1. A particle of mass 0.8 kg is held at rest on a rough plane. The plane is inclined at 30° to the horizontal. The particle is released from rest and slides down a line of greatest slope of the plane. The particle moves 2.7 m during the first 3 seconds of its motion. Find

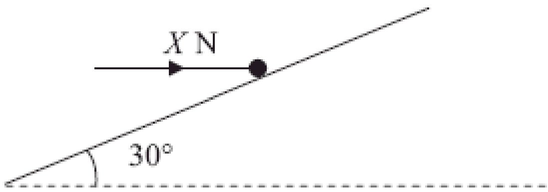
(a) the acceleration of the particle,

(3)

(b) the coefficient of friction between the particle and the plane.

(5)

The particle is now held on the same rough plane by a horizontal force of magnitude x newtons, acting in a plane containing a line of greatest slope of the plane, as shown in the diagram above. The particle is in equilibrium and on the point of moving up the plane.



(c) Find the value of X.

(7)
(Total 15 marks)

2. A small brick of mass 0.5 kg is placed on a rough plane which is inclined to the horizontal at an angle θ, where $\tan\theta = \frac{4}{3}$, and released from rest. The coefficient of friction between the brick and the plane is $\frac{1}{3}$.

Find the acceleration of the brick.

(Total 9 marks)

3. Two forces, $(4\mathbf{i} - 5\mathbf{j})$ N and $(p\mathbf{i} + q\mathbf{j})$ N, act on a particle P of mass m kg. The resultant of the two forces is $\mathbf{R}$. Given that $\mathbf{R}$ acts in a direction which is parallel to the vector $(\mathbf{i} - 2\mathbf{j})$,

(a) find the angle between $\mathbf{R}$ and the vector $\mathbf{j}$,

(3)

(b) show that $2p + q + 3 = 0$.

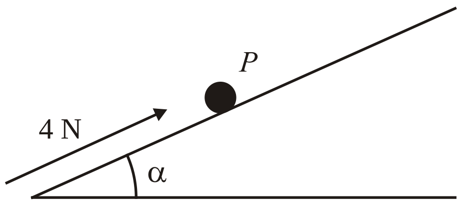
(4)

Given also that $q = 1$ and that P moves with an acceleration of magnitude $8\sqrt{5}$ m s^{-2},

(c) find the value of m.

(7)
(Total 14 marks)

4.



A particle P of mass 0.5 kg is on a rough plane inclined at an angle α to the horizontal, where $\tan \alpha = \frac{3}{4}$. The particle is held at rest on the plane by the action of a force of magnitude 4 N acting up the plane in a direction parallel to a line of greatest slope of the plane, as shown in the figure above. The particle is on the point of slipping up the plane.

(a) Find the coefficient of friction between P and the plane.

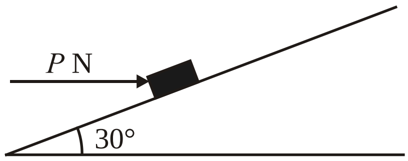
(7)

The force of magnitude 4 N is removed.

(b) Find the acceleration of P down the plane.

(4)
(Total 11 marks)

5.



A parcel of weight 10N lies on a rough plane inclined at an angle of 30° to the horizontal. A horizontal force of magnitude P newtons acts on the parcel, as shown in the figure above. The parcel is in equilibrium and on the point of slipping up the plane. The normal reaction of the plane on the parcel is 18N. The coefficient of friction between the parcel and the plane is μ. Find

(a) the value of P,

(4)

(b) the value of μ.

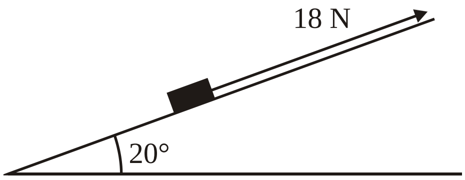
(5)

The horizontal force is removed.

(c) Determine whether or not the parcel moves.

(5)
(Total 14 marks)

6.



A box of mass 2 kg is pulled up a rough plane face by means of a light rope. The plane is inclined at an angle of 20° to the horizontal, as shown in the diagram. The rope is parallel to a line of greatest slope of the plane. The tension in the rope is 18 N. The coefficient of friction between the box and the plane is 0.6. By modelling the box as a particle, find

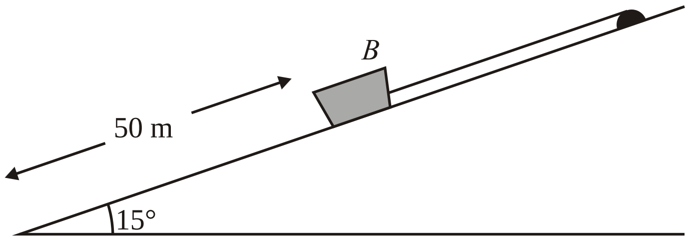
(a) the normal reaction of the plane on the box,

(3)

(b) the acceleration of the box.

(5)
(Total 8 marks)

7.



The diagram above shows a boat B of mass 400 kg held at rest on a slipway by a rope. The boat is modelled as a particle and the slipway as a rough plane inclined at 15° to the horizontal. The coefficient of friction between B and the slipway is 0.2. The rope is modelled as a light, inextensible string, parallel to a line of greatest slope of the plane. The boat is in equilibrium and on the point of sliding down the slipway.

(a) Calculate the tension in the rope.

(6)

The boat is 50 m from the bottom of the slipway. The rope is detached from the boat and the boat slides down the slipway.

(b) Calculate the time taken for the boat to slide to the bottom of the slipway.

(6)
(Total 12 marks)

8. A tile on a roof becomes loose and slides from rest down the roof. The roof is modelled as a plane surface inclined at 30° to the horizontal. The coefficient of friction between the tile and the roof is 0.4. The tile is modelled as a particle of mass m kg.

(a) Find the acceleration of the tile as it slides down the roof.

(7)

The tile moves a distance 3 m before reaching the edge of the roof.

(b) Find the speed of the tile as it reaches the edge of the roof.

(2)

(c) Write down the answer to part (a) if the tile had mass 2*m* kg.

(1)
(Total 10 marks)

9. A particle *P* of mass 3 kg is projected up a line of greatest slope of a rough plane inclined at an angle of 30° to the horizontal. The coefficient of friction between *P* and the plane is 0.4. The initial speed of P is 6 m s^{-1}. Find

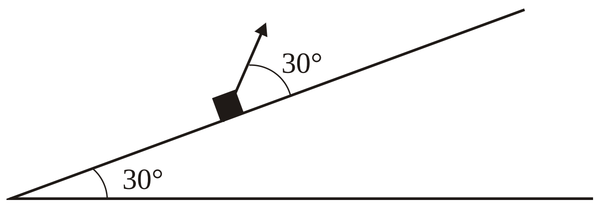
(a) the frictional force acting on *P* as it moves up the plane,

(4)

(b) the distance moved by *P* up the plane before *P* comes to instantaneous rest.

(7)
(Total 11 marks)

10.



A small parcel of mass 2 kg moves on a rough plane inclined at an angle of 30° to the horizontal. The parcel is pulled up a line of greatest slope of the plane by means of a light rope which is attached to it. The rope makes an angle of 30° with the plane, as shown in the diagram above. The coefficient of friction between the parcel and the plane is 0.4.

Given that the tension in the rope is 24 N,

(a) find, to 2 significant figures, the acceleration of the parcel.

(8)

The rope now breaks. The parcel slows down and comes to rest.

(b) Show that, when the parcel comes to this position of rest, it immediately starts to move down the plane again.

(4)

(c) Find, to 2 significant figures, the acceleration of the parcel as it moves down the plane after it has come to this position of instantaneous rest.

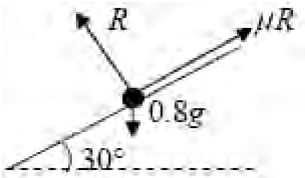
(3)

(Total 15 marks)

1. (a) $s = ut + \frac{1}{2}at^2 \Rightarrow 2.7 = \frac{1}{2}a \times 9$ A1

$a = 0.6$ (m s^{-2}) A1 3

(b)



↖ $R = 0.8g\cos 30° (\approx 6.79)$ B1

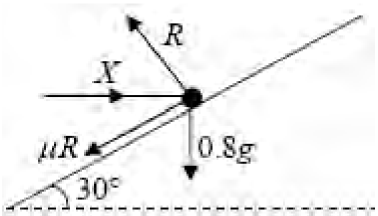
Use of $F = \mu R$ B1

↙ $0.8g\sin 30° - \mu R = 0.8 \times a$ A1

$(0.8g\sin 30° - \mu\, 0.8g\cos 30° = 0.8 \times 0.6)$

$\mu \approx 0.51$ accept 0.507 A1 5

(c)



↑ $R\cos 30° = \mu R\cos 60° + 0.8g$ A2 (1,0)

$(R \approx 12.8)$

→ $X = R\sin 30° + \mu R\sin 60°$ A1

Solving for X, $X \approx 12$ accept 12.0 DM1 A1 7

<u>Alternative</u>

↖ $R = X\sin 30° + 0.8 \times 9.8\sin 60°$ A2 (1,0)

↙ $\mu R + 0.8\mathrm{g}\cos 60° = X\cos 30°$ A1

$$X = \frac{\mu 0.8g\sin 60° + 0.8g\cos 60°}{\cos 30° - \mu\sin 30°}$$

Solving for X, $X \approx 12$ accept 12.0 DM1 A1

[15]

2. $0.5g\sin\theta - F = 0.5a$ A1 A1

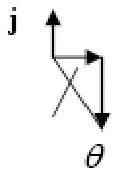
$F = \frac{1}{3}R$ seen B1

$R = 0.5g\cos\theta$ A1

Use of $\sin\theta = \frac{4}{5}$ or $\cos\theta = \frac{3}{5}$ or decimal equiv or

decimal angle e.g 53.1° or 53°	B1	
$a = \dfrac{3g}{5}$ or 5.88		
m s^{-2} or 5.9 m s^{-2}	DM1 A1	
		[9]

3. (a)



$\tan\theta = \dfrac{2}{1} \Rightarrow \theta = 63.4°$	A1	
angle is 153.4°	A1	3

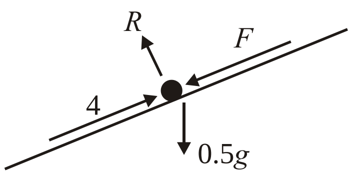
(b)

$(4 + p)\mathbf{i} + (q - 5)\mathbf{j}$	B1	
$(q - 5) = -2(4 + p)$	A1	
$2p + q + 3 = 0$ *	A1	4

(c)

$q = 1 \Rightarrow p = -2$	B1	
$\Rightarrow$ $\mathbf{R} = 2\mathbf{i} - 4\mathbf{j}$		
$\Rightarrow$ $\lvert\mathbf{R}\rvert = \sqrt{2^2 + (-4)^2} = \sqrt{20}$	A1 f.t.	
$\sqrt{20} = m8\sqrt{5}$	A1 f.t.	
$\Rightarrow$ $m = \dfrac{1}{4}$	A1 cao	7
		[14]

4. (a)

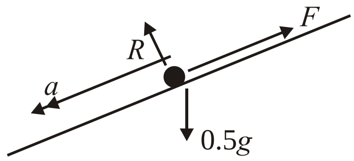


$R = 0.5g\cos\alpha = 0.4g$	A1	
$4 = F + 0.5g\sin\alpha$	A1	
$F = \mu R$ used		
$4 = 0.4g.\mu + 0.3g$		
$\Rightarrow \mu \approx 0.27(0)$	A1	7

1st two s require correct number of the correct terms,with valid attempt to resolve the correct relevant term (valid 'resolve' = x sin / cos).

4th (dept) for forming equn in μ, + numbers only

(b)



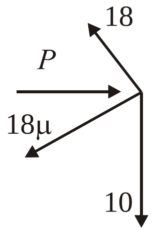
$0.5a = 0.3g - 0.27 \times 0.4g$	A2,1,0ft	
$\Rightarrow a \approx (+)\ 3.76$ m s^{-2} (or 3.8)	A1	4

In first equn, allow their R or F in the equation for full marks.

A marks: f.t. on their R, F etc. Deduct one A mark (up to 2) for each wrong term.

[11]

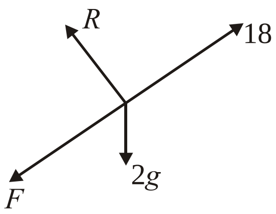
5.



(a)	R(perp to plane):		
	$P \sin 30 + 10 \cos 30 = 18$	A1	
	Solve: $P \approx$ <u>18.7 N</u>	A1	4
(b)	R(// plane):		
	$P \cos 30 = 10 \sin 30 + F$	A1	
	$F = 18\mu$ used		
	Sub and solve: μ = <u>0.621 or 0.62</u>	A1	5
(c)	Normal reaction now = 10 cos 30	A1	
	Component of weight down plane = 10 sin 30 (= 5 N) (seen)	B1	
	$F_{max} = \mu R_{new} \approx 5.37$ N (AWRT 5.4)		
	$5.37 > 5 \Rightarrow$ does not slide	A1 cso	5

[14]

6. (a)



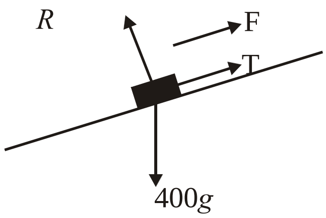
R (perp to plane): $R = 2g \cos 20$	A1	
$\approx$ 18.4 or 18 N	A1	3

(b)

R (// to plane): $18 - 2g \sin 20 - F = 2a$	M1 A1	
$F = 0.6\ R$ used	B1	
	↓	
Sub and solve: a = 0.123 or 0.12 m s^{-2}	M1 A1	5

[8]

7. (a)



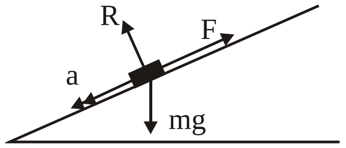
$R = 400g \cos 15°$ ($\approx$ 3786 N)	B1	
$F = 0.2R$ used	B1	
$T + 0.2R = 400g \sin 15°$	A1	
	↓	
$T \approx$ 257 or 260 N	A1	6

(b)

$400g \sin 15° - 0.2 \times 400g \cos 15° = 400a$	A1	
$a = 0.643(\ldots)$	A1	
$50 = \frac{1}{2} \times 0.643 \times t^2$	A1f.t.	
t = 12.5 or 12 s	A1	6

[12]

8. (a)



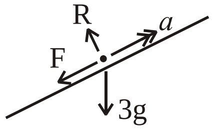
R(↖): $R = mg \cos 30$	B1	
R(↗): $ma = mg \sin 30 - F$	A1	
$F = 0.4\ R$ used	B1 ↓	
Eliminate R $\quad ma = mg \sin 30 - 0.4\ mg \cos 30$		
Solve: $a = 4.9 - 0.4 \times 9.8 \times \sqrt{3}/2$		
$\approx$ <u>1.5 or 1.51 m s^{-2}</u>	A1	7

(b) $v^2 = 2 \times 1.51 \times 3 \Rightarrow v = 3$ <u>or 3.01 m s^{-1}</u> — A1 — 2

(c) 1.5/1.51 m s^{-2} **(same as (a))** — B1 ft — 1

[10]

9. (a)



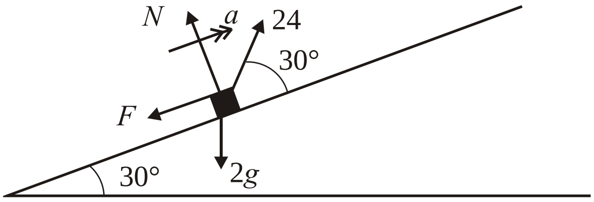
R(↖): $R = 3g \cos 30°$ (= 25.46 N)	A1	
$F = 0.4R \approx 10.2$ N (accept 10 N)	A1	4

(b)

R(↗): $-F + 3g \sin 30° = 3a$	A2	
(–1 eeoo)		
$\Rightarrow a \approx 8.3$ m s^{-2}	A1	
"$v^2 = u^2 + 2as$" : $6^2 = 2 \times a \times s$		
$\Rightarrow s \approx 2.17$ m (accept 2.2 m)	A1	7

[11]

10. (a)



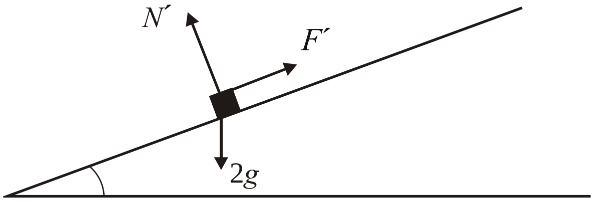
R(↖) $N + 24 \cos 60° = 2g \cos 30°$ A1 A1

$\Rightarrow N = 16.97 - 12 = 4.97$ N A1

$\Rightarrow F = 0.4 . 4.97 = 1.99$ N A1

R(↗) $2a = 24 \cos 30° - 2g \cos 60° - 1.99$ A1 8

(b) $\Rightarrow a \approx 4.5 \text{ m s}^{-2}$



R(↖) $N' = 2g \cos 30° = 16.97$ A1

$\Rightarrow F'_{max} = 0.4 . 16.97 = 6.79$ N

Component of weight down plane = $2g \sin 30° = 9.8$ N

(c) $9.8 > F'_{max} \Rightarrow$ net force down plane $\Rightarrow$ parcel moves A1 4

$2f = 9.8 - 6.79, \Rightarrow f \approx 1.5 \text{ m s}^{-2}$ A1, A1

[12]

1. Part (a) had a very high success rate and all three marks were regularly scored but the second part was found to be more challenging. Most were able to resolve perpendicular to the plane to find the reaction and use it to find the limiting friction. However, all too often there were omissions from the equation of motion parallel to the plane, either the mass x acceleration term and/or the weight component or else g was missing. Part (c) was a good discriminator and candidates needed to realise that this was a new system and that there was no acceleration. Those who failed to appreciate this and used their friction force from part (b) scored no marks. The majority of successful candidates resolved parallel and perpendicular to the plane (although a sizeable minority resolved vertically and horizontally) but even then a correct final answer was rarely seen due to premature approximation or else it was given to too many figures.

2. This question was well done by the majority of candidates. Most made valid attempts at resolving parallel and perpendicular to the plane. The most common error was where candidates obtained the sin/cos of the complementary angle. Others used sin(4/5) or cos(3/5). Many successful candidates used the actual angle 53.1 rather than working with fractions for the trig. ratios. Some thought that the friction force was 1/3. A few managed to obtain the “correct” answer fortuitously by using $R = 0.5a$.

3. Many were able, in the first part, to use tan to find an acute angle, scoring two of the three marks, but were then unable to identify and find the required angle. In part (b), the first mark was for adding the two vectors together but many students then stated that this sum was equal to ($\mathbf{i} - 2\mathbf{j}$) rather than a multiple of it and were unable to make any progress. In the final part, many who failed in (b), obtained $p = -2$ from the printed equation and, even if their $\mathbf{R}$ was wrong, were able to benefit from follow-through marks. It was amazing to see so many arrive correctly at $\sqrt{20} = m8\sqrt{5}$ then correctly write $m = 2\sqrt{5} / 8\sqrt{5}$ but then give $m = 5/4$!

4. This was generally well done and many fully correct solutions were seen to part (a). However, a number of weaker candidates could not handle the angle in question (e.g using 0.75 degrees); also some weaker candidates were evidently confused about what precisely ‘F’ was in the equations $F = \mu R$ and $F = ma$. In part (b) a number of candidates also lost marks by effectively omitting one of the two terms in the equation of motion, forgetting about either the friction or (more commonly) the component of the weight acting down the plane.

5. In parts (a) and (b) candidates managed to recover and most could make good attempts here. Most could resolve perpendicular to the plane and parallel to the plane, with a correct use of the frictional force. Some lost marks by omitting forces, but several gained at least all the method marks here. Part (c) proved to be more discriminating, at least for gaining all 5 marks. Some could make little progress since they did not realise that the normal reaction had now changed. Others did realise this and could get to the stage of setting up the value of the component of the weight down the plane and the value of μR. However it proved to be very difficult for candidates to understand clearly that ‘μR’ was not necessarily the actual frictional force acting (except in limiting equilibrium): hence there were many final answers to part (c) stating that the box remained in equilibrium ‘because the frictional force was greater than the component of the weight’.

6. In part (a), most obtained $R = 2g \cos 20$ correctly; however, a large number failed to give their answer to an 'appropriate' degree of accuracy (here at most 3 significant figures), thus losing a mark. In part (b), most realised that the frictional force was equal to μR; but there was a surprisingly high number of errors in attempting to write down the equation of motion with several omitting a force (e.g. the component of the weight) in their equation; others appeared to be very confused with what 'F' was, using the same 'F' in both '$F = ma$' and '$F = \mu R$'. The figures involved were also quite sensitive to the accuracy presumed, and premature approximation led to a number of incorrect answers. Candidates should be aware that, if they give a final answer to 3 s.f., then they must work with previous values which are accurate to at least 4 s.f.

7. Some very good answers were seen to this question with many fully correct (or all but correct) answers. However, as with Q4, many again lost a mark by giving their answers (especially in part (a)) to 4 or more significant figures. The most common other mistake in (a) was to have the wrong sign with the friction in the equilibrium equation. It was however pleasing to note the very high standard generally of accuracy in processing the resulting equation here with awkward figures involved. In part (b), most realised that they had to find the acceleration, but several omitted one or other of the relevant forces in doing so. Most however could use their resulting acceleration to find a value of the time appropriately.

8. This proved to be a little more demanding for the weaker candidates. Some omitted forces when trying to write down the equation of motion of the tile down the slope. Others too failed to make clear which direction they were assuming was positive, and then produced some rather unclear working to come up with a positive answer at the end. Some too lost a mark by failing to give their answer to 2 or 3 significant figures. Most realised how to tackle part (b) correctly.

In part (c) very few ignored the hint in the instruction to 'write down' their answer (and in the fact that there was only one mark available) and proceeded to repeat the whole calculation; even when doing so, not many came out with the same answer as part (a).

9. This question tended to be handled very well or rather poorly. In part (a) there was sometimes some confusion between the 'frictional force' and the 'resultant force', though candidates then often proceeded correctly in part (b). There were also a number who lost a mark for failing to given their answer to part (a) to an 'appropriate' degree of accuracy again (i.e. 2 or 3 significant figures). In part (b), some correct answers were seen, but frequently candidates missed out a force (e.g. the weight) in writing down the equation of motion to find the acceleration of the particle. A clear diagram with the forces clearly marked would have helped candidates here to sort out the Mechanics of the situation better.

10. No Report available for this question.