

1 Kinematics

1. A motorboat going downstream overcame a raft at point A ; $\tau = 60$ min later it turned back and after some time passed the raft at a distance $l = 6.0$ km from the point A . Find flow velocity assuming the duty of the engine to be constant.

Solution:

Let u be the flow velocity and v be velocity of boat in still water,

$$\frac{l}{u} = \tau + \frac{(u + v)\tau - l}{v - u} \quad (1.1)$$

$$u = \frac{l}{2\tau} = \frac{6}{2 \cdot 1} = 3 \text{ km/hr} \quad (1.2)$$

2. A point traversed half the distance with a velocity v_0 . The remaining part of the distance was covered with velocity v_1 for half the time, and with velocity v_2 for the other half of the time. Find the mean velocity of the point averaged over the whole time of motion.

Solution:

$$v_{av} = \frac{2 \cdot v_0 \cdot \frac{v_1 + v_2}{2}}{v_0 + \frac{v_1 + v_2}{2}} \quad (2.1)$$

3. A car starts moving rectilinearly, first with acceleration $w = 5.0 \text{ ms}^{-2}$ (the initial velocity is equal to zero), then uniformly, and finally, decelerating at the same rate w , comes to a stop. The total time of motion equals $\tau = 25$ s. The average velocity during that time is equal to $\langle v \rangle = 72$ kmph. How long does the car move uniformly?

Solution:

Let the time for which car moves with acceleration be t since they are equal and let total time be T ,

$$S = \frac{1}{2}wt^2 + wt \cdot (T - 2t) + wt^2 - \frac{1}{2}wt^2 \quad (3.1)$$

$$S = wtT - wt^2 \quad (3.2)$$

Let the average velocity be v ,

$$v = \frac{wtT - wt^2}{T} \quad (3.3)$$

$$t^2 \cdot w - t \cdot wT + vT = 0 \quad (3.4)$$

$$t = \frac{wT + \sqrt{wT^2 - 4vwT}}{2w} \quad (3.5)$$

$$t = 5, 20 \text{ sec} \quad (3.6)$$

$t = 20$ sec will be rejected as $2t > T$ so time for which the object moves uniformly $= T - 2t = 25 - 2 \cdot 5 = 15$ sec.

4. Two particles, 1 and 2, move with constant velocities \vec{v}_1 and \vec{v}_2 . At the initial moment, their radius vectors are equal to \vec{r}_1 and \vec{r}_2 . How must these four vectors be interrelated for the particles to collide?

Solution:

For these particles to collide,

$$\vec{s}_1 = \vec{s}_2 \quad (4.1)$$

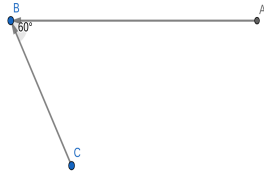
$$\vec{r}_1 + \vec{v}_1 \cdot t = \vec{r}_2 + \vec{v}_2 \cdot t \quad (4.2)$$

$$\vec{r}_1 - \vec{r}_2 = t(\vec{v}_2 - \vec{v}_1) \quad (4.3)$$

$$\frac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|} = \frac{\vec{v}_2 - \vec{v}_1}{|\vec{v}_2 - \vec{v}_1|} \quad (4.4)$$

5. A ship moves along the equator to the east with velocity $v_0 = 30$ km/hour. The southeastern wind blows at an angle $\phi = 60^\circ$ to the equator with velocity $v = 15$ km/hour. Find the wind velocity v' relative to the ship and the angle ϕ' between the equator and the wind direction in the reference frame fixed to the ship.

Solution:



(5.1)

6. If there are n ants on each vertex of n sided regular polygon with side length a . If the first moves towards the second, second moves towards third, and so on then if they move with speed v , how long will it take them to converge at a single point?

Solution:

$$T = \frac{a}{v + v \cdot \cos\left(\frac{\pi(n-2)}{n}\right)} \quad (6.1)$$

$$T = \frac{a}{v - v \cdot \cos\left(\frac{2\pi}{n}\right)} \quad (6.2)$$

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Solution: