} \times 2 \times t^2$$

$$\Rightarrow 2t = \frac{t^2}{2}$$

$$\Rightarrow t = 4 \mathrm{~s}$$

Putting the value in any one of the equations, we get

$$s = 4 \times 4 + \frac{1}{2} \times 1 \times 4^2 = 24 \mathrm{~m}$$

Alternate Solution:
Initial velocity of 1^{st} car w.r.t. 2,
$u_{12} = 4 - 2 = 2 \mathrm{~m/s}$
Acceleration of 1 car w.r.t. 2, $a_{12} = 1 - 2 = -1 \mathrm{~m/s^2}$

Finally, displacement of 1 car w.r.t 2, $S_{12} = 0$
Using second equation of motion,

$$S_{12} = u_{12} + \frac{1}{2}a_{12}t^2$$

$$\Rightarrow 0 = 2t - \frac{1}{2} \times 1 \times t^2 \Rightarrow t = 4 \mathrm{~s}$$

$\therefore$ Distance travelled by 1^{st} car $= ut + \frac{1}{2}at^2$

$$= 4 \times 4 + \frac{1}{2} \times 1 \times 4^2 = 24 \mathrm{~m}$$

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4. In a bicycle competition called Tour De France, two riders; A and B are riding bicycles at constant acceleration of magnitude $1\ \mathrm{m/s^2}$ and $3\ \mathrm{m/s^2}$ respectively, in the North direction. Their initial speeds are $15\ \mathrm{m/s}$ and $10\ \mathrm{m/s}$ respectively while they were heading in the North direction. Find the separation between them after $t = 10\ \mathrm{s}$.

A. $80\ \mathrm{m}$

B. $95\ \mathrm{m}$

C. $50\ \mathrm{m}$ ✔

D. $125\ \mathrm{m}$

Let the north direction is represented by $\hat{i}$
Initial velocity of A, $\vec{u}_A = 15\ \hat{i}\ \mathrm{m/s}$
Initial velocity of B, $\vec{u}_B = 10\ \hat{i}\ \mathrm{m/s}$
Initial velocity of A w.r.t. B, $\vec{u}_{AB} = \vec{u}_A - \vec{u}_B$
$= 15\hat{i} - 10\hat{i} = 5\hat{i}\ \mathrm{m/s}$
Acceleration of A, $\vec{a}_A = \hat{i}\ \mathrm{m/s^2}$
Acceleration of B, $\vec{a}_A = 3\ \hat{i}\ \mathrm{m/s^2}$
Acceleration of A w.r.t. B, $\vec{a}_{AB} = \vec{a}_A - \vec{a}_B$
$= \hat{i} - 3\hat{i} = -2\hat{i}\ \mathrm{m/s^2}$
So, separation between A and B after $t = 10$ can be given by
$\therefore \vec{x}_{AB} = \vec{u}_{AB}\, t + \frac{1}{2}\vec{a}_{AB}\, t^2$ (using second equation of motion)
$= 5\hat{i} \times 10 + \frac{1}{2}(-2\hat{i}) \times 10^2$
$= (50 - 100)\hat{i} = -50\hat{i}\ \mathrm{m}$
$\therefore$ After time $t = 10$ separation between them will be $50\ \mathrm{m}$

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5. One body is dropped, while a second body is thrown downward with an initial velocity of 1 m s^{-1} simultaneously. The separation between these is 18 m after a time

A. 4.5 s

B. 4.5 s

C. 18 s ✔

D. 36 s

Let t be the time after which the separation between two bodies is 18 m
Let S_{rel} be the relative distance between two bodies after time t
$\Rightarrow S_{rel} = 18 \text{ m}$
Relative acceleration of two bodies during downfall $= a_{rel} = g - g = 0$
Relative initial velocity of two bodies $= u_{rel} = 1 - 0 = 1 \text{ m/s}$

$$S_{rel} = u_{rel}t + \frac{1}{2}a_{rel}t^2$$

$\Rightarrow 18 = 1 \times t + 0$
$\Rightarrow t = 18 \text{ s}$