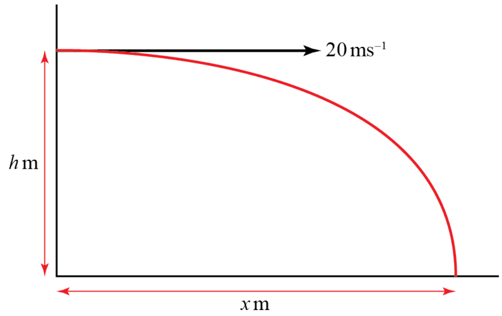
Projectiles 6A

In this exercise, the positive direction is considered to be downwards.

1 a R(↓): $u_y = 0$, $t = 5$ s, $a = g = 9.8$ ms^{-2}, $s = h$



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

$h = 0 + \frac{1}{2} \times 9.8 \times 5^2$

$= 122.5$

The height h is 122.5 m.

b R(→): $u_x = 20$ ms^{-1}, $t = 5$ s, $s = x$

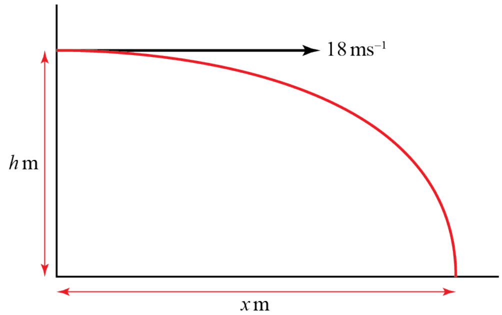
$s = vt$

$x = 20 \times 5$

$= 100$

The particle travels a horizontal distance of 100 m.

2 a R(→): $u_x = 18$ ms^{-1}, $t = 2$ s, $s = x$



$s = vt$

$x = 18 \times 2$

$= 36$

R(↓): $u_y = 0$, $t = 2$ s, $a = g = 9.8$ ms^{-2}, $s = y$

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

$h = 0 + \frac{1}{2} \times 9.8 \times 2^2$

$= 19.6$

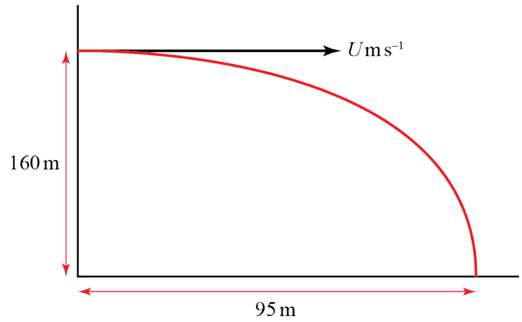
The horizontal and vertical components of the displacement are 36 m and 19.6 m respectively.

b $d^2 = 36^2 + 19.6^2$

$d = \sqrt{1680.16} = 40.989...$

The distance from the starting point is 41.0 m (3s.f.).

3 R(↓): $u_y = 0$, $a = g = 9.8\text{ ms}^{-2}$, $s = 160\text{ m}$, $t = ?$



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

$$160 = 0 + \frac{1}{2} \times 9.8 \times t^2$$

$$t^2 = \frac{160}{4.9}$$

$$t = \pm\frac{40}{7}$$

The negative root can be ignored.

R(→): $u_x = U$, $t = \frac{40}{7}$ s, $s = 95$ m

$$s = vt$$

$$95 = U \times \frac{40}{7}$$

$$U = \frac{7 \times 95}{40} = 16.625$$

The projection speed is 16.6 ms^{-1} (3s.f.).

4 $R(\downarrow)$

$$u = 0,\quad s = 16,\quad a = 9.8,\quad t = ?$$

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

$$16 = 0 + 4.9t^2$$

$$t^2 = \frac{16}{4.9} = 3.265...$$

$$t = 1.807$$

Let the speed of the projection be $u\text{ m s}^{-1}$

$R(\rightarrow)$

$$s = ut$$

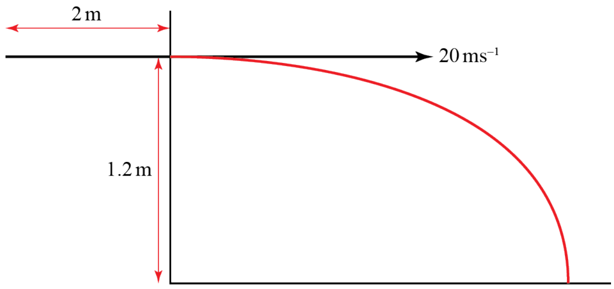
$$140 = u \times 1.807...$$

$$u = \frac{140}{1.807...}$$

$$= 77.475$$

The speed of projection of the particle is 77.5 m s^{-1} (3 s.f.)

5 Whilst particle is on the table:



$R(\rightarrow)$

$s = vt$

$2 = 20 \times t$

$t = 0.1$

Once particle leaves the table:

$R(\downarrow)$ $u_y = 0$, $a = g = 9.8$ ms^{-2}, $s = 1.2$ m, $t = ?$

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

$1.2 = 0 + \frac{1}{2} \times 9.8 \times t^2$

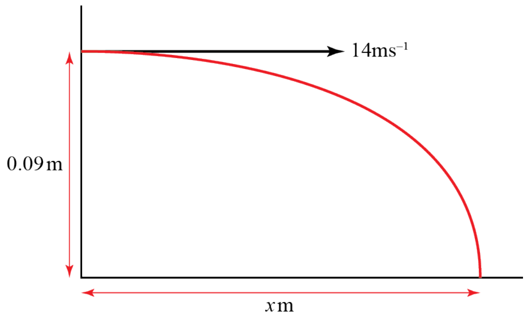
$t^2 = \frac{1.2}{4.9}$

$t = \pm 0.49487...$

The negative root can be ignored.

The total time the particle takes to reach the floor is 0.1 + 0.49 = 0.59 s (2s.f.).

6 $R(\downarrow)$ $u_y = 0$, $a = g = 9.8$ ms^{-2}, $s = 9$ cm $= 0.09$ m, $t = ?$



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

$0.09 = 0 + \frac{1}{2} \times 9.8 \times t^2$

$t^2 = \frac{0.09}{4.9}$

$t = \pm 0.13552...$

The negative root can be ignored.

$R(\rightarrow)$: $u_x = 14$ ms^{-1}, $t = 0.13552...$ s, $s = x$

$s = vt$

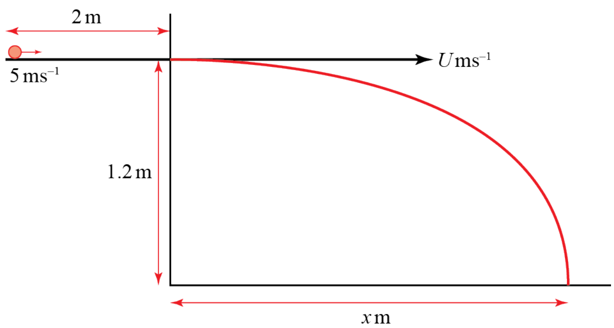
$x = 14 \times 0.13552...$

$x = 1.8973...$

The dart is thrown from a point 1.90 m (3s.f.) from the board.

7 **a** Once particle leaves the surface:

$R(\downarrow)$ $u_y = 0$, $a = g = 9.8$ ms^{-2}, $s = 1.2$ m, $t = ?$



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

$1.2 = 0 + \frac{1}{2} \times 9.8 \times t^2$

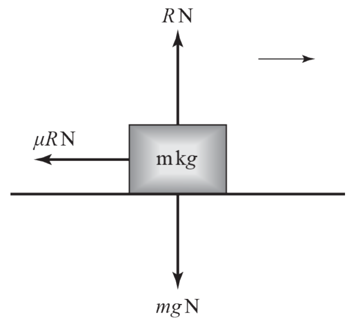
$t^2 = \frac{1.2}{4.9}$

$t = \pm 0.49487...$

Total travel time is 1.0 s, so particle is in contact with the surface for 1.0 – 0.49 = 0.51 s (2s.f.).

7 b Considering forces acting on particle while on surface:

$R(\downarrow)$: $R = mg$



$$R(\rightarrow): \quad F = ma$$

$$-\mu R = ma \quad \text{since } F = F_{MAX}$$

$$-\mu mg = ma$$

$$a = -\mu g \qquad \textbf{(1)}$$

Use equations of motion to calculate the acceleration of the particle whilst on the surface:

$s = 2$ m, $u = 5$ ms^{-1}, $t = 0.50513\ldots$ s, $a = ?$

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

$$2 = (5 \times 0.50513...) + \left(\frac{1}{2} \times a \times 0.50513...^2\right)$$

$$0.12757... \times a = 2 - 2.5256...$$

$$a = \frac{-0.52564...}{0.12757...}$$

$$a = -4.1201... \qquad \textbf{(2)}$$

Substitute (**2**) in (**1**):

$$-4.1201... = -\mu g$$

$$-4.1201... = -9.8 \times \mu$$

$$\mu = 0.42042...$$

The coefficient of friction is 0.42 (2s.f.).

c While particle is on the surface: $s = 2$ m, $u = 5$ ms^{-1}, $t = 0.50513\ldots$ s, $v = U$

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

$$2 = \frac{1}{2}(5 + U)0.50513\ldots$$

$$5 + U = \frac{4}{0.50513...}$$

$$U = 7.9187... - 5 = 2.9187...$$

Considering horizontal motion of particle once it has left the surface:

R($\rightarrow$): $u_x = U = 2.9187\ \ldots$ ms^{-1}, $t = 0.495$ s, $s = x$

$$s = vt$$

$$x = 2.9187... \times 0.495$$

$$x = 1.4447...$$

The total distance travelled = 1.4447… + 2 = 3.44 (3 s.f.)