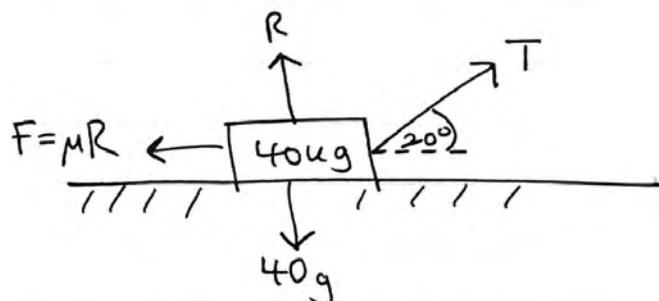


M1 October 2017 (IAL) (MA)

Q1)



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

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

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

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

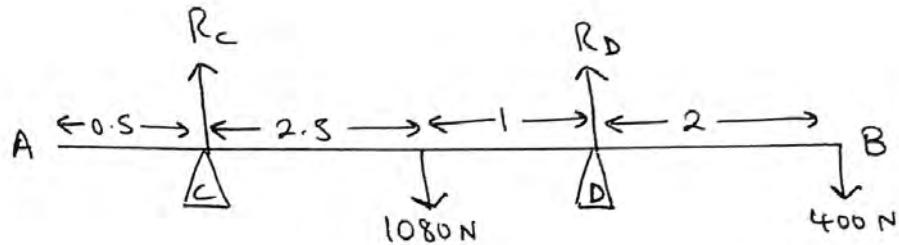
$$\text{so } T \cos 20 = \frac{3}{4}(40g - T \sin 20)$$

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

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

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

Q2ai)



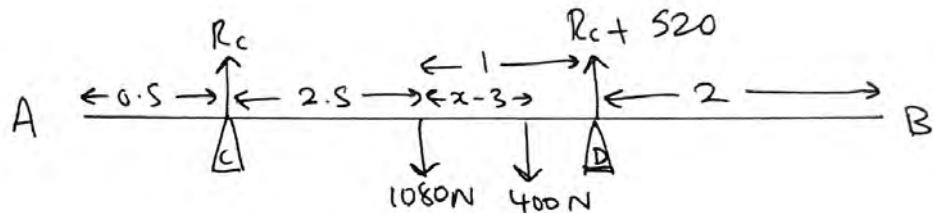
$$\text{M}(D): R_C(3 \cdot 5) + 400(2) = 1080 \quad (1)$$

$$\Rightarrow R_C = \frac{1080 - 400(2)}{3 \cdot 5} = \boxed{80 \text{ N}}$$

ii) $\text{M}(C): R_D(3 \cdot 5) = 1080(2 \cdot 5) + 400(5 \cdot 5)$

$$\Rightarrow R_D = \frac{1080(2 \cdot 5) + 400(5 \cdot 5)}{3 \cdot 5} = \boxed{1400 \text{ N}}$$

b)



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

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

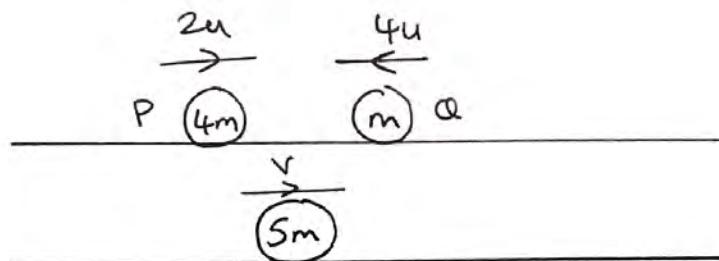
$$= \boxed{480 \text{ N}} //$$

$$\underline{\text{M}(A)}: R_C(0 \cdot 5) + (R_C + 520)(4) = 1080(3) + 400(2 \cdot 5)$$

$$\therefore x = \frac{480(0 \cdot 5) + (480 + 520)(4) - 1080(3)}{480}$$

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

(Q3)



$$\text{C.L.M} : 4m(2u) - m(4u) = 5m(v)$$

$$8u - 4u = 5v$$

$$\Rightarrow v = \frac{4}{5}u \quad // \quad \left. \begin{array}{l} v \text{ is +ve so the final} \\ \text{particle travels in a} \\ \text{direction opposite to which} \\ Q \text{ was initially travelling} \\ \text{in.} \end{array} \right\}$$

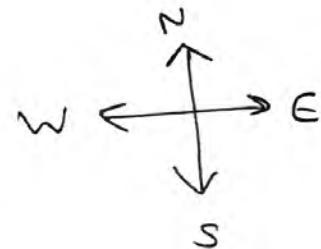
$$\text{Impulse on } Q = m(v - u)$$

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

(Q4)

$$F_1 = 8N$$

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

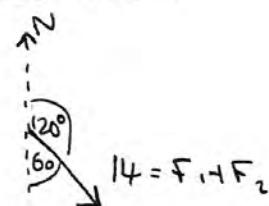


$$\text{and } F_2 = \begin{pmatrix} x \\ y \end{pmatrix}$$

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

or in vector form :

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



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

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

$R(\uparrow)$ for A : $R - 3mg \cos \alpha = 0$

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

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

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

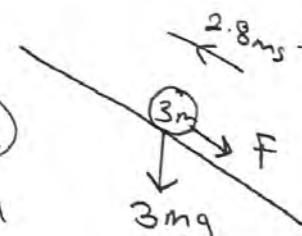
c) Particles have the same acceleration ...

d) find speed when B hits the ground :

$$\begin{array}{l} s = 1.75 \\ u = 0 \\ v = v \\ a = 8g/35 \\ t \end{array} \left. \begin{array}{l} v^2 = u^2 + 2as \\ \Rightarrow v^2 = 0^2 + 2\left(\frac{8g}{35}\right)(1.75) \\ \Rightarrow v = \sqrt{2\left(\frac{8g}{35}\right)(1.75)} = \boxed{2.8 \text{ ms}^{-1}} \end{array} \right\}$$

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

N2L(A) : $-F - 3mg \sin \alpha = 3m(a)$
 $-\frac{1}{4}\left(\frac{12mg}{5}\right) - 3mg\left(\frac{3}{5}\right) = 3ma$



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

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

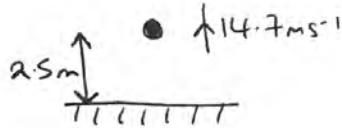
$$\therefore |F_2| = \sqrt{x^2 + y^2} = \sqrt{(-7)^2 + (7\sqrt{3} - 8)^2} \\ = \boxed{8.12 \text{ N}}$$

ii) $F_2 = \begin{pmatrix} 7\sqrt{3} - 8 \\ -7 \end{pmatrix} \rightarrow$

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

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

(Q5a)



$$\begin{aligned} S &= h \\ u &= 14.7 \text{ ms}^{-1} \\ v &= 0 \\ a &= -g \\ t &= \end{aligned} \quad \left. \begin{aligned} v^2 &= u^2 + 2as \\ 0^2 &= 14.7^2 - 2gh \\ h &= \frac{14.7^2}{2g} \end{aligned} \right\}$$

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

displacement from starting position will be -1.5m !

b) $\uparrow S = -1.5 \quad \left. \begin{array}{l} u = 14.7 \\ v = \\ a = -g \\ t = t \end{array} \right\}$

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

$$-1.5 = 14.7t - \frac{1}{2}gt^2$$

$$4.9t^2 - 14.7t - 1.5 = 0$$

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

$t > 0$ so $t = 3.105$

c) $\uparrow S = -2.5 \quad \left. \begin{array}{l} u = 14.7 \\ v = v \\ a = -g \\ t = \end{array} \right\}$

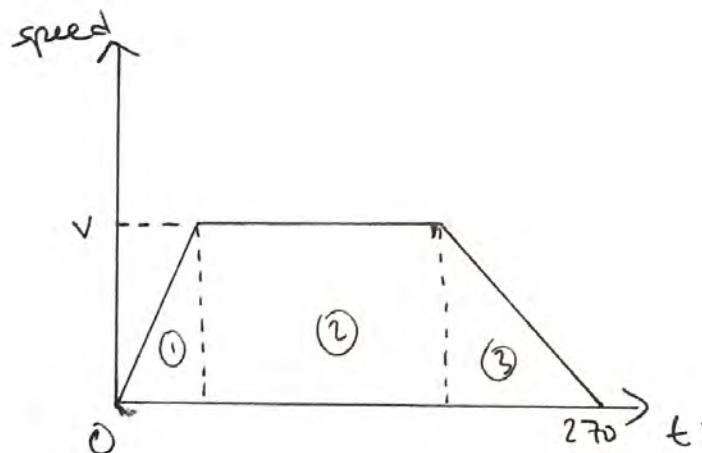
$$v^2 = u^2 + 2as$$

$$v^2 = 147^2 + 2(-g)(-2.5)$$

$$v^2 = 265.09$$

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

(Q6a)

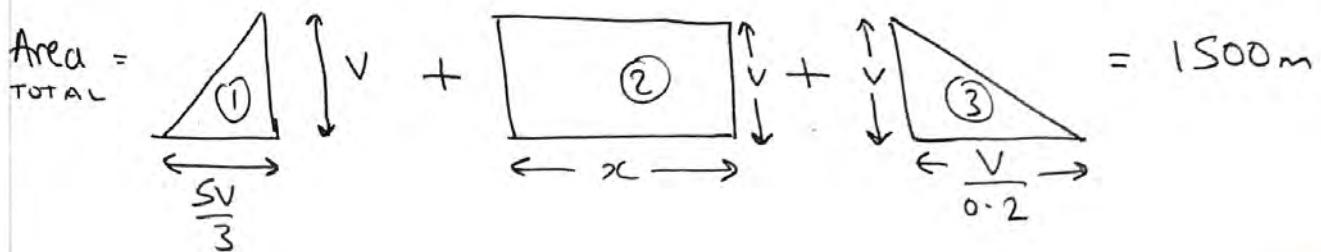


b) $a = \frac{v-u}{t} \Rightarrow 0.6 = \frac{v}{t}$

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

c) area under graph = distance

So... total area = 1500



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

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

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

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

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

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

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

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

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

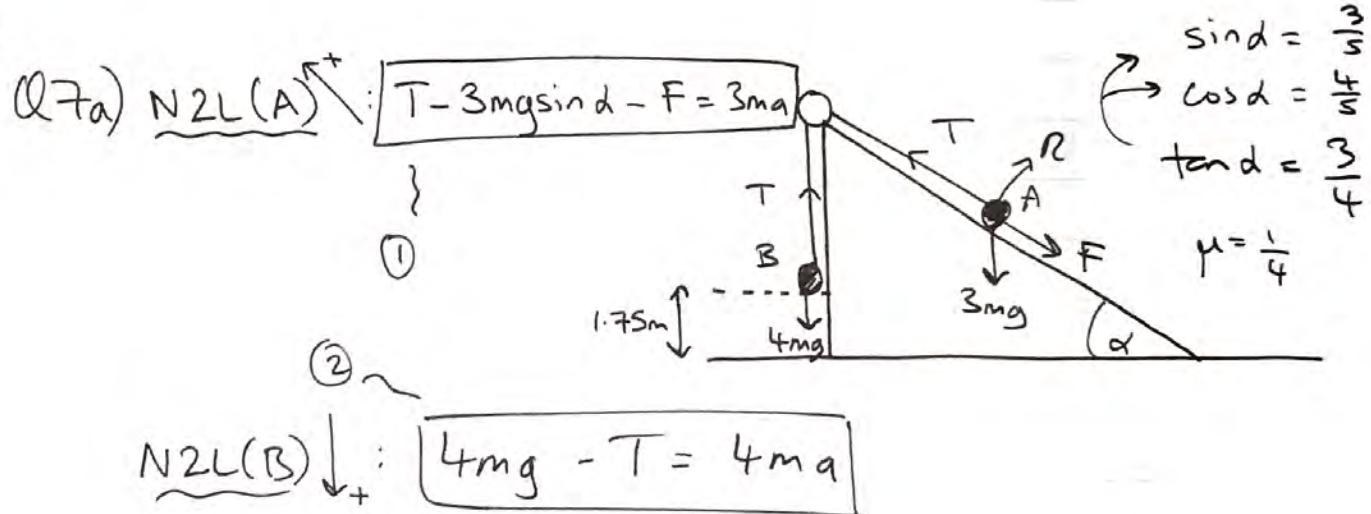
or by factorisation :

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

$$\Rightarrow V = 75 \text{ or } V = 6$$

the correct answer is $\boxed{V=6}$.

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

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

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

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

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

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