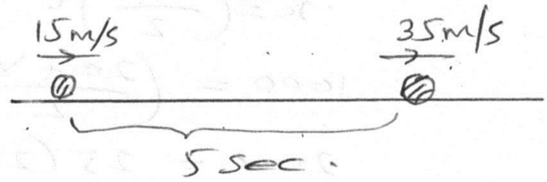
Equations for Constant Acceleration Motion

1 A police car accelerates from 15 m s^{-1} to 35 m s^{-1} in 5 seconds. The acceleration is constant.



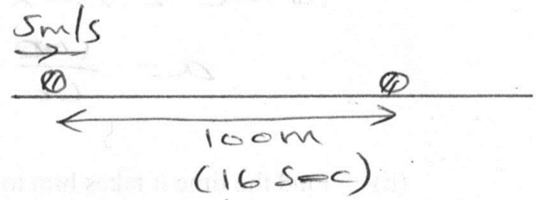
(a) Calculate the acceleration of the police car.

$$a = \frac{v-u}{t} = \frac{35-15}{5} = 4\ m/s^2$$

(b) Work out the distance travelled by the police car during this time.

$$x = \left(\frac{u+v}{2}\right)t = \left(\frac{15+35}{2}\right) \times 5 = 125\ m$$

2 A marathon competitor running at 5 m s^{-1} puts on a sprint when she is 100 metres from the finish, and covers this distance in 16 seconds. Assuming that her acceleration is Constant,



(a) calculate her speed as she crosses the finish line.

$$x = \left(\frac{u+v}{2}\right)t$$

$$100 = \left(\frac{5+v}{2}\right) \times 16$$

$$100 = 8(5+v)$$

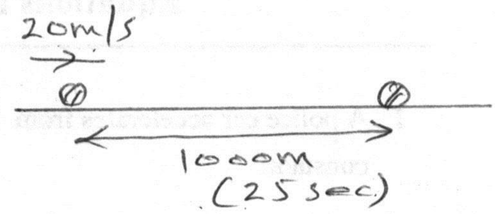
$$12.5 = 5+v$$

$$v = 7.5\ m/s$$

(b) calculate her acceleration.

$$a = \frac{v-u}{t} = \frac{7.5-5}{16} = 0.16\ m/s^2\ (2\ s.f.)$$

3 **A train travelling at 20 m s^{-1} starts to accelerate with constant acceleration. It covers the next kilometre in 25 seconds.**



(a) Find the speed of the train at the end of the 25 seconds.

$x = \left(\frac{u+v}{2}\right)t$

$1000 = \left(\frac{20+v}{2}\right) \times 25$

$2000 = 25(20+v)$

$80 = 20+v$

$v = 60 m/s$

(b) Calculate the acceleration of the train during the 25 seconds.

$a = \frac{v-u}{t}$

$= \frac{60-20}{25}$

$= 1.6 m/s^2$ //

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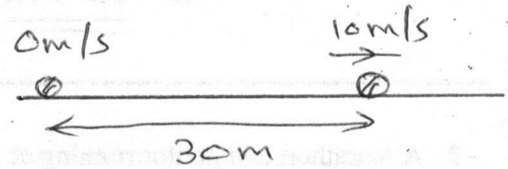
4 **A long-jumper takes a run of 30 metres to accelerate to a speed of 10 m s^{-1} from a standing start.**



(a) Work out his acceleration during this period.

$v^2 - u^2 = 2ax$

$10^2 - 0^2 = 2a \times 30$

$a = \frac{100}{60} = 1.67 m/s^2$ (3 s.f.)

(b) Find the time it takes him to run the 30 m.

$x = \left(\frac{u+v}{2}\right)t$

$30 = \left(\frac{0+10}{2}\right)t$

$30 = 5t$

$t = 6 sec$

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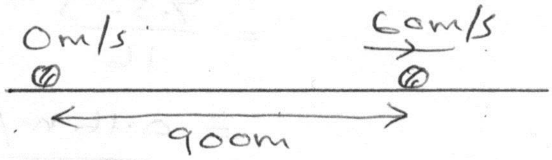
5 **Starting from rest, an aircraft accelerates to its take-off speed of 60 m s^{-1} in a distance of 900 metres. Assuming constant acceleration,**



(a) work out the acceleration of the aircraft.

$v^2 - u^2 = 2ax$

$60^2 - 0^2 = 2a \times 900$

$3600 = 1800a$

$a = 2 m/s^2$

(c) the time it takes for the aircraft to reach the take-off speed of 60m/s.

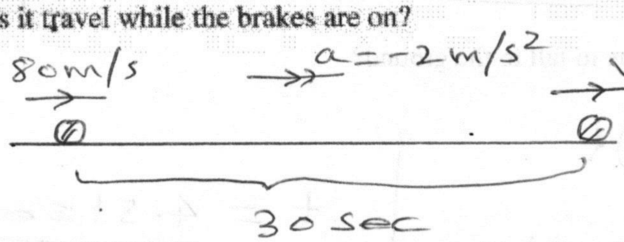
$$x = \left(\frac{u+v}{2}\right)t$$

$$900 = \left(\frac{0+60}{2}\right)t$$

$$900 = 30t$$

$$t = 30 \text{ sec}$$

6 **A train is travelling at 80 m s^{-1} when the driver applies the brakes, producing a deceleration of 2 m s^{-2} for 30 seconds. How fast is the train then travelling, and how far does it travel while the brakes are on?**



$$a = \frac{v-u}{t}$$

$$-2 = \frac{v-80}{30}$$

$$-60 = v - 80$$

$$v = 20 \text{m/s}$$

$$v^2 - u^2 = 2ax$$

$$20^2 - 80^2 = 2 \times -2x$$

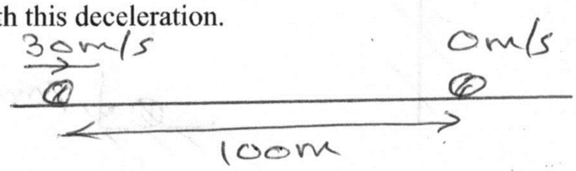
$$-6000 = -4x$$

$$x = 1500 \text{m}$$

7. A car travelling at a speed of 30m/s decelerates with a constant deceleration.

It stops after travelling a distance of 100 m with this deceleration.

(a) Calculate the deceleration of the car.



$$v^2 - u^2 = 2ax$$

$$0^2 - 30^2 = 2a \times 100$$

$$a = \frac{-900}{200}$$

$$a = -4.5 \text{m/s}^2$$

Deceleration = 4.5m/s^2

(b) Work out the time it takes for the car to decelerate and stop.

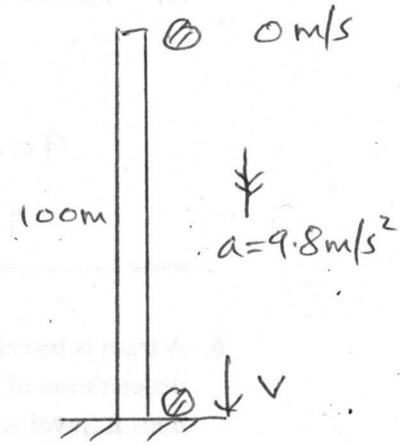
$$a = \frac{v-u}{t}$$

$$-4.5 = \frac{0-30}{t}$$

$$-4.5t = -30$$

$$t = 6.67 \text{ sec (3s.f.)}$$

8. A stone is dropped from the top of a tower of height 100m.
Assume that there is no air resistance.



(a) Work out the speed with which the stone hits the ground.

$v^2 - u^2 = 2ax$

$v^2 - 0^2 = 2 \times 9.8 \times 100$

$v^2 = 1960$

$v = 44.3 m/s$ (3 s.f.)

(b) How long does it take the stone to fall to the ground?

$x = \left(\frac{u+v}{2}\right)t$

$100 = \left(\frac{0+44.3}{2}\right)t$

$200 = 44.3t$

$t = 4.51 sec$ (3 s.f.)

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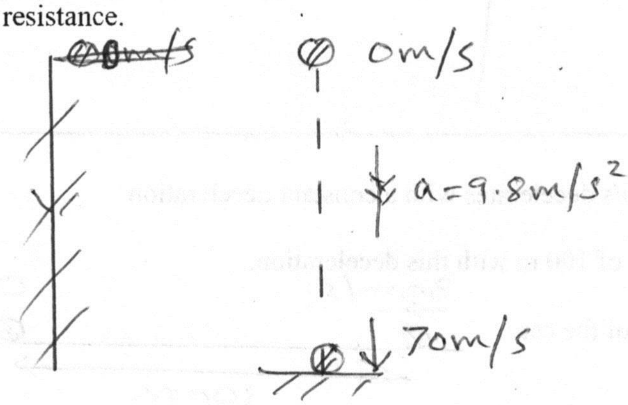
9. A parcel is dropped from a helicopter hovering in the air.

The parcel travels vertically downwards and hits the ground with a speed of 70 m/s.

At what height above the ground is the helicopter hovering in? You may assume that there is no air resistance.



$v^2 - u^2 = 2ax$

$70^2 - 0^2 = 2 \times 9.8x$

$4900 = 19.6x$

$x = 250m$

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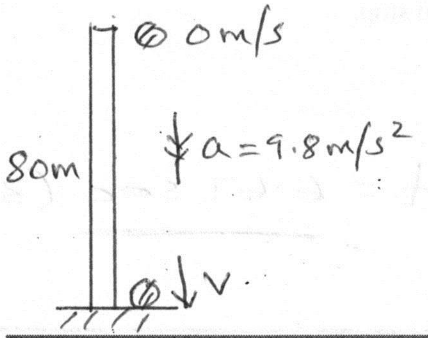
10. Sam drops a stone of mass 1 kg from the top of a building of height 80m. Assume that there is no air resistance.

(a) Calculate the speed with which the stone hits the ground.



$v^2 - u^2 = 2ax$

$v^2 - 0^2 = 2 \times 9.8 \times 80$

$v^2 = 1568$

$v = 39.6 m/s$ (3 s.f.)

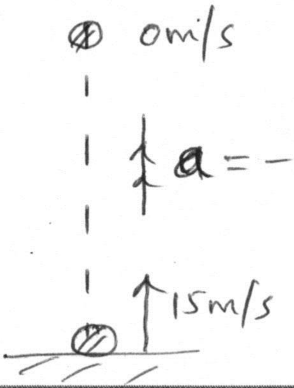
Sam then drops another stone of mass 15 kg from the top of the same building.

(b) Without further calculations, state whether the 15 kg stone would hit the ground with a greater, lower speed or with the same speed as the 1 kg stone. Explain the reason for your answer.

If air resistance is ignored, all objects will fall with the same acceleration of $9.8 m/s^2$. Since the initial velocity and the height are the same for both the objects, the 15kg will hit the ground with the same speed as the 1kg.

11. A stone is thrown vertically upwards with a speed of 15 m/s.

Assuming no air resistance, calculate the maximum height reached by the stone.



$$v^2 - u^2 = 2ax$$

$$0 - 15^2 = 2 \times -9.8\,x$$

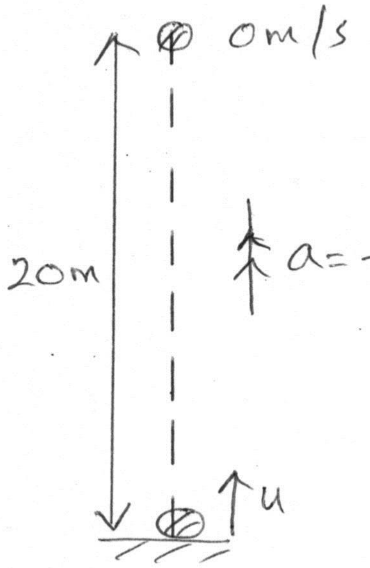
$$-225 = -19.6x$$

$$x = 11.5 m$$

12. An arrow fired vertically upwards from ground level reaches a maximum height of 20m.

How fast should the arrow have left the bow to reach this height?

You may assume that there is no air resistance against the motion of the arrow.



$$v^2 - u^2 = 2ax$$

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

$$-u^2 = -392$$

$$u^2 = 392$$

$$u = 19.8 m/s$$

(3 s.f.)