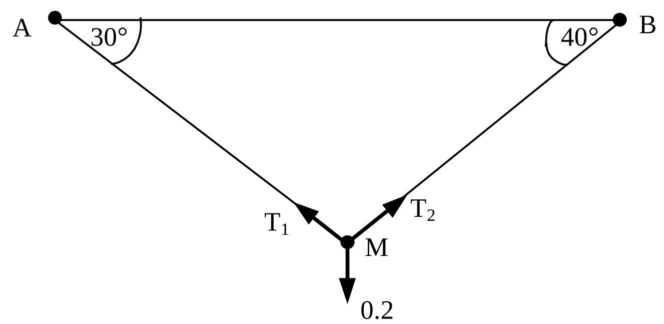
STATICS, FRICTION & NEWTON'S SECOND LAW

1.	a) Smooth string $\therefore$ tension same throughout the string	B1
	For the forces acting on the bead:	
	Resolving horizontally:	M1
	$T\cos\alpha = T\cos\beta$	A1
	$\therefore \quad \alpha = \beta$	
		[3]
	b) Resolving vertically:	M1
	$2T\sin\alpha - 10 = 0$	A1
	$\sin\alpha = \frac{3}{5}$	B1
	$T = 8\frac{1}{3}$ N	A1 f.t.
		[4]

2.	Resolving perpendicular to force P:	M1
	$Q\sin 45^0 + 3\sin 30^0 = 6$	A1
	$Q = \dfrac{9\sqrt{2}}{2}$ (6.36 to 3 S.F.)	A1 c.a.o.
	Resolving parallel to force P	M1
	Gives $P + 3\cos30^0 = Q\cos45^0$	A1
	$P = 1.90$ (3 S.F.)	A1 c.a.o.
		[6]

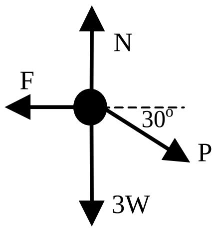
3.



Resolving vertically	M1
$T_1\sin30^0 + T_2\sin40^0 = 0.2$	A1
Resolving horizontally	M1
$T_1\cos30^0 = T_2\cos40^0$	A1
Solving for T_1 and T_2	M1
$T_1 = 0.163$ N	A1 c.a.o.
$T_2 = 0.184$ N	A1 c.a.o.
	[7]

STATICS, FRICTION & NEWTON'S SECOND LAW

4.



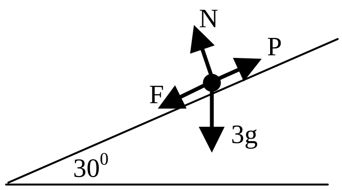
Resolving horizontally :	M1
$F = P\cos30^0$	A1
Resolving vertically :	
$N - P\sin30^0 - 3W = 0$	A1
Moving $\therefore$ $F = \mu N$	M1
$P\dfrac{\sqrt{3}}{2} = \dfrac{1}{\sqrt{3}}\left(\dfrac{P}{2} + 3W\right)$	A1 f.t.
$P = 3W$	A1 c.a.o.
	[6]
When returning the trolley, let force's magnitude be P_1	
$N = W + P_1\sin20^0$	M1 A1
$F = P_1\cos20^0$	A1 c.a.o.
Again $F = \mu N$ $\quad\therefore$ $P_1\cos 20^0 = \dfrac{1}{\sqrt{3}}(W + P_1\sin20^0)$	A1 ft
$P_1 = 0.778W$ (3 S.F)	A1 c.a.o.
	[5]

5.

a) Steady speed $\therefore$ no acceleration	B1
Resolving $\uparrow$ normal reaction = 150	M1 A1
$\rightarrow$ frictional force = 100	A1
Since moving $F = \mu N$	M1
$\therefore$ $\mu = \frac{2}{3}$	A1
	[6]
b) $\uparrow$ $T\cos30 + N - 150 = 0$ $\quad\Rightarrow N = 150 - T\cos30$	M1 A1
$\rightarrow$ $T\sin30 - F = 0$ $\quad\Rightarrow N = \frac{1}{2}T$	A1
$F = \mu N$	B1
So $\dfrac{T}{2} = \dfrac{2}{3}\left(150 - \dfrac{\sqrt{3}T}{2}\right)$	M1
$T = 92.8$ N	A1
	[5]
c) Block is modelled as a particle	B1
	[1]

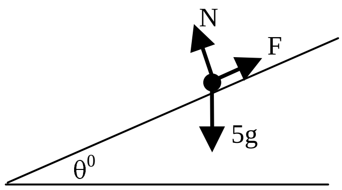
STATICS, FRICTION & NEWTON'S SECOND LAW

6.



Resolving parallel to plane	M1
$P - F - 3g\sin 30^0 = 0$	A1 c.a.o.
Resolving perpendicular to plane	
$N - 3g\cos 30^0 = 0$	A1 c.a.o.
Limiting equilibrium $\Rightarrow F = \mu N$	B1
$F = g\sqrt{3}$	M1 (combining)
$P = g\sqrt{3} + \dfrac{3g}{2}$	
$P = 31.7$	A1 c.a.o.
	[6]

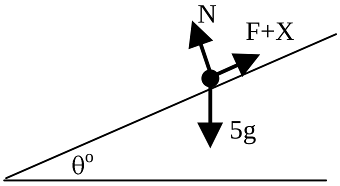
7.



Resolving parallel and perpendicular to plane	M1
$// : F = 5g\sin\theta$	A1
$\perp : N = 5g\cos\theta$	A1
$\cos\theta = \frac{4}{5}$	B1
$F = \mu R$	M1
$5g\sin\theta = \mu 5g\cos\theta$	
$\tan\theta = \mu$	
$\mu = \frac{3}{4}$	A1
	[6]

STATICS, FRICTION & NEWTON'S SECOND LAW

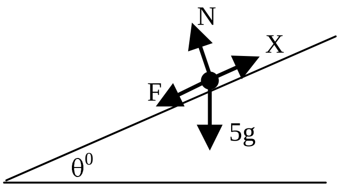
8. a)



For case where particle about to move down plane:

resolving parallel and perpendicular to plane	M1
$5g\sin\theta - X - F = 0$	A1
$N - 5g\cos\theta = 0$	A1
$\cos\theta = \frac{4}{5}$	
$F = \mu N$ (as about to move)	M1
$F = g$	A1
$\therefore\ X = 2g\ (= 19.6)$	M1 A1
	[7]

b)



For case where about to move up plane

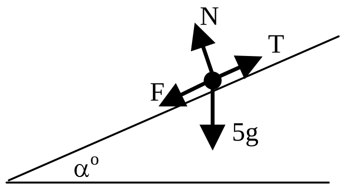
Resolving parallel to plane	M1
$5g\sin\theta - X + F = 0$	A1
N unchanged, so $F = g$	B1
$X = 4g\ (= 39.2)$	M1 A1
	[5]

---

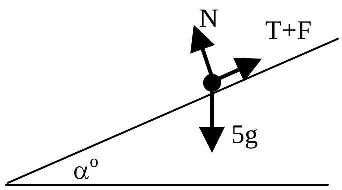
9. a) $(3\mathbf{i} + 2\mathbf{j}) + (7\mathbf{i} - 5\mathbf{j}) + (a\mathbf{i} + b\mathbf{j}) = 0$	M1
$a = -10 \qquad b = 3$	A1 A1
	[3]
b) Resultant force $= \mathbf{F}_2 + \mathbf{F}_3 + \mathbf{F}_4$	M1
$= -4\mathbf{i} + 4\mathbf{j}$	A1 f.t.
magnitude $= \sqrt{\left(-4^2\right) + 4^2}$	M1
$= 4\sqrt{2}$N or 5.66 N(3 S.F.)	
So acceleration $= \dfrac{4\sqrt{2}}{5}$ ms^{-2} or 1.13 ms^{-2} (3 S.F.)	A1 c.a.o.
	[4]

STATICS, FRICTION & NEWTON'S SECOND LAW

10.



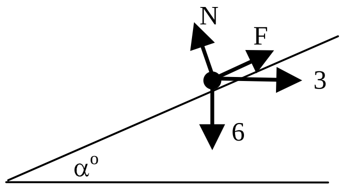
Considering case where about to move up the plane	M1
Resolving parallel to plane	M1
$T - F - 5g \sin\alpha = 0$	A1
Resolving perpendicular to plane	
$N - 5g \cos\alpha = 0$	A1
Not moving $\therefore$ $F \le \mu N$	B1
$\therefore$ $T - 4g \le 0.6 \times 3g$	
i.e. $T \le 5.8g$	A1 c.a.o.



Case when about to slide down plane	
$T + F - 5g \sin\alpha = 0$	M1 A1
$F \le \mu N$	
$4g - T \le 0.6 \times 3g$	M1
$T \ge 2.2g$	A1 c.a.o.
ie. $2.2g \le T \le 5.8g$	B1 ft.
	[11]

STATICS, FRICTION & NEWTON'S SECOND LAW

11.a)

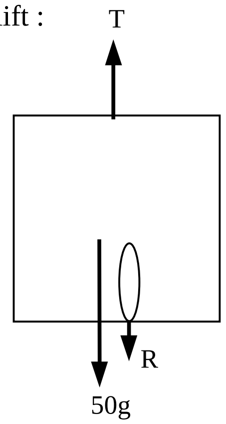


Resolving parallel to plane	M1
$\Rightarrow$ F + 3cosα – 6 sinα = 0	A1
$\cos\alpha = \frac{12}{13}$	B1
$F = \frac{6}{13}$	A1 c.a.o.
Resolving perpendicular to plane	M1
$\Rightarrow$ N – 6 cosα – 3sinα = 0	
$N = \frac{87}{13}$	A1
	[6]

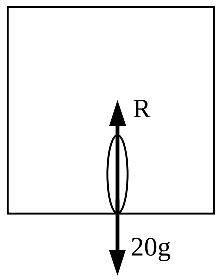
b) Do not know if equilibrium is limiting

$\therefore F \le \mu N$	M1
$\mu \ge \frac{6}{87}$	A1ft. (<u>not</u> for $\mu = \frac{6}{87}$)
	[2]

12.a) For lift :



For boy :



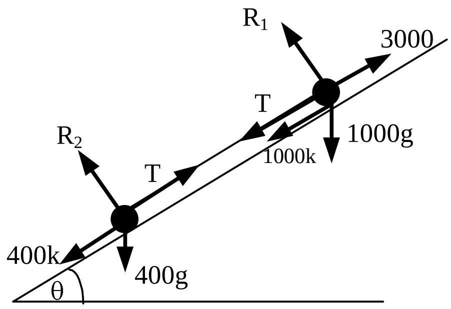
For boy : R – 20g = 20a	M1 A1
$\Rightarrow$ R = 20g + 20 × 0.1 = 198N	B1
	[3]

b)

For lift : T – R – 50g = 50a	B1
$\Rightarrow$ T = 50a + R + 50g	M1
= 5 + 198 + 490	
= 693N	A1
	[3]

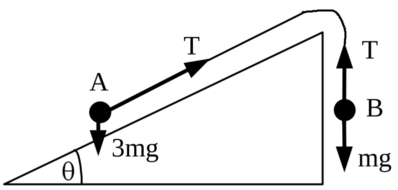
STATICS, FRICTION & NEWTON'S SECOND LAW

13.



Resistance 400k, 1000k		B1
For car : $3000 - T - 1000k = 1000a$	①	M1 A1
For trailer : $T - 400k = 400a$	②	A1
Total resistance 700, so $400k + 1000k = 700$		
$k = \frac{1}{2}$		B1
So ① becomes : $3000 - T - 500 = 1000a$	③	
② becomes : $T - 200 = 400a$	④	
③ + ④ : $3000 - 500 - 200 = 1400a$		M1
$2300 = 1400a$		
$\frac{23}{14}\ \text{ms}^{-2} = a$		A1
		[7]
b) Substitute into ④ : $T = 200 + 400a$		M1
$= 857\frac{1}{7}$ N		A1 f.t.
		[2]

14.

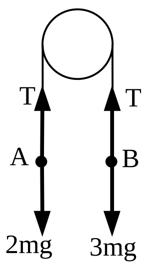


For A resolving parallel to plane	M1
$T - 3mg\sin\theta = 0$	A1
For B resolving vertically	M1
$T - mg = 0$	A1
$mg = 3mg\sin\theta$	M1
$\theta = \sin^{-1}\left(\frac{1}{3}\right) = 19.5°$ (3 S.F.)	A1 c.a.o.
	[6]

STATICS, FRICTION & NEWTON'S SECOND LAW

15. For A resolving perpendicular to plane	M1
gives N = 5g cos 30^0	A1
Resultant force up the plane	
is T – F – 5g sin30^0	
Newton II gives T – F – 5g sin30^0 = 5a	M1 A1
For B downward resultant force = 8g – T	
Newton II $\Rightarrow$ 8g – T = 8a	A1
A moving $\therefore$ F = μN	
$\therefore$ F = $0.7 \times \frac{5\sqrt{3}g}{2}$ (= 29.70)	B1
$\therefore$ $\left.\begin{array}{l} T - 54.20 = 5a \\ 78.4 - T = 8a \end{array}\right\}$	M1
a = 1.86ms^{-2} (3 S.F.)	A1 cao
	[8]

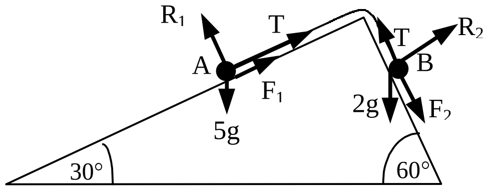
16.a)



Using F = ma in direction of acceleration:	M1
For A : T – 2mg = 2ma ①	A1
For B : 3mg – T = 3ma ②	A1
① + ② : mg = 5ma $\Rightarrow$ $\frac{1}{5}$g = a	A1
	[4]
b) Using s = ut + $\frac{1}{2}at^2$	M1
0.25 = $\frac{1}{2}$ x $\frac{1}{5}$g x t^2	A1
t = 0.505 seconds	A1
	[3]
c) Need speed with which B hits floor	M1
Using "v = u + at"	
v = $\frac{g}{5} \times 0.505..$ = 0.990 ms^{-1}	A1
A rises until its speed is zero	M1
a = -g	B1
2as = $v^2 - u^2$	M1
-2gs = 0 – 0.990^2 $\Rightarrow$ s = 0.05m	A1 f.t.
A is now 55 cm above floor	B1 f.t.
	[7]

17.a)	Using F = ma		M1
	For P : $T = ma$	①	A1
	For Q : $mg - T = ma$	②	A1
	① + ② : $mg = 2ma$		
	$\frac{1}{2}g = a$		A1
			[4]
c)	Q must travel 90cm		B1
	$s = ut + \frac{1}{2}at^2$		M1
	$0.9 = \frac{1}{2} \times \frac{1}{2}gt^2$		
	$0.606 = t$		A1
			[3]

18.



For A :	$5g\sin30 - F_1 - T = 5a$		M1 A1
	$5g\cos30 = R_1$		A1
Since it is moving, $F_1 = \mu R_1$			M1
So $5g\sin30 - \mu 5g\cos30 - T = 5a$		①	B1
For B :	$T - 2g\sin60 - F_2 = 2a$		A1
	$2g\cos60 = R_2$		
	$F_2 = \mu R_2$		A1
So $T - 2g\sin60 - \mu 2g\cos60 = 2a$		②	B1

① + ② : $5g\sin30 - \mu 5g\cos30 - 2g\sin60 - \mu 2g\cos60 = 7a = \frac{7g}{20}$ M1

$$\frac{5g}{2} - \mu 5g\frac{\sqrt{3}}{2} - 2g\frac{\sqrt{3}}{2} - \mu 2g\frac{1}{2} = \frac{7g}{20}$$

$$\frac{5}{2} - \sqrt{3} - \frac{7}{20} = \mu\left(\frac{5\sqrt{3}}{2} + 1\right)$$ M1 (solving)

$0.078 = \mu$ A1 c.a.o.

[11]

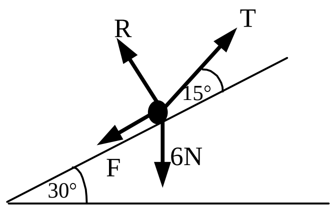
b) Tensions on each side of the pulley are the same B1

[1]

STATICS, FRICTION & NEWTON'S SECOND LAW

19. a)	For A using Newton II for horizontal motion	M1
	$T - F = ma$	A1
	Resolving vertically $N = mg$	A1
	A is moving $\therefore F = \mu N$	
	$\therefore F = \dfrac{mg}{2}$	B1
	For B using Newton II for vertical motion	
	$2mg - T = 2ma$	A1
	Solving $T - \dfrac{mg}{2} = ma$ and $2mg - T = 2ma$	M1
	$a = \frac{1}{2}g$	A1 cao
		[7]
b)	For A using "$v^2 = u^2 + 2as$" and $s = 0.64$	M1
	$v = 0.8\sqrt{g}$	A1 f.t. (but answer must be in terms of g)
		[2]
c)	Using equations of motion	M1
	<u>For B.</u> — <u>For A.</u>	
	$u = 0.8\sqrt{g}$ — $u = 0$	B1 B1
	$a = g$ — $a = g$	
	$s = 0.36$ — $s = 1$	B1 (both)
	$t = ?$ — $t = ?$	
	For B :	
	$s = ut + \frac{1}{2}at^2$	
	$0.36 = 0.8\sqrt{g}\,t + \frac{1}{2}g\,t^2$	M1
	$t = 0.1170$	M1 A1
	For A :	
	$s = ut + \frac{1}{2}at^2$	
	$1 = \frac{1}{2}g\ t^2$	M1
	$t = 0.4518$	A1
	Time between A and B reaching the floor is $0.4518 - 0.1170 = 0.335$ seconds	A1 f.t.
		[10]

20. a)



Resolving up slope:	M1
$T \cos 15 - F - 6 \sin 30 = 0$	A1
Resolving perpendicular to slope	
$R - 6 \cos 30 + T \sin 15 = 0$	A1
Limiting equilibrium $\therefore F = \mu N$	M1
$\therefore T \cos 15 - 3 = \frac{1}{\sqrt{3}}(3\sqrt{3} - T \sin 15)$	A1
$\Rightarrow T = 5.38$ N (3 S.F.)	A1 c.a.o.
	[6]
b) When moving using $s = ut + \frac{1}{2}at^2$	M1
$a = \frac{1}{8}$	A1 c.a.o.
Newton II applied to motion up slope	M1
And using mass = $\frac{6}{g}$	M1
$T \cos 15 - F - 6 \sin 30 = \frac{6}{g} \times \frac{1}{8}$	A1 ft.
$F = \frac{1}{\sqrt{3}}(6 \cos 30 - T \sin 15)$	M1
So $T\left(\cos 15 + \frac{\sin 15}{\sqrt{3}}\right) - \frac{6 \cos 30}{\sqrt{3}} - 6 \sin 30 = \frac{6}{8g}$	A1
$T = 5.45$N	A1
	[8]
c) Crate treated as a particle No other external forces Tension increased instantaneously	B2 (any 2)
	[2]