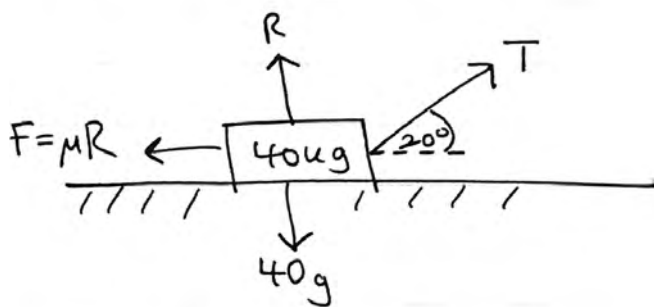


M1 October 2017 (IAL) (MA)

Q1)



$$\underline{N2L(\text{suitcase})} \uparrow^+ : T \sin 20 + R - 40g = 40(0)$$

$$R = 40g - T \sin 20 //$$

$$\underline{N2L(\text{suitcase})} \rightarrow^+ : T \cos 20 - F = 40(0)$$

$$\therefore T \cos 20 = \mu R = \frac{3}{4} R$$

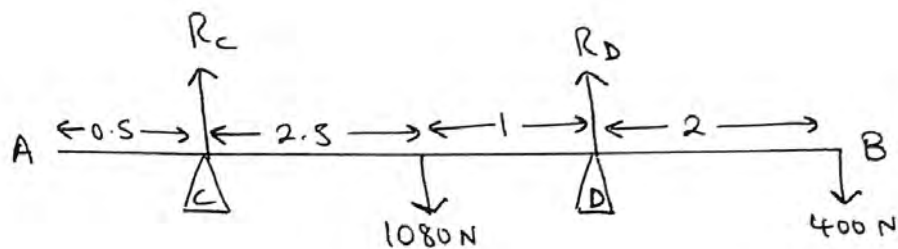
$$\text{so } T \cos 20 = \frac{3}{4} (40g - T \sin 20)$$

$$T \cos 20 = 30g - \frac{3}{4} T \sin 20$$

$$T \left(\cos 20 + \frac{3}{4} \sin 20 \right) = 30g$$

$$\therefore T = \frac{30g}{\cos 20 + \frac{3}{4} \sin 20} = \boxed{246\text{N}} \quad (3 \text{ s.f.})$$

Q2ai)



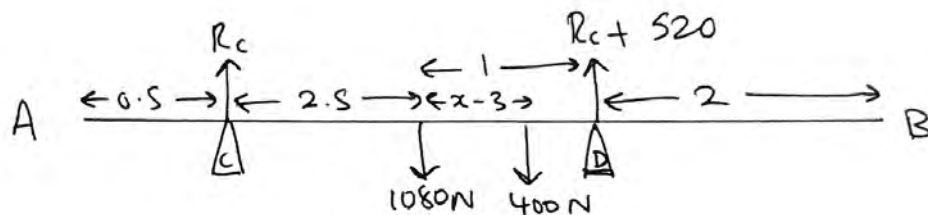
$$\underline{M(D)}: R_C(3.5) + 400(2) = 1080(1)$$

$$\Rightarrow R_C = \frac{1080 - 400(2)}{3.5} = \boxed{80\text{N}}$$

$$\text{ii) } \underline{M(C)}: R_D(3.5) = 1080(2.5) + 400(5.5)$$

$$\Rightarrow R_D = \frac{1080(2.5) + 400(5.5)}{3.5} = \boxed{1400\text{N}}$$

b)



$$\underline{R(\uparrow\downarrow)}: R_C + (R_C + 520) = 1080 + 400$$

$$\Rightarrow R_C = \frac{1080 + 400 - 520}{2}$$

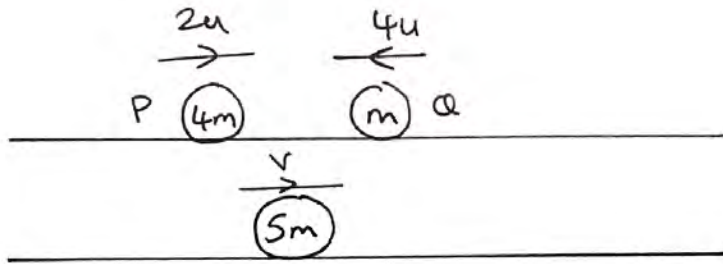
$$= 480\text{N} //$$

$$\underline{M(A)}: R_C(0.5) + (R_C + 520)(4) = 1080(3) + 400(3.5)$$

$$\therefore x = \frac{480(0.5) + (480 + 520)(4) - 1080(3)}{480}$$

$$= \boxed{2.5\text{m}}$$

Q3)



C.L.M : $4m(2u) - m(4u) = 5m(v)$
 $8u - 4u = 5v$

$\Rightarrow v = \frac{4}{5}u$

\leftarrow (v is +ve so the final particle travels in a direction opposite to which Q was initially travelling in.)

Impulse on $Q = m(v - u)$

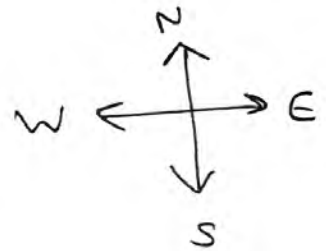
$= m\left(\frac{4}{5}u - 4u\right) = \boxed{4.8mu}$

Q4a)

$F_1 = 8N$

(ie) $F_1 = \begin{pmatrix} 8 \\ 0 \end{pmatrix}$ in vector form.

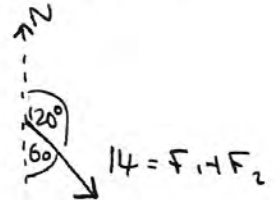
and $F_2 = \begin{pmatrix} x \\ y \end{pmatrix}$



We are told $F_1 + F_2$ can be represented as :

or in vector form :

$F_1 + F_2 = \begin{pmatrix} 14\sin 60 \\ -14\cos 60 \end{pmatrix}$



$\therefore \begin{pmatrix} 8 \\ 0 \end{pmatrix} + \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 14\sin 60 \\ -14\cos 60 \end{pmatrix}$

$$\frac{11}{5}mg - \frac{1}{4}(R) = 7ma$$

$$\underline{R(\uparrow^+) \text{ for A: } R - 3mg \cos d = 0}$$

$$R = 3mg \cos d = 3mg \left(\frac{4}{5}\right) = \left(\frac{12mg}{5}\right)$$

$$\text{so } \frac{11}{5}mg - \frac{12mg}{5 \times 4} = 7ma$$

$$\therefore a = \frac{\frac{11}{5}g - \frac{12g}{20}}{7} = \boxed{\frac{8g}{35}}$$

c) Particles have the same acceleration ...

d) find speed when B hits the ground:

$$\left. \begin{array}{l} s = 1.75 \\ u = 0 \\ v = v \\ a = 8g/35 \\ + \downarrow t \end{array} \right\} \Rightarrow v^2 = u^2 + 2as$$

$$\Rightarrow v^2 = 0^2 + 2\left(\frac{8g}{35}\right)(1.75)$$

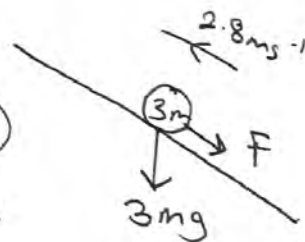
$$\Rightarrow v = \sqrt{2\left(\frac{8g}{35}\right)(1.75)} = \boxed{2.8 \text{ms}^{-1}}$$

new model of A's motion once B hits the ground (string is now slack)

$$\underline{N2L(A)} \uparrow^+ : -F - 3mg \sin d = 3m(a)$$

$$-\frac{1}{4}\left(\frac{12mg}{5}\right) - 3mg\left(\frac{3}{5}\right) = 3ma$$

$$\therefore a = -\frac{4}{5}g //$$



$$\text{So } x = 14\sin 60 - 8 = 7\sqrt{3} - 8$$

$$y = -14\cos 60 = -7$$

$$\begin{aligned} \therefore |F_2| &= \sqrt{x^2 + y^2} = \sqrt{(-7)^2 + (7\sqrt{3} - 8)^2} \\ &= \boxed{8.12\text{N}} \end{aligned}$$

$$\text{ii) } F_2 = \begin{pmatrix} 7\sqrt{3} - 8 \\ -7 \end{pmatrix} \rightarrow \begin{array}{c} \text{N} \\ \nearrow \theta \\ \text{---} 7\sqrt{3} - 8 \\ \searrow \\ \text{---} 7 \\ \downarrow \\ F_2 \end{array}$$

$$\text{so } \tan \theta = \frac{7}{7\sqrt{3} - 8}$$

$$\begin{aligned} \therefore \text{Bearing required} &= 90 + \tan^{-1} \left(\frac{7}{7\sqrt{3} - 8} \right) \\ &= \boxed{149^\circ} \end{aligned}$$

(Q5a)

$$\begin{array}{l} \uparrow \\ \bullet \uparrow 14.7\text{ms}^{-1} \\ \uparrow 2.5\text{m} \\ \text{|||||} \end{array} \quad \left. \begin{array}{l} \uparrow \\ S = h \\ u = 14.7\text{ms}^{-1} \\ v = 0 \\ a = -g \\ t = \end{array} \right\} \begin{array}{l} v^2 = u^2 + 2as \\ 0^2 = 14.7^2 - 2gh \\ h = \frac{14.7^2}{2g} // \end{array}$$

$$\begin{aligned} \text{So greatest height above ground} \\ \text{will be } 2.5 + \frac{14.7^2}{2g} &= \boxed{13.5\text{m}} \end{aligned}$$

displacement from starting position will be -1.5m

$$\begin{array}{l}
 \text{b)} \left. \begin{array}{l}
 \uparrow S = -1.5 \\
 u = 14.7 \\
 v = \\
 a = -g \\
 t = t
 \end{array} \right\} \begin{array}{l}
 s = ut + \frac{1}{2} at^2 \\
 -1.5 = 14.7t - \frac{g}{2} t^2 \\
 4.9t^2 - 14.7t - 1.5 = 0
 \end{array}
 \end{array}$$

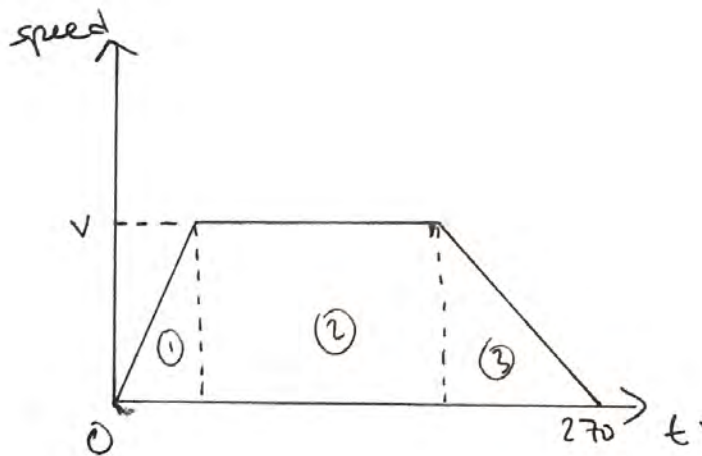
By Quadratic Formula: $t_1 = 3.0988\dots \text{ s}$
 $t_2 = -0.0988\dots \text{ s}$

$t > 0$ so $t = 3.10 \text{ s}$

$$\begin{array}{l}
 \text{c)} \left. \begin{array}{l}
 \uparrow S = -2.5 \\
 u = 14.7 \\
 v = v \\
 a = -g \\
 t =
 \end{array} \right\} \begin{array}{l}
 v^2 = u^2 + 2as \\
 v^2 = 14.7^2 + 2(-g)(-2.5) \\
 v^2 = 265.09
 \end{array}
 \end{array}$$

so $v = \sqrt{265.09} = 16.3 \text{ ms}^{-1}$

Q6a)



$$\text{b)} \quad a = \frac{v - u}{t} \Rightarrow 0.6 = \frac{v}{t}$$

$$\therefore t = \frac{v}{0.6} = \frac{5v}{3} //$$

c) area under graph = distance .

So... total area = 1500

$$\text{Area}_{\text{TOTAL}} = \text{Area } \textcircled{1} + \text{Area } \textcircled{2} + \text{Area } \textcircled{3} = 1500 \text{ m}$$

The diagram illustrates the decomposition of the area under a graph into three parts: a triangle (labeled 1) with base $\frac{SV}{3}$ and height v ; a rectangle (labeled 2) with width x and height v ; and another triangle (labeled 3) with base $\frac{V}{0.2}$ and height v . The total area is given as 1500 m.

$$x = 270 - \left(\frac{SV}{3} + \frac{V}{0.2} \right) = 270 - \frac{20V}{3}$$

$$\therefore \text{Area}_{\text{TOTAL}} = \frac{1}{2} \left(\frac{SV}{3} \right) (v) + (270 - \frac{20V}{3}) (v) + \frac{1}{2} (v) \left(\frac{V}{0.2} \right) = 1500$$

$$\Rightarrow \frac{SV^2}{6} + 270V - \frac{20V^2}{3} + \frac{V^2}{0.4} = 1500$$

$$\Rightarrow V^2 \left(\frac{S}{6} - \frac{20}{3} + \frac{1}{0.4} \right) + V(270) - 1500 = 0$$

$$\Rightarrow -\frac{10V^2}{3} + 270V - 1500 = 0$$

$$\times \left(\frac{-3}{10} \right) : V^2 - 81V + 450 = 0$$

d) $V^2 - 81V + 450 = 0$

By Quadratic Formula: $V = 75$ or $V = 6$ //

$\begin{pmatrix} a=1 \\ b=-81 \\ c=450 \end{pmatrix}$

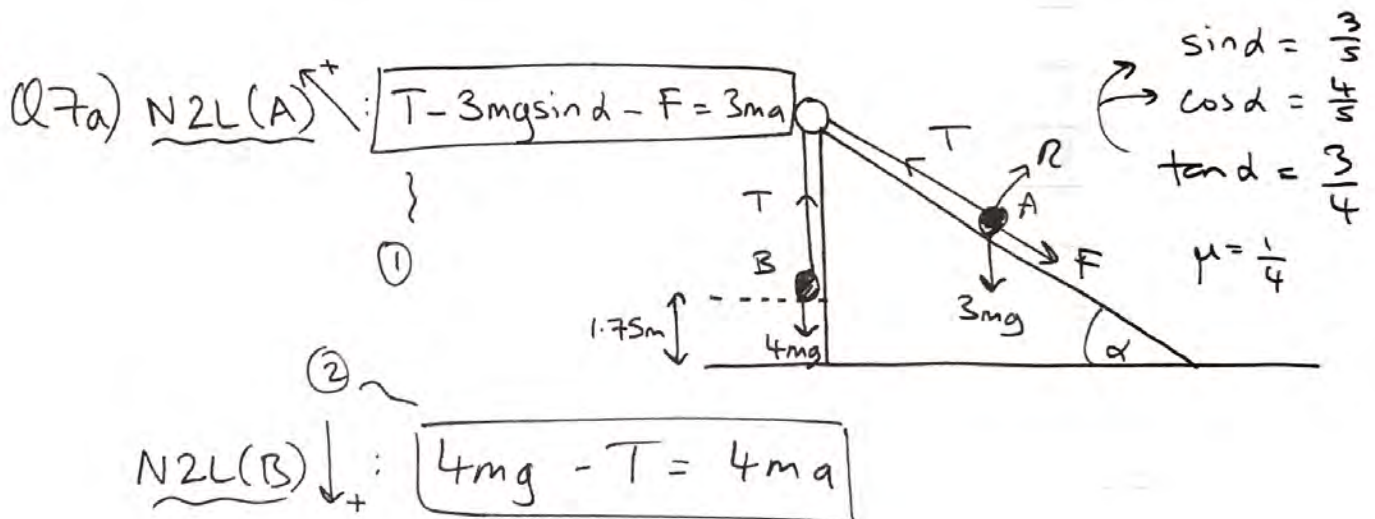
or by factorisation:

$(V-6)(V-75) = 0$

$\Rightarrow V = 75$ or $V = 6$ //

the correct answer is $V = 6$.

This can be checked by simply inputting $V = 75$ back into any equation for the area of ①, ② or ③ and you will see the answer will be greater than 1500m, so $V = 75$ is clearly false.



b) ① + ②: $4mg - 3mg \sin \alpha + \cancel{T} - \cancel{T} - F = 7ma$
 $4mg - 3mg \left(\frac{3}{5}\right) - \mu R = 7ma$

use suvat for a now from the moment B hits the ground til A comes to rest:

$$\begin{array}{l}
 (\uparrow+) \left. \begin{array}{l}
 S = d \\
 u = 2.8 \\
 v = 0 \\
 a = -\frac{4g}{5} \\
 t =
 \end{array} \right\} \begin{array}{l}
 v^2 = u^2 + 2as \\
 0^2 = 2.8^2 - \frac{8gd}{5} \\
 \frac{8gd}{5} = 2.8^2
 \end{array}
 \end{array}$$

$$\Rightarrow d = \frac{(2.8^2)(5)}{8 \times 9.8} = 0.5 \text{m} //$$

$$\text{so total distance} = 1.75 + 0.5 = \boxed{2.25 \text{m}}$$

(if B travels 1.5m then so does A!)