Numerical Problems 2.1 – 2.10 — Solution Notes

Physics — Chapter 2 — Every step shown — $g = 10\ \text{m s}^{-2}$

Formulas Used

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \Rightarrow t = \frac{S}{v}$$

$$a = \frac{v_f - v_i}{t}$$

$$v_f = v_i + at$$

$$S = v_i t + \frac{1}{2}at^2$$

$$2aS = v_f^2 - v_i^2$$

$$v_{av} = \frac{\text{Total distance}}{\text{Total time}}$$

Free fall: replace a by g ($v_i = 0$): $h = \frac{1}{2}gt^2$, $v_f = gt$

Upward throw: $a = -g$

$$1\ \text{km h}^{-1} = \frac{1000}{3600}\ \text{m s}^{-1} = \frac{5}{18}\ \text{m s}^{-1}$$

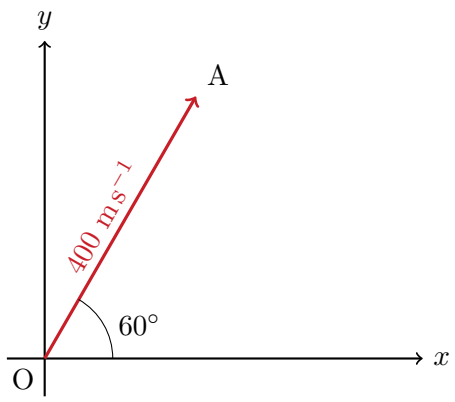
2.1 Draw the representative lines of the following vectors

(a) A velocity of $400\ \text{m s}^{-1}$ making an angle of $60°$ with x-axis.

$$\text{Choose scale:} \quad 1\ \text{cm} = 100\ \text{m s}^{-1}$$

$$\text{Length of line} = \frac{400}{100} = 4\ \text{cm}$$

Steps: (1) Draw the x-axis and y-axis meeting at O. (2) With a protractor mark $60°$ from the +x axis. (3) Draw a line OA of length 4 cm along this mark. (4) Put an arrowhead at A (head = direction of the vector).



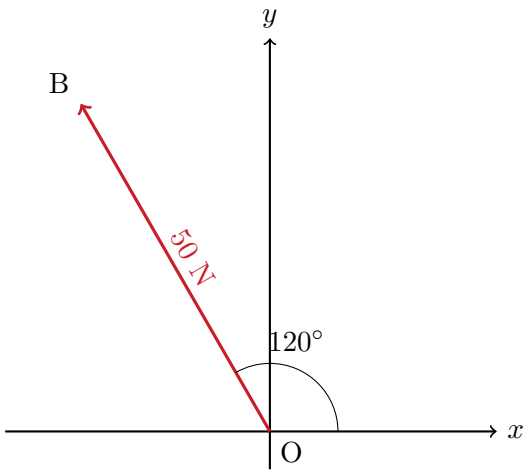
Scale: $1\ \text{cm} = 100\ \text{m s}^{-1}$

(b) A force of $50\ \text{N}$ making an angle of $120°$ with x-axis.

$$\text{Choose scale:} \quad 1\ \text{cm} = 10\ \text{N}$$

$$\text{Length of line} = \frac{50}{10} = 5\ \text{cm}$$

Steps: (1) Draw x and y axes meeting at O. (2) Mark $120°$ from the +x axis (anticlockwise; it lies in the 2nd quadrant, $30°$ beyond the y-axis). (3) Draw line OB of length 5 cm. (4) Put an arrowhead at B.



Scale: 1 cm = 10 N

2.2 Time to cover 360 km at average speed 72 km h^{-1}

Given: $v = 72\ \text{km h}^{-1}$, $S = 360\ \text{km}$
To find: $t = ?$

$$v = \frac{S}{t} \Rightarrow t = \frac{S}{v}$$

$$t = \frac{360\ \text{km}}{72\ \text{km h}^{-1}}$$

$$\boxed{t = 5\ \text{h}}$$

2.3 Truck starts from rest, reaches 90 km h^{-1} in 50 s

Given: $v_i = 0$, $v_f = 90\ \text{km h}^{-1}$, $t = 50\ \text{s}$
To find: $a = ?$

Step 1: Convert v_f into m s^{-1}

$$v_f = 90 \times \frac{1000}{3600} = 90 \times \frac{5}{18} = 25\ \text{m s}^{-1}$$

Step 2: Use $a = \dfrac{v_f - v_i}{t}$

$$a = \frac{25 - 0}{50} = \frac{25}{50}$$

$$\boxed{a = 0.5\ \text{m s}^{-2}}$$

2.4 Car at 5 m s^{-1} accelerates at 1.5 m s^{-2} for 5 s

Given: $v_i = 5\ \text{m s}^{-1}$, $a = 1.5\ \text{m s}^{-2}$, $t = 5\ \text{s}$
To find: $v_f = ?$

$$\begin{aligned} v_f &= v_i + at \\ &= 5 + (1.5)(5) \\ &= 5 + 7.5 \\ \boxed{v_f &= 12.5\ \text{m s}^{-1}} \end{aligned}$$

2.5 Motorcycle at 18 km h^{-1}, accelerates at 2 m s^{-2}, distance in 10 s

Given: $v_i = 18\ \text{km h}^{-1}$, $a = 2\ \text{m s}^{-2}$, $t = 10\ \text{s}$
To find: $S = ?$

Step 1: Convert v_i into m s^{-1}

$$v_i = 18 \times \frac{5}{18} = 5\ \text{m s}^{-1}$$

Step 2: Use $S = v_i t + \frac{1}{2}at^2$

$$\begin{aligned} S &= (5)(10) + \frac{1}{2}(2)(10)^2 \\ &= 50 + \frac{1}{2}(2)(100) \\ &= 50 + 100 \\ \boxed{S &= 150\ \text{m}} \end{aligned}$$

2.6 Wagon at 54 km h^{-1} stops after 25 m

Given: $v_i = 54\ \text{km h}^{-1}$, $v_f = 0$, $S = 25\ \text{m}$
To find: $a = ?$

Step 1: Convert v_i into m s^{-1}

$$v_i = 54 \times \frac{5}{18} = 15\ \text{m s}^{-1}$$

Step 2: Use $2aS = v_f^2 - v_i^2$

$$\begin{aligned} 2a(25) &= (0)^2 - (15)^2 \\ 50a &= -225 \\ a &= \frac{-225}{50} \\ \boxed{a &= -4.5\ \text{m s}^{-2}} \end{aligned}$$

The negative sign shows **retardation** (the wagon is slowing down).

2.7 Stone dropped from 45 m

Given: $h = 45$ m, $v_i = 0$, $g = 10\ \text{m s}^{-2}$
To find: (a) $t = ?$ (b) $v_f = ?$

(a) Time: use $h = \frac{1}{2}gt^2$

$$45 = \frac{1}{2}(10)t^2$$
$$45 = 5t^2$$
$$t^2 = \frac{45}{5} = 9$$
$$t = \sqrt{9}$$
$$\boxed{t = 3\ \text{s}}$$

(b) Velocity just before hitting the ground: use $v_f = v_i + gt$

$$v_f = 0 + (10)(3)$$
$$\boxed{v_f = 30\ \text{m s}^{-1}}$$

2.8 Car: 10 km at 20 m s^{-1}, then 0.8 km at 4 m s^{-1}

Given: $S_1 = 10$ km $= 10000$ m, $v_1 = 20\ \text{m s}^{-1}$
$S_2 = 0.8$ km $= 800$ m, $v_2 = 4\ \text{m s}^{-1}$
To find: v_{av} for the total journey

Step 1: Time for each part ($t = S/v$)

$$t_1 = \frac{10000}{20} = 500\ \text{s}$$
$$t_2 = \frac{800}{4} = 200\ \text{s}$$

Step 2: Totals

$$S = S_1 + S_2 = 10000 + 800 = 10800\ \text{m}$$
$$t = t_1 + t_2 = 500 + 200 = 700\ \text{s}$$

Step 3: Average velocity

$$v_{av} = \frac{S}{t} = \frac{10800}{700}$$
$$\boxed{v_{av} = 15.4\ \text{m s}^{-1}}$$

Note: the answer is NOT $\frac{20+4}{2} = 12$, because the car spends different times at the two speeds.

2.9 Ball dropped from top of a tower, reaches ground in 5 s

Given: $t = 5$ s, $v_i = 0$, $g = 10\ \text{m s}^{-2}$
To find: (a) $h = ?$ (b) $v_f = ?$

(a) Height of tower: use $h = \frac{1}{2}gt^2$

$$\begin{aligned} h &= \frac{1}{2}(10)(5)^2 \\ &= \frac{1}{2}(10)(25) \\ &= 5 \times 25 \\ \boxed{h &= 125\ \text{m}} \end{aligned}$$

(b) Velocity on striking the ground: use $v_f = v_i + gt$

$$\begin{aligned} v_f &= 0 + (10)(5) \\ \boxed{v_f &= 50\ \text{m s}^{-1}} \end{aligned}$$

2.10 Cricket ball hit straight up, 3 s to highest point

Given: $t = 3$ s, $v_f = 0$ (at highest point), $a = -g = -10\ \text{m s}^{-2}$ (upward motion)
To find: (a) $v_i = ?$ (b) total height above ground $= ?$

(a) Initial velocity: use $v_f = v_i + at$

$$\begin{aligned} 0 &= v_i + (-10)(3) \\ 0 &= v_i - 30 \\ \boxed{v_i &= 30\ \text{m s}^{-1}} \end{aligned}$$

(b) Height risen from the hitting point: use $S = v_i t + \frac{1}{2}at^2$

$$\begin{aligned} S &= (30)(3) + \frac{1}{2}(-10)(3)^2 \\ &= 90 - \frac{1}{2}(10)(9) \\ &= 90 - 45 \\ &= 45\ \text{m} \end{aligned}$$

The ball was hit 1 m above the ground, so

$$\begin{aligned} \text{Height from ground} &= 45 + 1 \\ \boxed{&= 46\ \text{m}} \end{aligned}$$

— End of Numerical Problems —

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