PQ 5d

Questions and Answers

Q1

- Drop a coin from rest. Assume air resistance is negligible.
- A Calculate displacement after 0.500 s.
- B Calculate how long it takes to fall 1.50m.
- C Calculate its velocity after 0.500 s.
- D Calculate its speed after falling 2.00m.

Q1 Answer

Choose a sign convention. Down is positive. Use the symbol $\overset{+}{\downarrow}$.

a $\mathbf{a} = +9.80\ \text{m s}^{-2}$, $t = 0.500\ \text{s}$, $\mathbf{u} = 0\ \text{m s}^{-1}$, $\mathbf{s} = ?$

The formula containing these is: $\mathbf{s} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$

Substitute: $\mathbf{s} = 0 \times 0.500 + \frac{1}{2} \times 9.80 \times 0.500^2 = +1.225\ \text{m} \approx 1.23\ \text{m down}$

Q1 Answer

b $\mathbf{a} = +9.80\ \text{m s}^{-2}$, $\mathbf{s} = 1.50\ \text{m}$, $\mathbf{u} = 0\ \text{m s}^{-1}$, $t = ?$

The formula containing these is: $\mathbf{s} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$

Substitute: $1.50 = 0 \times t + \frac{1}{2} \times 9.80 \times t^2$

Then rearrange: $t = \sqrt{\frac{2 \times 1.50}{9.80}} = 0.553\ \text{s}$

Q1 Answer

c $\mathbf{a} = +9.80\ \text{m s}^{-2}$, $t = 0.500\ \text{s}$, $\mathbf{u} = 0\ \text{m s}^{-1}$, $\mathbf{v} = ?$

The formula containing these is: $\mathbf{v} = \mathbf{u} + \mathbf{a}t$

Substitute: $\mathbf{v} = 0 + 9.80 \times 0.500 = +4.90\ \text{m s}^{-1}$, i.e. $\mathbf{v} = 4.90\ \text{m s}^{-1}$ down

Q1 Answer

d $\mathbf{a} = +9.80\ \text{m s}^{-2}$, $\mathbf{s} = +2.00\ \text{m}$, $\mathbf{u} = 0\ \text{m s}^{-1}$, $v = ?$

The formula containing these is: $v^2 = u^2 + 2\mathbf{as}$

Substitute: $v^2 = 0^2 + 2 \times 9.80 \times 2.00 = 39.2$

Find the square root: $v = \sqrt{39.2} = 6.26\ \text{m s}^{-1}$

Q2

- **A bus leaves a bus stop by accelerating at $0.8ms^{-2}$ for 5s. It then travels at a constant speed for 2 minutes before slowing down uniformly at $4ms^{-2}$ to come to rest at the next bus stop.**
- **a) Find the constant speed in the middle part of the journey**
- **b) Find the distance travelled in the first part of the journey**
- **c) Find the total distance between the two bus stops**

Q2 Answer

- a) $u = 0,\ t = 5,\ a = 0.8$
- $v = u + at$
- $v = 0 + 5 \times 0.8$
- $v = 4\ ms^{-1}$
- b) $u = 0,\ t = 5,\ a = 0.8$
- $s = ut + {}^{1}/_{2}at^{2}$
- $s = 0 + {}^{1}/_{2} \times 0.8 \times 25$
- $s = 10m$

Q2 Answer

- c) Distance in acceleration phase = 10m
- Distance in middle section = $120 \times 4 = 280$m
- Distance in deceleration phase
- $u = 4, v = 0, a = -4,$
- $v^2 = u^2 + 2as$
- $0 = 16 - 2 \times 4 \times 0.8\ s$
- $s = 25$m

- Total distance = $10 + 280 + 25 = 315$m

Q3

- **A particle positioned at O is travelling at $20ms^{-1}$.**
- **It starts to decelerate at a constant rate of $3ms^{-2}$ and continues to do so for 12 seconds.**
- **Find the time taken for the particle to come instantaneously to rest.**
- **Find the final velocity of the particle.**
- **Find the position of the particle relative to O at the end of the journey.**
- **Find the distance travelled in the entire 12 seconds**

Q3 Answer

- a) u = 20, a = -3, v = 0 $v = u + at$
- $0 = 20 - 3t$
- $t = 6^2/_3$ s

- b) u = 20, a = -3, t = 12
- v = u + at
- v = 20 + -3 × 12
- v = -16 ms^{-1} (speed is 16 in the opposite direction)

Q3 Answer

- c) $u = 20, a = -3, t = 12$
- $s = ut + \frac{1}{2}at^2$
- $s = 20 \times 12 + \frac{1}{2} \times -3 \times 144$
- $s = 240 - 216$
- $s = 24$ m (so 24 to 'the right' of the start position)

Q3 Answer

- Distance travelled = Distance up to stopping (at $6^2/_3$ s) + Distance back
-
- Distance up to stopping
- u = 20, a = -3, v = 0
- $v^2 = u^2 + 2as$
- $0 = 400 – 6s$
- $s = 66^2/_3$ m
- Distance back = $66^2/_3 – 24 = 42^2/_3$ m
-
- Total distance = $66^2/_3 + 42^2/_3 = 109^1/_3$ m
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- (May be worth while showing that had the particle returned to the start position its speed would have been back up to $20ms^{-1}$ but in the negative direction)

Q4

- **A particle is moving in a straight line from *O* to *A* with a constant acceleration of $2ms^{-2}$. Its velocity at *A* is $30ms^{-1}$ and it takes 12 seconds to travel from *O* to *A*. Find the particle's velocity at *O* and the distance *OA*.**
- $a = 2 \quad v = 30 \quad t = 12$ Find u and s.
- The velocity at *O* is $6ms^{-1}$.

Q4 Answer

$$s = ut + \frac{1}{2}at^2$$

$$= 6 \times 12 + \frac{1}{2} \times 2 \times 12^2$$

$$= 216 \text{ m}$$

The distance *OA* is 216m.

Q5

- **A train starts from rest at a station *S* and moves with constant acceleration. It passes a signal box *B* 15 seconds later with a speed of 81kmh^{-1}. Find the acceleration of the train in ms^{-2} and the distance in metres between the station and the signal box.**

Q5 Answer

- **We must first change the units of the speed at *B* into ms^{-1} :**

$$81\,\text{kmh}^{-1} = 80000\,\text{mh}^{-1} = 22.5\,\text{ms}^{-1}$$

- $u = 0 \quad v = 22.5 \quad t = 15$ Find a and s.

$$v = u + at$$

$$22.5 = 0 + 15a$$

$$a = 1.5\,\text{ms}^{-2}$$

The acceleration is 1.5ms^{-2}.

Q5 Answer

$$s = \frac{1}{2}(u+v)t$$

$$= \frac{1}{2}(0+22.5)\times 15$$

$$= 168.75 \text{ m}$$

The distance between the station and the signal box is 168.75m.

Q6

- A particle starts from rest and moves along a straight line with a constant acceleration until it reaches a velocity of $15ms^{-1}$. It is then brought to rest again by a constant retardation of $3ms^{-2}$. If the particle is then 60m from its starting point, find the time for which the particle is moving.
- Acceleration phase : $u = 0 \quad v = 15$
- Deceleration phase : $u = 15 \quad v = 0 \quad a = -3$ (negative since the particle is retarding)
- There is not enough information on the acceleration phase to proceed, so we consider the deceleration phase first.

Q6 Answer

$$v = u + at$$

$$0 = 15 - 3t$$

$$t = 5 \text{ seconds}$$

$$v^2 = u^2 + 2as$$

$$0^2 = 15^2 + 2 \times -3 \times s$$

$$s = \frac{225}{6}$$

$$= 37.5 \text{ m}$$

Q6 Answer

- So for the acceleration phase, .

$$s = \frac{1}{2}(u+v)t$$

$$22.5 = \frac{1}{2}(0+15)\times t$$

$$t = 3 \text{ seconds}$$

So the particle travels for a total of 5 + 3 = 8 seconds.

Q7

- **Dissatisfied with the quality of his Chinese meal, an oriental tourist drops his plate from a rooftop restaurant, 100m above the ground. How long does it take for the chop suey to hit the ground, and at what speed is it then travelling?**
- $u = 0 \quad a = 9.8 \quad s = 100$ Find t, v.

Q7 Answer

$$s = ut + \tfrac{1}{2}at^2$$

$$100 = 0 + \tfrac{1}{2} \times 9.8 \times t^2$$

$$t^2 = \frac{100}{4.9}$$

$$t = 4.52 \text{ seconds (2 d.p.)}$$

$$v^2 = u^2 + 2as$$

$$= 0 + 2 \times 9.8 \times 100$$

$$= 1960$$

$$v = 44.3 \text{ ms}^{-1} \text{ (1 d.p.)}$$

Q8

- A competitor at the highland games throws a haggis vertically into the air with a velocity of $20ms^{-1}$, letting go at a height of 2m above the ground. Find its maximum height, the time taken to fall to the ground, and the speed on impact.
- $u = 20$ $a = -9.8$ (negative since in the opposite direction to initial velocity) $v = 0$ Find s.

Q8 Answer

$$v^2 = u^2 + 2as$$

$$0 = 20^2 - 2 \times 9.8 \times s$$

$$s = \frac{400}{19.6}$$

$$= 20.4 \text{ m (1 d.p.)}$$

Q8 Answer

- The maximum height above the ground is therefore 22.4 m.
- On impact with the ground,
- $u = 20 \quad a = -9.8 \quad s = -2$ Find t, v.

Q8 Answer

$$s = ut + \tfrac{1}{2}at^2$$

$$-2 = 20t + \tfrac{1}{2} \times -9.8 \times t^2$$

$$4.9t^2 - 20t - 2 = 0$$

$$t = \frac{20 \pm \sqrt{(-20)^2 - 4 \times 4.9 \times -2}}{2 \times 4.9}$$

$$= 4.18 \text{ seconds (2 d.p., ignoring negative root)}$$

$$v^2 = u^2 + 2as$$

$$= 20^2 + 2 \times -9.8 \times -2$$

$$= 439.2$$

$$v = 20.9 \text{ ms}^{-1} \text{ (1 d.p.)}$$

Q9

- A cannon fires a shell vertically upwards from ground level at $35ms^{-1}$. At what times is it 10m above the ground? For how long is it more than 10m high?
- $u = 35$ $a = -9.8$ $s = 10$ Find t.

Q9 Answer

$$s = ut + \tfrac{1}{2}at^2$$

$$10 = 35t + \tfrac{1}{2} \times -9.8 \times t^2$$

$$4.9t^2 - 35t + 10 = 0$$

$$t = \frac{35 \pm \sqrt{(-35)^2 - 4 \times 4.9 \times 10}}{2 \times 4.9}$$

$$t = 0.30 \text{ seconds}, 6.84 \text{ seconds}$$

The time for which the height is above 10m is 6.84 – 0.30 = 6.54 seconds

Q10

- **A juggler throws a ball up in the air with an initial speed of $5ms^{-1}$ from a height of 1.2m. Assuming that g is $10ms^{-2}$, find the maximum height that the ball reaches above the ground and the time it takes to reach this height.**

Q10 Answer

- Max height when velocity is zero
- u = 5, a = -10, v = 0 Find t
- $v = u + at$
- $0 = 5 – 10t$
- $T = 0.5s$
-
- Find s
- $v^2 = u^2 + 2as$
- $0 = 25 – 20s$
- $s = 1.25$
- So max height is 1.2 + 1.25 = 2.45m