Newton's Laws of Motion

Starter

1. **(Review of last lesson)** A lift travels vertically upwards from rest at floor A to rest at floor B, which is 20 m above A, in three stages as follows. Firstly, the lift accelerates from rest at A at 2 m/s² for 2 s; secondly, it travels at a constant speed; thirdly it slows down uniformly at 4 m/s² coming to rest at B. Find how long the journey from floor A to floor B takes.

Working: ***Accelerating:*** $u = 0, a = 2, t = 2, s = ?$

No v $\Rightarrow$ $s = ut + \frac{1}{2}at^2$: $s = 0 + \frac{1}{2} \times 2 \times 2^2$

$s = 4$

i.e. the lift travels 4 m while accelerating

We also need the maximum speed reached.

$u = 0, a = 2, t = 2, v = ?$

No s $\Rightarrow$ $v = u + at$: $v = 0 + 2 \times 2$

$v = 4$

Decelerating: $u = 4, a = -4, v = 0, s = ?$

No t $\Rightarrow$ $v^2 = u^2 + 2as$: $0^2 = (-4)^2 + 2 \times 4 \times s$

$s = 2$

i.e. the lift travels 2 m while accelerating

$u = 4, a = -4, v = 0, t = ?$

No s $\Rightarrow$ $v = u + at$: $0 = 4 + (-4) \times t$

$t = 1$

Distance travelled at constant speed $= 20 - 4 - 2 = 14$

Travelling at 4 m/s the lift takes $\frac{14}{4} = 3.5$ s

So total time $= 2 + 3.5 + 1 = 6.5$ seconds

E.g. 1 A force of 420 N acts on a block, causing an acceleration of 10.5 m/s². Assuming that no other force acts on the block, find its mass.

Working: $F = ma$: $420 = m \times 10.5$

$m = 40$ kg

The mass of the block is 40 kg.

E.g. 2 A body of mass 2 kg accelerates uniformly from 3 m/s to 23 m/s in 4 seconds. Find the force acting on the body.

Working: ***The acceleration needs to be calculated first.***

$u = 3, v = 23, t = 4, a = ?$

No s $\Rightarrow$ $v = u + at$: $23 = 3 + a \times 4$

$a = 5$

$F = ma$: $F = 2 \times 5$

$F = 10$ N

The force acting on the body is 10 N

E.g. 3 An object of mass 5 kg has an acceleration of $\begin{pmatrix} 3 \\ -4 \end{pmatrix}$ ms^{-2}. Find:

(a) the force vector, $\mathbf{F}$,
(b) the magnitude of the force
(c) the direction of the force.

N.B. The direction of a vector is the angle it makes with the positive $x-$axis.

Working:

(a) $\mathbf{F} = m\mathbf{a}$: $\quad \mathbf{F} = 5 \times \begin{pmatrix} 3 \\ -4 \end{pmatrix} = \begin{pmatrix} 15 \\ -20 \end{pmatrix}$

The force vector is $\begin{pmatrix} 15 \\ -20 \end{pmatrix}$ N.

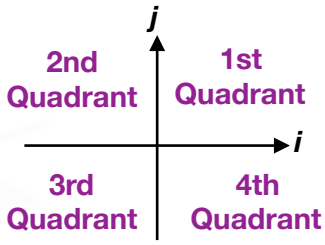
(b) $\left|\mathbf{F}\right| = \left|\begin{pmatrix} 15 \\ -20 \end{pmatrix}\right| = \sqrt{15^2 + (-20)^2} = 25$ N

The magnitude of the force is 25 N.

(c) The force acts in the 4th quadrant:

Direction $= 360^o - \tan^{-1}\dfrac{20}{15} = 306.9^o$

N.B. Or -53.1^o



E.g. 4 A force of magnitude of 104 N acts on a body. Given that the acceleration is $\begin{pmatrix} -12 \\ 5 \end{pmatrix}$ ms^{-2}, find the mass of the body

Working: $\left|\begin{pmatrix} -12 \\ 5 \end{pmatrix}\right| = \sqrt{(-12)^2 + 20^2} = 13$

$F = ma$: $\quad 104 = m \times 13$

$m = 8$ kg

The mass of the body is 8 kg.

Video: Newton's 2nd law

Solutions to Starter and E.g.s

Exercise

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