1)

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

$$y = ut - 4.9t^2$$

when particle lands $y = 0$

$$\Rightarrow \quad 0 = ut - 4.9t^2$$
$$0 = t(u - 4.9t)$$

Given $t = 6s$

$$\Rightarrow \quad u - 4.9 \times 6 = 0$$

$$u = 29.4 \text{ ms}^{-1}$$

Speed of projection $= 29.4 \text{ ms}^{-1}$

Reaches maximum height after $t = 3$ s

$$y = 29.4 \times 3 - 4.9 \times 3^2$$

$$y = 44.1 \text{ m}$$

Maximum height $= 44.1$ m

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2) i) $\underline{F}_1 = \begin{pmatrix} -6 \\ 13 \end{pmatrix}$

$$|\underline{F}_1| = \sqrt{(-6)^2 + 13^2}$$

$= 14.3$ N to 3 s.f.

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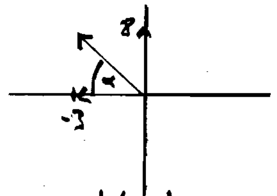
ii) $\underline{F}_1 = \begin{pmatrix} -6 \\ 13 \end{pmatrix}$ $\quad \underline{F}_2 = \begin{pmatrix} -3 \\ 5 \end{pmatrix}$

$$\underline{F}_1 - \underline{F}_2 = \begin{pmatrix} -6 \\ 13 \end{pmatrix} - \begin{pmatrix} -3 \\ 5 \end{pmatrix} = \begin{pmatrix} -3 \\ 8 \end{pmatrix}.$$



$$\alpha = \tan^{-1}\left(\frac{8}{3}\right) = 69.4^\circ$$

Bearing $= 270^\circ + 69.4^\circ$

$= 339.4^\circ$

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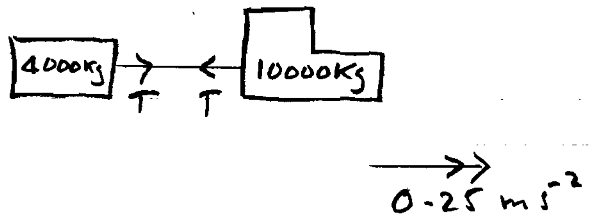
3)



i) Using $F = ma$ for whole system

$$F = 14000 \times 0.25$$

$$F = 3500 \text{ N}$$

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3) ii) Resultant Force = Drive Force − Resistance

$$3500 = 4000 - R$$

$$\Rightarrow R = 500 \text{ N}$$

Resistance $= 500$ N

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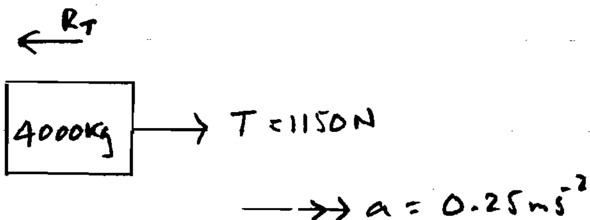
3 iii)



For truck using $F = ma$

$$T - R_T = 4000 \times 0.25$$
$$1150 - R_T = 4000 \times 0.25$$

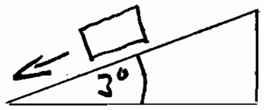
3 iii) (cont)

$1150 - 1000 = R_T$

$R_T = 150\text{ N}$

Truck resistance to motion = 150N

3iv)



Force parallel to slope due to gravity $= mg\sin\theta$

$= 14000 \times 9.8 \times \sin 3°$

$= 7180\text{ N}$

Extra drive force required to oppose this = 7180 N

4)

$\underline{r} = 3t\,\underline{i} + (18t^2-1)\,\underline{j}$

$\underline{r} = \begin{pmatrix} 3t \\ 18t^2-1 \end{pmatrix}$

i) Cuts x axis when $18t^2-1=0$

$\Rightarrow 18t^2 = 1$

$t^2 = \frac{1}{18}$

$t = \pm\sqrt{\frac{1}{18}}$

But since $t \geq 0$

only solution is when $t = \sqrt{\frac{1}{18}}$ s

4 ii)

$\underline{v} = \begin{pmatrix} 3 \\ 36t \end{pmatrix} = 3\underline{i} + 36t\underline{j}$

Never travels in $\underline{j}$ direction because velocity always has a component $3\underline{i}$

4 iii)

$x = 3t$ ①

$y = 18t^2 - 1$ ②

From ① $t = \frac{x}{3}$

Subst for t in ②

$y = 18\frac{x^2}{9} - 1$

$y = 2x^2 - 1$

5) i)

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

$v_y^2 = u_y^2 - 19.6y$

At max height $y = 22.5\text{m}$, $v_y = 0$

$0 = u_y^2 - 19.6 \times 22.5$

$u_y = \sqrt{19.6 \times 22.5}$

$u_y = 21\text{ ms}^{-1}$

$\therefore$ vertical component of initial velocity $= 21\text{ ms}^{-1}$

5 ii)

$u_y = u\sin\theta$

where u is initial velocity and θ is angle of projection

$21 = 28\sin\theta$

5 ii) cont)

$$\sin\theta = \frac{21}{28}$$

$$\theta = 48.6^\circ$$

5 iii)

Find time of flight

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

$$y = 21t - 4.9t^2$$

On landing $y = 0$

$$0 = 21t - 4.9t^2$$

$$0 = t(21 - 4.9t)$$

$$\Rightarrow t = 0 \text{ or } t = \frac{21}{4.9}$$

Horizontal distance travelled

$$x = u\cos\theta \times t$$

Range $x = 28\cos 48.6^\circ \times \frac{21}{4.9}$

$$x = 79.357$$

$$x = 79.4 \text{ m}$$

6) i) Distance travelled represented by area under graph from $t = 0$ to $t = 8$

$$= \frac{1}{2} \times 2 \times 12 + \frac{1}{2} \times 4 \times 12$$

$$= 12 + 24 = 36 \text{ m}$$

6 ii) Time to travel 36 m at 12 ms^{-1}

$$= \frac{36}{12} = 3 \text{ s}$$

$\therefore$ $8 - 3 = 5$ less seconds

Would take 5 s less

6 iii)

Acceleration = gradient of velocity time graph

$$a = \frac{-12}{2} = -6 \text{ ms}^{-2}$$

6 iv)

Starting clock again at $t = 8$

Next journey $t = 6$ s
$s = 58.5$ m
$u = 12 \text{ ms}^{-1}$

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

$$58.5 = 12 \times 6 + \frac{1}{2} \times a \times 6^2$$

$$58.5 = 72 + 18a$$

$$a = \frac{58.5 - 72}{18}$$

$$a = -0.75 \text{ ms}^{-2}$$

6 v)

$$v = 12 - 10t + \frac{9}{4}t^2 - \frac{1}{8}t^3$$

$$a = \frac{dv}{dt} = -10 + \frac{9}{2}t - \frac{3}{8}t^2$$

when $t = 1$

$$a = -10 + \frac{9}{2} - \frac{3}{8} = -5.875 \text{ ms}^{-2}$$

6 vi) $s = \int v\,dt$

$= \int \left(12 - 10t + \frac{9}{4}t^2 - \frac{1}{8}t^3\right) dt$

$= 12t - 5t^2 + \frac{3}{4}t^3 - \frac{1}{32}t^4 + c$

Since displacement $= 0$ at $t = 0$ then $c = 0$

$\therefore\ s = 12t - 5t^2 + \frac{3}{4}t^3 - \frac{1}{32}t^4$

When $t = 8$

$s = 12 \times 8 - 5 \times 8^2 + \frac{3}{4} \times 8^3 - \frac{1}{32} \times 8^4$

$s = 32\text{ m}$

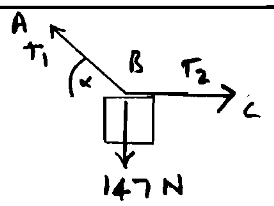
6 vii) When $t = 3$

$v = 12 - 10 \times 3 + \frac{9}{4} \times 3^2 - \frac{1}{8} \times 3^3$

$v = -1.125\text{ m s}^{-1}$

Model predicts motion in opposite direction between $t = 2$ and $t = 4$

7) i)



Resolving vertically

$T_1 \sin\alpha = 147$

$T_1 \times 0.6 = 147$

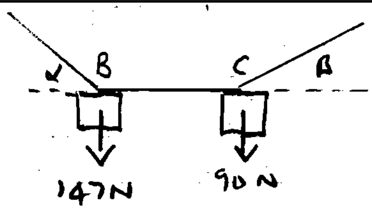
$T_1 = \frac{147}{0.6} = 245\text{ N}$

ii) Resolving horizontally

$T_2 = T_1 \cos\alpha$

$T_2 = 245 \times 0.8 = 196\text{ N}$

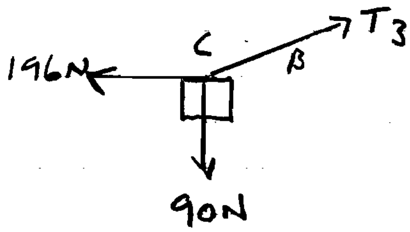
7 iii)



T_1 unchanged or B would not be in vertical equilibrium

Since T_1 is unchanged, T_2 still 196 N or B would not be in horizontal equilibrium.

7 iv)



Resolving horizontally

$T_3 \cos\beta = 196$ (1)

Vertically $T_3 \sin\beta = 90$ (2)

(2) ÷ (1) $\tan\beta = \frac{90}{196}$

$\Rightarrow \beta = 24.6638^\circ$

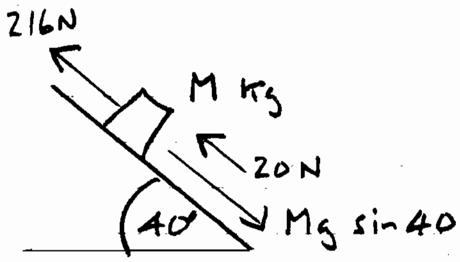
$\beta = 24.7^\circ$

Subst in (1) $T_3 \cos 24.6638^\circ = 196$

$T_3 = \frac{196}{\cos 24.6638} = 215.68\text{ N}$

$T_3 = 216\text{ N}$ to 3 s.f.

7v)



Forces as shown on diagram since pulley is smooth
In equilibrium so

$$216 + 20 = Mg \sin 40^\circ$$

$$\frac{236}{g \sin 40^\circ} = M$$

$$M = \frac{236}{9.8 \sin 40^\circ}$$

$$M = 37.464 \text{ kg}$$

$$M = 37.5 \text{ Kg to 3s.f.}$$

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