Section Check In – 3.02 Kinematics

Questions

Take the value of g to be $9.8\,\text{ms}^{-2}$

1. A particle is projected vertically upwards with a speed of $10\,\text{ms}^{-1}$.
   Find the greatest height reached by the particle.

2. A train leaves station A and accelerates at a uniform rate of $0.8\,\text{ms}^{-2}$ for 25 seconds. It then maintains a constant speed for 2 minutes until it approaches a second station. The train decelerates uniformly for 20 seconds until it comes to rest at station B. Find the distance between station A and station B.

3. (i) Using the equations $a = \dfrac{v-u}{t}$ and $s = \dfrac{1}{2}(u+v)t$, show that the displacement of a particle moving with constant acceleration can be given by the formula $v^2 = u^2 + 2as$.
   (ii) A particle starts from a fixed point O with velocity $8\,\text{ms}^{-1}$ and accelerates at a constant rate of $3\,\text{ms}^{-2}$ until it reaches a velocity of $20\,\text{ms}^{-1}$. How far will it be from O at this point?

4. Two particles, A and B, are initially $37.5\,\text{m}$ apart. A is projected in a straight line directly towards B with initial speed $2\,\text{ms}^{-1}$ and accelerates uniformly at $0.6\,\text{ms}^{-2}$. At the instant when A is released, B is projected in a straight line directly towards A with an initial speed of $3\,\text{ms}^{-1}$ and it accelerates uniformly at $0.4\,\text{ms}^{-2}$. The particles collide at point C.
   Find the distance from A's starting point to C.

5. A particle P is projected from a fixed point O. It passes O again after it has been moving for 2 and 6 seconds, respectively.
   By modelling the path of the particle between 2 to 6 seconds as a parabola,
   (i) show that the displacement of P at time t seconds is given by $s = t^2 - 8t + 12$
   (ii) find the time at which P is instantaneously at rest
   (iii) find the distance travelled by P between $t = 2$ s and $t = 6$ s
   (iv) show that P is moving with constant acceleration.

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Worked solutions

1. $u = 10\,\text{m s}^{-1}$
$a = -9.8\ \text{m s}^{-2}$
$v = 0$

Let the greatest height reached be h

$$v^2 = u^2 + 2as$$
$$0 = 10^2 - 2 \times 9.8 \times h$$
$$h = \frac{100}{2 \times 9.8} = 5.10\,\text{m (3 s.f.)}$$

2. Distance covered while accelerating $= \frac{1}{2} \times 0.8 \times 25^2 = 250\,\text{m}$

Maximum speed $= 0.8 \times 25 = 20\,\text{m s}^{-1}$
Distance travelled at constant speed $= 2 \times 60 \times 20 = 2400\,\text{m}$
Distance travelled while decelerating $= \frac{1}{2} \times 20 \times 20 = 200\ \text{m}$
Total distance between A and B $= 250 + 2400 + 200 = 2850\,\text{m} = 2.85\,\text{km}$.

3. (i) Rearranging $a = \frac{v-u}{t}$ gives $t = \frac{v-u}{a}$

Substituting for t in $s = \frac{1}{2}(u+v)t$ gives

$$s = \frac{(u+v)}{2} \times \frac{(v-u)}{a}$$
$$2as = (u+v)(v-u)$$
$$2as = v^2 - u^2$$
so $v^2 = u^2 + 2as$

(ii) $u = 8\ \text{ms}^{-1}$
$v = 20\,\text{ms}^{-1}$
$a = 3\,\text{ms}^{-2}$

$$v^2 = u^2 + 2as$$
$$20^2 = 8^2 + 2 \times 3 \times s$$
$$s = \frac{20^2 - 8^2}{2 \times 3} = 56\,\text{m}$$

4. For A, $s_A = 2t + \frac{1}{2} \times 0.6t^2$

For B, $s_B = 3t + \frac{1}{2} \times 0.4t^2$

$S_A + S_B = 37.5$

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$$2t + \frac{1}{2} \times 0.6t^2 + 3t + \frac{1}{2} \times 0.4t^2 = 37.5$$
$$0.5t^2 + 5t - 37.5 = 0$$
$$t^2 + 10t - 75 = 0$$
$$(t + 15)(t - 5) = 0$$
$$t = 5$$

So the distance from A's starting point to C is given by

$$s_A = 2t + \frac{1}{2} \times 0.6t^2 = 2 \times 5 + \frac{1}{2} \times 0.6 \times 5^2 = 17.5 \text{ m}$$

5. (i) $t = 2$ and $t = 6$ are solutions of $s = 0$
so $(t - 2)(t - 6) = 0$
and therefore
$$s = (t - 2)(t - 6)$$
$$s = t^2 - 8t + 12$$

(ii) $v = \frac{\mathrm{d}s}{\mathrm{d}t} = 2t - 8$
Particle is at rest when $v = 0$
$$2t = 8$$
$$t = 4 \text{ s}$$

(iii) When $t = 4$, $s = 4^2 - 8 \times 4 + 12 = -4$
The distance travelled between $t = 2$ and $t = 6$ is $2 \times 4 = 8$ m

(iv) $a = \frac{\mathrm{d}v}{\mathrm{d}t} = 2$
This is not dependent on t so the particle is moving with constant acceleration.

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