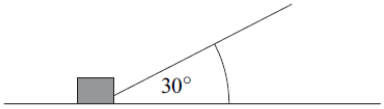
Practice examination questions for forces and Newton’s laws

1. Jan2005

3 The diagram shows a rope that is attached to a box of mass 25 kg, which is being pulled along rough horizontal ground. The rope is at an angle of 30° to the ground. The tension in the rope is 40 N. The box accelerates at $0.1\,\mathrm{m\,s^{-2}}$.



(a) Draw a diagram to show all of the forces acting on the box. *(1 mark)*

(b) Show that the magnitude of the friction force acting on the box is 32.1 N, correct to three significant figures. *(3 marks)*

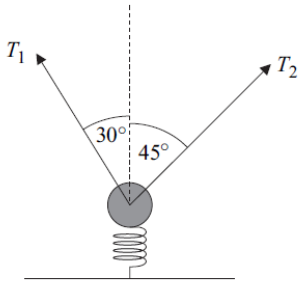
(c) Show that the magnitude of the normal reaction force that the ground exerts on the box is 225 N. *(3 marks)*

(d) Find the coefficient of friction between the box and the ground. *(2 marks)*

(e) State what would happen to the magnitude of the friction force if the angle between the rope and the horizontal were increased. Give a reason for your answer. *(2 marks)*

2. Jan 2005

5 Two ropes are attached to a load of mass 500 kg. The ropes make angles of 30° and 45° to the vertical, as shown in the diagram. The tensions in these ropes are T_1 and T_2 newtons. The load is also supported by a vertical spring.



The system is in equilibrium and $T_1 = 200$.

(a) Show that $T_2 = 141$, correct to three significant figures. *(3 marks)*

(b) Find the force that the spring exerts on the load. *(4 marks)*

3. June2005

5 A sphere of mass 200 grams is released from rest and allowed to fall vertically.

(a) A student states that the acceleration of the sphere is $9.8\,\mathrm{m\,s^{-2}}$ while it is falling. What modelling assumption is this student making? *(1 mark)*

(b) The student conducts an experiment and finds that the acceleration of the ball is in fact $8\,\mathrm{m\,s^{-2}}$. He formulates a model for the motion that assumes a constant resistance force acts on the ball as it is falling.

(ii) Describe how the resistance force would vary in reality. *(1 mark)*

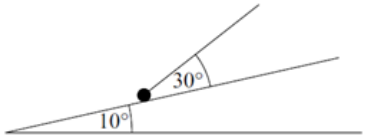
(c) In a revised model the resistance force is assumed to be proportional to the speed of the sphere.

(i) State the initial acceleration of the sphere. *(1 mark)*

(ii) State what would happen to the acceleration of the sphere if it were able to fall for a long period of time. *(1 mark)*

4. June 2005

8 A rough slope is inclined at an angle of 10° to the horizontal. A particle of mass 6 kg is on the slope. A string is attached to the particle and is at an angle of 30° to the slope. The tension in the string is 20 N. The diagram shows the slope, the particle and the string.



The particle moves up the slope with an acceleration of $0.4\,\mathrm{m\,s^{-2}}$.

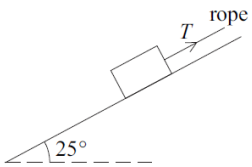
(a) Draw a diagram to show the forces acting on the particle. *(1 mark)*

(b) Show that the magnitude of the normal reaction force is 47.9 N, correct to three significant figures. *(4 marks)*

(c) Find the coefficient of friction between the particle and the slope. *(6 marks)*

5. Jan 2006

8 A rough slope is inclined at an angle of 25° to the horizontal. A box of weight 80 newtons is on the slope. A rope is attached to the box and is parallel to the slope. The tension in the rope is of magnitude T newtons. The diagram shows the slope, the box and the rope.



(a) The box is held in equilibrium by the rope.

(i) Show that the normal reaction force between the box and the slope is 72.5 newtons, correct to three significant figures. *(3 marks)*

(ii) The coefficient of friction between the box and the slope is 0.32. Find the magnitude of the maximum value of the frictional force which can act on the box. *(2 marks)*

(iii) Find the least possible tension in the rope to prevent the box from moving down the slope. *(4 marks)*

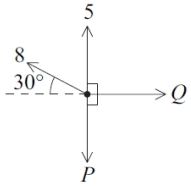
(iv) Find the greatest possible tension in the rope. *(3 marks)*

(v) Show that the mass of the box is approximately 8.16 kg. *(1 mark)*

(b) The rope is now released and the box slides down the slope. Find the acceleration of the box. *(3 marks)*

6. June 2006

2 A particle is in equilibrium under the action of four horizontal forces of magnitudes 5 newtons, 8 newtons, P newtons and Q newtons, as shown in the diagram.



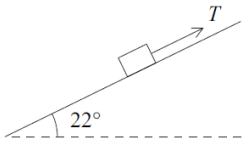
(a) Show that $P = 9$. *(3 marks)*

(b) Find the value of Q. *(2 marks)*

7. June 2006

4 A block is being pulled up a rough plane inclined at an angle of 22° to the horizontal by a rope parallel to the plane, as shown in the diagram.

The mass of the block is 0.7 kg, and the tension in the rope is T newtons.



(a) Draw a diagram to show the forces acting on the block. *(1 mark)*

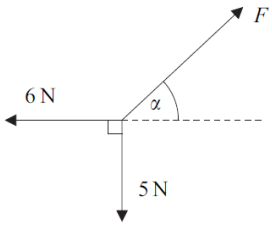
(b) Show that the normal reaction force between the block and the plane has magnitude 6.36 newtons, correct to three significant figures. *(3 marks)*

(c) The coefficient of friction between the block and the plane is 0.25. Find the magnitude of the frictional force acting on the block during its motion. *(2 marks)*

(d) The tension in the rope is 5.6 newtons. Find the acceleration of the block. *(4 marks)*

8. Jan 2007

3 The diagram shows three forces which act in the same plane and are in equilibrium.



(a) Find F. *(3 marks)*

(b) Find α. *(3 marks)*

9. Jan 2007

6 A trolley, of mass 100 kg, rolls at a constant speed along a straight line down a slope inclined at an angle of 4° to the horizontal.

Assume that a constant resistance force, of magnitude P newtons, acts on the trolley as it moves. Model the trolley as a particle.

(a) Draw a diagram to show the forces acting on the trolley. *(1 mark)*

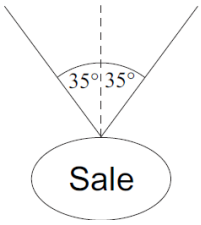
(b) Show that $P = 68.4$ N, correct to three significant figures. *(3 marks)*

(c) (i) Find the acceleration of the trolley if it rolls down a slope inclined at 5° to the horizontal and experiences the same constant force of magnitude P that you found in part (b). *(4 marks)*

(ii) Make one criticism of the assumption that the resistance force on the trolley is constant. *(1 mark)*

10. June 2007

3 A sign, of mass 2 kg, is suspended from the ceiling of a supermarket by two light strings. It hangs in equilibrium with each string making an angle of 35° to the vertical, as shown in the diagram. Model the sign as a particle.



(a) By resolving forces horizontally, show that the tension is the same in each string. *(2 marks)*

(b) Find the tension in each string. *(5 marks)*

(c) If the tension in a string exceeds 40 N, the string will break. Find the mass of the heaviest sign that could be suspended as shown in the diagram. *(3 marks)*

11. June 2007

6 A box, of mass 3 kg, is placed on a slope inclined at an angle of 30° to the horizontal. The box slides down the slope. Assume that air resistance can be ignored.

(a) A simple model assumes that the slope is smooth.

(i) Draw a diagram to show the forces acting on the box. *(1 mark)*

(ii) Show that the acceleration of the box is $4.9\,\mathrm{m\,s^{-2}}$. *(2 marks)*

(b) A revised model assumes that the slope is rough. The box slides down the slope from rest, travelling 5 metres in 2 seconds.

(i) Show that the acceleration of the box is $2.5\,\mathrm{m\,s^{-2}}$. *(2 marks)*

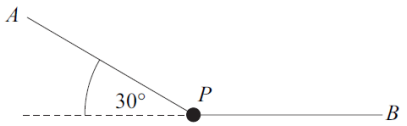
(ii) Find the magnitude of the friction force acting on the box. *(3 marks)*

(iii) Find the coefficient of friction between the box and the slope. *(5 marks)*

(iv) In reality, air resistance affects the motion of the box. Explain how its acceleration would change if you took this into account. *(2 marks)*

12. Jan 2008

3 A particle, of mass 4 kg, is suspended in equilibrium by two light strings, AP and BP. The string AP makes an angle of 30° to the horizontal and the other string, BP, is horizontal, as shown in the diagram.



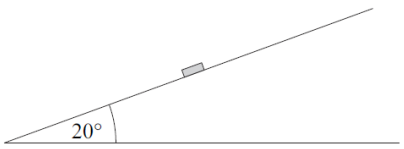
(a) Draw and label a diagram to show the forces acting on the particle. *(1 mark)*

(b) Show that the tension in the string AP is 78.4 N. *(3 marks)*

(c) Find the tension in the horizontal string BP. *(2 marks)*

13. Jan 2008

5 A puck, of mass 0.2 kg, is placed on a slope inclined at 20° above the horizontal, as shown in the diagram.



The puck is hit so that initially it moves with a velocity of $4\,\mathrm{m\,s^{-1}}$ directly up the slope.

(a) A simple model assumes that the surface of the slope is smooth.

(i) Show that the acceleration of the puck up the slope is $-3.35\,\mathrm{m\,s^{-2}}$, correct to three significant figures. *(3 marks)*

(ii) Find the distance that the puck will travel before it comes to rest. *(3 marks)*

(iii) What will happen to the puck after it comes to rest?

Explain why. *(2 marks)*

(b) A revised model assumes that the surface is rough and that the coefficient of friction between the puck and the surface is 0.5.

(i) Show that the magnitude of the friction force acting on the puck during this motion is 0.921 N, correct to three significant figures. *(3 marks)*

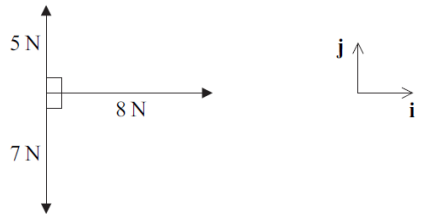
(ii) Find the acceleration of the puck up the slope. *(3 marks)*

(iii) What will happen to the puck after it comes to rest in this case?

Explain why. *(2 marks)*

14. June 2008

2 The diagram shows three forces and the perpendicular unit vectors **i** and **j**, which all lie in the same plane.



(a) Express the resultant of the three forces in terms of **i** and **j**. *(2 marks)*

(b) Find the magnitude of the resultant force. *(2 marks)*

(c) Draw a diagram to show the direction of the resultant force, and find the angle that it makes with the unit vector **i**. *(3 marks)*

15. June 2008

6 A block, of mass 5 kg, slides down a rough plane inclined at 40° to the horizontal. When modelling the motion of the block, assume that there is no air resistance acting on it.

(a) Draw and label a diagram to show the forces acting on the block. *(1 mark)*

(b) Show that the magnitude of the normal reaction force acting on the block is 37.5 N, correct to three significant figures. *(2 marks)*

(c) Given that the acceleration of the block is $0.8\,\mathrm{m\,s^{-2}}$, find the coefficient of friction between the block and the plane. *(6 marks)*

(d) In reality, air resistance does act on the block. State how this would change your value for the coefficient of friction and explain why. *(2 marks)*

16. Jan 2009

3 A box of mass 4 kg is held at rest on a plane inclined at an angle of 40° to the horizontal. The box is then released and slides down the plane.

(a) A simple model assumes that the only forces acting on the box are its weight and the normal reaction from the plane. Show that, according to this simple model, the acceleration of the box would be $6.30\,\mathrm{m\,s^{-2}}$, correct to three significant figures. *(3 marks)*

(b) In fact, the box moves down the plane with constant acceleration and travels 0.9 metres in 0.6 seconds. By using this information, find the acceleration of the box. *(3 marks)*

(c) Explain why the answer to part (b) is less than the answer to part (a). *(1 mark)*

17. Jan 2009

5 A sledge of mass 8 kg is at rest on a rough horizontal surface. A child tries to move the sledge by pushing it with a pole, as shown in the diagram, but the sledge **does not move**. The pole is at an angle of 30° to the horizontal and exerts a force of 40 newtons on the sledge.

Model the sledge as a particle.

(a) Draw a diagram to show the four forces acting on the sledge. *(1 mark)*

(b) Show that the normal reaction force between the sledge and the surface has magnitude 98.4 N. *(3 marks)*

(c) Find the magnitude of the friction force that acts on the sledge. *(2 marks)*

(d) Find the least possible value of the coefficient of friction between the sledge and the surface. *(3 marks)*

18. Jan 2009

6 Two forces, $\mathbf{P} = (6\mathbf{i} - 3\mathbf{j})$ newtons and $\mathbf{Q} = (3\mathbf{i} + 15\mathbf{j})$ newtons, act on a particle. The unit vectors $\mathbf{i}$ and $\mathbf{j}$ are perpendicular.

(a) Find the resultant of $\mathbf{P}$ and $\mathbf{Q}$. *(2 marks)*

(b) Calculate the magnitude of the resultant of $\mathbf{P}$ and $\mathbf{Q}$. *(2 marks)*

(c) When these two forces act on the particle, it has an acceleration of $(1.5\mathbf{i} + 2\mathbf{j})\,\mathrm{m\,s^{-2}}$. Find the mass of the particle. *(2 marks)*

(d) The particle was initially at rest at the origin.

(i) Find an expression for the position vector of the particle when the forces have been applied to the particle for t seconds. *(2 marks)*

(ii) Find the distance of the particle from the origin when the forces have been applied to the particle for 2 seconds. *(2 marks)*

19. June 2009

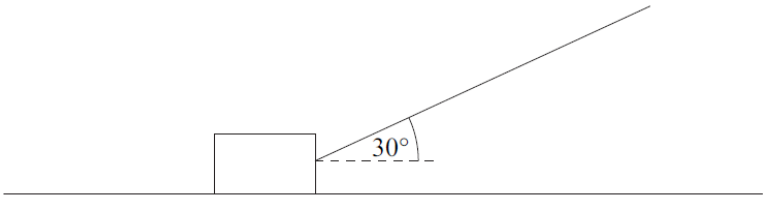
3 A car is travelling in a straight line on a horizontal road. A driving force, of magnitude 3000 N, acts in the direction of motion and a resistance force, of magnitude 600 N, opposes the motion of the car. Assume that no other horizontal forces act on the car.

(a) Find the magnitude of the resultant force on the car. *(2 marks)*

(b) The mass of the car is 1200 kg. Find the acceleration of the car. *(2 marks)*

20. June 2009

8 The diagram shows a block, of mass 20 kg, being pulled along a rough horizontal surface by a rope inclined at an angle of 30° to the horizontal.



The coefficient of friction between the block and the surface is μ. Model the block as a particle which slides on the surface.

(a) If the tension in the rope is 60 newtons, the block moves at a constant speed.

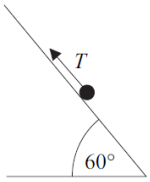
(i) Show that the magnitude of the normal reaction force acting on the block is 166 N. *(3 marks)*

(ii) Find μ. *(4 marks)*

(b) If the rope remains at the same angle and the block accelerates at $0.8\,\mathrm{m\,s^{-2}}$, find the tension in the rope. *(5 marks)*

21. Jan 2010

3 A particle of mass 3 kg is on a smooth slope inclined at 60° to the horizontal. The particle is held at rest by a force of T newtons parallel to the slope, as shown in the diagram.



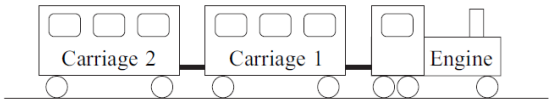
(a) Draw a diagram to show all the forces acting on the particle. *(1 mark)*

(b) Show that the magnitude of the normal reaction acting on the particle is 14.7 newtons. *(2 marks)*

(c) Find T. *(2 marks)*

22. Jan 2010

6 A small train at an amusement park consists of an engine and two carriages connected to each other by light horizontal rods, as shown in the diagram.



The engine has mass 2000 kg and each carriage has mass 500 kg.

The train moves along a straight horizontal track. A resistance force of magnitude 400 newtons acts on the engine, and resistance forces of magnitude 300 newtons act on each carriage. The train is accelerating at $0.5\,\mathrm{m\,s^{-2}}$.

(a) Draw a diagram to show the **horizontal** forces acting on Carriage 2. *(1 mark)*

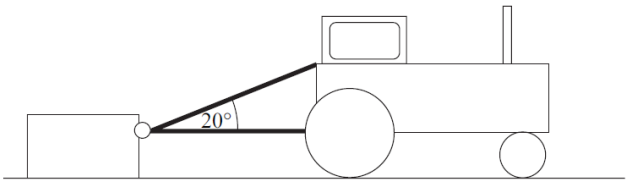
(b) Show that the magnitude of the force that the rod exerts on Carriage 2 is 550 newtons. *(2 marks)*

(c) Find the magnitude of the force that the rod attached to the engine exerts on Carriage 1. *(3 marks)*

(d) A forward driving force of magnitude P newtons acts on the engine. Find P. *(3 marks)*

23. Jan 2010

8 A crate, of mass 200 kg, is initially at rest on a rough horizontal surface. A smooth ring is attached to the crate. A light inextensible rope is passed through the ring, and each end of the rope is attached to a tractor. The lower part of the rope is horizontal and the upper part is at an angle of 20° to the horizontal, as shown in the diagram.



When the tractor moves forward, the crate accelerates at $0.3\,\mathrm{m\,s^{-2}}$. The coefficient of friction between the crate and the surface is 0.4.

Assume that the tension, T newtons, is the same in both parts of the rope.

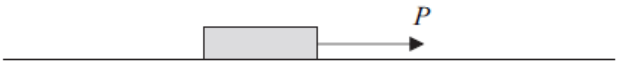
(a) Draw and label a diagram to show the forces acting on the crate. *(2 marks)*

(b) Express the normal reaction between the surface and the crate in terms of T. *(3 marks)*

(c) Find T. *(5 marks)*

24. June 2010

2 A block, of mass $10\,\mathrm{kg}$, is at rest on a rough horizontal surface, when a horizontal force, of magnitude P newtons, is applied to the block, as shown in the diagram.



The coefficient of friction between the block and the surface is 0.5.

(a) Draw and label a diagram to show all the forces acting on the block. *(1 mark)*

(b) (i) Calculate the magnitude of the normal reaction force acting on the block. *(1 mark)*

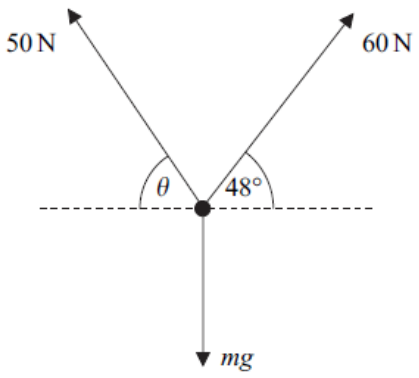
(ii) Find the maximum possible magnitude of the friction force between the block and the surface. *(1 mark)*

(iii) Given that $P = 30$, state the magnitude of the friction force acting on the block. *(1 mark)*

(c) Given that $P = 80$, find the acceleration of the block. *(3 marks)*

25. June 2010

4 A particle, of mass m kg, remains in equilibrium under the action of three forces, which act in a vertical plane, as shown in the diagram. The force with magnitude 60 N acts at 48° above the horizontal and the force with magnitude 50 N acts at an angle θ above the horizontal.

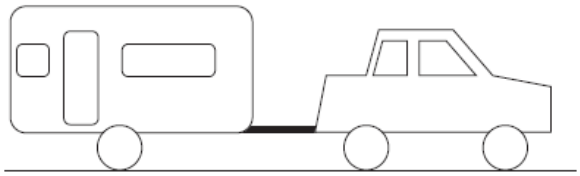


(a) By resolving horizontally, find θ. *(4 marks)*

(b) Find m. *(3 marks)*

26. Jan 2011

3 A car, of mass 1200 kg, tows a caravan, of mass 1000 kg, along a straight horizontal road. The caravan is attached to the car by a horizontal tow bar, as shown in the diagram.



Assume that a constant resistance force of magnitude 200 newtons acts on the car and a constant resistance force of magnitude 300 newtons acts on the caravan.
A constant driving force of magnitude P newtons acts on the car in the direction of motion. The car and caravan accelerate at $0.8\,\text{m s}^{-2}$.

(a) (i) Find P. *(3 marks)*

(ii) Find the magnitude of the force in the tow bar that connects the car to the caravan. *(3 marks)*

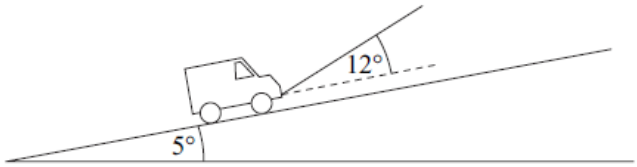
(b) (i) Find the time that it takes for the speed of the car and caravan to increase from $7\,\text{m s}^{-1}$ to $15\,\text{m s}^{-1}$. *(3 marks)*

(ii) Find the distance that they travel in this time. *(3 marks)*

(c) Explain why the assumption that the resistance forces are constant is unrealistic. *(1 mark)*

27. Jan 2011

8 A van, of mass 2000 kg, is towed up a slope inclined at 5° to the horizontal. The tow rope is at an angle of 12° to the slope. The motion of the van is opposed by a resistance force of magnitude 500 newtons. The van is accelerating up the slope at $0.6\,\mathrm{m\,s^{-2}}$.



Model the van as a particle.

(a) Draw a diagram to show the forces acting on the van. *(2 marks)*

(b) Show that the tension in the tow rope is 3480 newtons, correct to three significant figures. *(5 marks)*

28. June 2011

1 A crane is used to lift a load, using a single vertical cable which is attached to the load. The load accelerates uniformly from rest. When it has risen 0.9 metres, its speed is $0.6\,\mathrm{m\,s^{-1}}$.

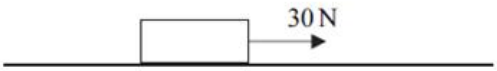
(a) (i) Show that the acceleration of the load is $0.2\,\mathrm{m\,s^{-2}}$. *(3 marks)*

(ii) Find the time taken for the load to rise 0.9 metres. *(2 marks)*

(b) Given that the mass of the load is 800 kg, find the tension in the cable while the load is accelerating. *(3 marks)*

29. June 2011

2 A wooden block, of mass 4 kg, is placed on a rough horizontal surface. The coefficient of friction between the block and the surface is 0.3. A horizontal force, of magnitude 30 newtons, acts on the block and causes it to accelerate.



(a) Draw a diagram to show all the forces acting on the block. *(1 mark)*

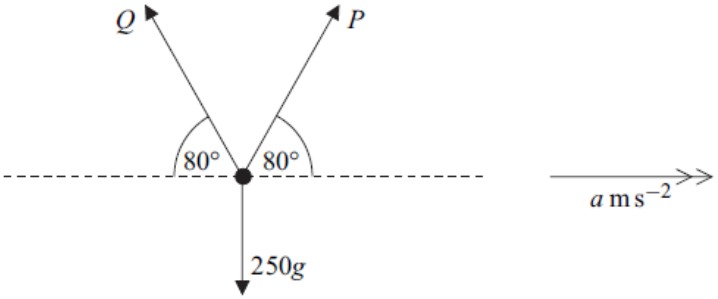
(b) Calculate the magnitude of the normal reaction force acting on the block. *(1 mark)*

(c) Find the magnitude of the friction force acting on the block. *(2 marks)*

(d) Find the acceleration of the block. *(3 marks)*

30. June 2011

8 Three forces act in a vertical plane on an object of mass 250 kg, as shown in the diagram.



The two forces P newtons and Q newtons each act at 80° to the horizontal. The object accelerates horizontally at $a\,\mathrm{m\,s^{-2}}$ under the action of these forces.

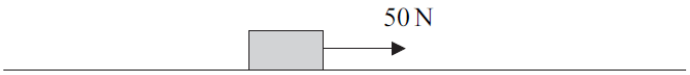
(a) Show that

$$P = 125\left(\frac{a}{\cos 80°} + \frac{g}{\sin 80°}\right)$$ *(5 marks)*

(b) Find the value of a for which Q is zero. *(3 marks)*

31. Jan 2012

2 A block, of mass 4 kg, is made to move in a straight line on a rough horizontal surface by a horizontal force of 50 newtons, as shown in the diagram.



Assume that there is no air resistance acting on the block.

(a) Draw a diagram to show all the forces acting on the block. *(1 mark)*

(b) Find the magnitude of the normal reaction force acting on the block. *(1 mark)*

(c) The acceleration of the block is $3\,\mathrm{m\,s^{-2}}$. Find the magnitude of the friction force acting on the block. *(3 marks)*

(d) Find the coefficient of friction between the block and the surface. *(2 marks)*

(e) Explain how and why your answer to part **(d)** would change if you assumed that air resistance did act on the block. *(2 marks)*

32. Jan 2012

5 A car, of mass 1200 kg, tows a caravan, of mass 1000 kg, along a straight horizontal road. The caravan is attached to the car by a horizontal towbar. A resistance force of magnitude R newtons acts on the car and a resistance force of magnitude $2R$ newtons acts on the caravan. The car and caravan accelerate at a constant $1.6\,\mathrm{m\,s^{-2}}$ when a driving force of magnitude 4720 newtons acts on the car.

(a) Find R. *(4 marks)*

(b) Find the tension in the towbar. *(3 marks)*

33. June 2012

3 A car is travelling at a speed of $20\,\mathrm{m\,s^{-1}}$ along a straight horizontal road. The driver applies the brakes and a constant braking force acts on the car until it comes to rest.

(a) Assume that no other horizontal forces act on the car.

(i) After the car has travelled 75 metres, its speed has reduced to $10\,\mathrm{m\,s^{-1}}$. Find the acceleration of the car. *(3 marks)*

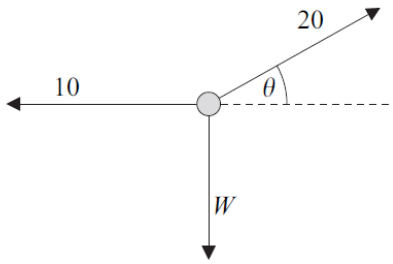
(ii) Find the time taken for the speed of the car to reduce from $20\,\mathrm{m\,s^{-1}}$ to zero. *(2 marks)*

(iii) Given that the mass of the car is 1400 kg, find the magnitude of the constant braking force. *(2 marks)*

(b) Given that a constant air resistance force of magnitude 200 N acts on the car during the motion, find the magnitude of the constant braking force. *(1 mark)*

34. June 2012

4 A particle, of weight W newtons, is held in equilibrium by two forces of magnitudes 10 newtons and 20 newtons. The 10-newton force is horizontal and the 20-newton force acts at an angle θ above the horizontal, as shown in the diagram. All three forces act in the same vertical plane.



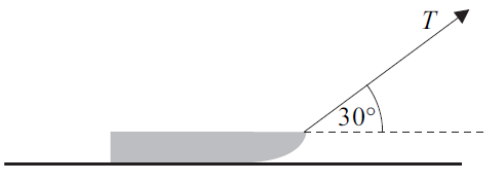
(a) Find θ. *(3 marks)*

(b) Find W. *(2 marks)*

(c) Calculate the mass of the particle. *(2 marks)*

35. June 2012

6 A child pulls a sledge, of mass 8 kg, along a rough horizontal surface, using a light rope. The coefficient of friction between the sledge and the surface is 0.3. The tension in the rope is T newtons. The rope is kept at an angle of 30° to the horizontal, as shown in the diagram.



Model the sledge as a particle.

(a) Draw a diagram to show all the forces acting on the sledge. *(1 mark)*

(b) Find the magnitude of the normal reaction force acting on the sledge, in terms of T. *(3 marks)*

(c) Given that the sledge accelerates at $0.05\ \text{m s}^{-2}$, find T. *(6 marks)*

36. Jan 2013

3 A box, of mass 3 kg, is placed on a rough slope inclined at an angle of 40° to the horizontal. It is released from rest and slides down the slope.

(a) Draw a diagram to show the forces acting on the box. *(1 mark)*

(b) Find the magnitude of the normal reaction force acting on the box. *(2 marks)*

(c) The coefficient of friction between the box and the slope is 0.2. Find the magnitude of the friction force acting on the box. *(2 marks)*

(d) Find the acceleration of the box. *(3 marks)*

(e) State an assumption that you have made about the forces acting on the box. *(1 mark)*

37. Jan 2013

4 A tractor, of mass 3500 kg, is used to tow a trailer, of mass 2400 kg, across a horizontal field. The trailer is connected to the tractor by a horizontal tow bar. As they move, a constant resistance force of 800 newtons acts on the trailer and a constant resistance force of R newtons acts on the tractor. A forward driving force of 2500 newtons acts on the tractor. The trailer and tractor accelerate at $0.2\,\mathrm{m\,s^{-2}}$.

(a) Find R. *(3 marks)*

(b) Find the magnitude of the force that the tow bar exerts on the trailer. *(3 marks)*

(c) State the magnitude of the force that the tow bar exerts on the tractor. *(1 mark)*

38. Jan 2012

6 A cyclist freewheels, with a constant acceleration, in a straight line down a slope. As the cyclist moves 50 metres, his speed increases from $4\,\mathrm{m\,s^{-1}}$ to $10\,\mathrm{m\,s^{-1}}$.

(a) (i) Find the acceleration of the cyclist. *(3 marks)*

(ii) Find the time that it takes the cyclist to travel this distance. *(3 marks)*

(b) The cyclist has a mass of 70 kg. Calculate the magnitude of the resultant force acting on the cyclist. *(2 marks)*

(c) The slope is inclined at an angle α to the horizontal.

(i) Find α if it is assumed that there is no resistance force acting on the cyclist. *(3 marks)*

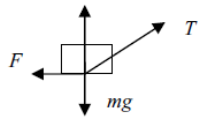
(3 marks)

(ii) Find α if it is assumed that there is a constant resistance force of magnitude 30 newtons acting on the cyclist. *(3 marks)*

(d) Make a criticism of the assumption described in part **(c)(ii)**. *(1 mark)*

Answers

1. Jan 2005

3 (a)		B1	1	Correct diagram
(b)	$40\cos 30° - F = 25 \times 0.1$ $F = 40\cos 30° - 2.5 = 32.1$ N	M1 A1 A1	3	Three term equation of motion Correct equation AG; correct force from correct working
(c)	$R + 40\sin 30° = 25 \times 9.8$ $R = 225$ N	M1 A1 A1	3	Resolving vertically Correct equation AG; correct force from correct working
(d)	$32.1 = 225\mu$ $\mu = \frac{32.1}{225} = 0.143$	M1 A1	2	use of $F = \mu R$ Correct μ
(e)	Friction will decrease as normal reaction decreases	B1 B1	2	Decrease in friction Normal reaction decreases
	Total		**11**	

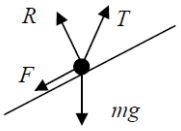
2. Jan 2005

5(a)	$200\sin 30° = T\sin 45°$ $T = \frac{200\sin 30°}{\sin 45°} = 141$ N	M1 A1 A1	3	Resolving horizontally Correct equation AG; correct T from correct working
(b)	$200\cos 30° + 141\cos 45° + R = 500 \times 9.8$ $R = 4630$ N	M1 A1 A1 A1	4	Resolving vertically with four terms Correct values Correct signs Correct R
	Total		**7**	

3. June 2005

5(a)	No air resistance/Only gravity or weight	B1	1	B1: Acceptable assumption
(b)(i)	$0.2 \times 8 = 0.2 \times 9.8 - R$ $R = 0.36$ N	M1 A1 A1	3	M1: Three term equation of motion A1: Correct equation A1: Correct magnitude of the resistance force
(b)(ii)	**Increases** as the speed increases	B1	1	B1: Correct explanation
(c) (i)	$\pm$ 9.8 ms^{-2}	B1	1	B1: CAO
(ii)	**Decreases** towards zero	B1	1	B1: Correct explanation
	Total		**7**	

4. June 2005

8(a)		B1	1	B1: Correct force diagram
(b)	$R + 20\sin 30° = 6g\cos 10°$ $R = 6g\cos 10° - 20\sin 30°$ $R = 47.9$ N (to 3 sf) **AG**	M1 A1 dM1 A1	4	M1: Resolving perpendicular to the slope with 3 terms A1: Correct equation dM1 Solving for R A1: Correct R from correct working
(c)	$F = \mu R$ $6 \times 0.4 = 20\cos 30° - 6g\sin 10° - \mu R$ $\mu R = 4.710$ $\mu = \frac{4.710}{47.91} = 0.0983$	M1 M1 A1 A1 dM1 A1	6	M1: Use of F = μR M1: Resolving parallel to slope to get 4 term equation of motion A1: Correct equation A1: Correct F / μR dM1: Solving for μ A1: AWRT 0.098
	Total		**11**	

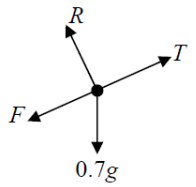
5. Jan 2006

8(a)(i)	$R = 80\cos 25°$ $R = 72.5$N	M1 A1 A1	3	component attempted correct component cao
(ii)	$F = 0.32 \times 72.5$ $F = 23.2$N	M1 A1	2	condone inequality cao
(iii)	$T + F = 80\cos 65°$ $T = 10.6$N	M2 A1 A1√	4	3 forces direction correct, component attempted component √ friction
(iv)	$T = F + 80\cos 65°$ $T = 57.0$N (57N)	M1 A1 A1√	3	3 forces, direction correct, component attempted component √ friction
(iv)	Mass $= \frac{80}{g} = (8.16\text{kg})$	B1	1	
(b)	$80\cos 65° - F = \text{mass} \times \text{acceleration}$ $10.6 = \frac{80}{g} \times \text{acc}$ $\text{acc} = 1.30\,\text{ms}^{-2}$ $(1.3\,\text{ms}^{-2})$	M1 A1 A1	3	3 terms, component attempted all correct cao
	Total		**16**	

6. June 2006

2(a)	$P = 5 + 8\cos 60^\circ$	M1		Both relevant forces, component of 8N attempted
		A1		All correct
	$P = 9$	A1	3	CAO
(b)	$Q = 8\cos 30^\circ$	M1		Component of 8N attempted
	$Q = 6.93$ or $4\sqrt{3}$	A1	2	AWRT 6.93
	Total		**5**	

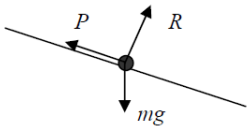
7. June 2006

4(a)		B1	1	Accept W or mg (or 6.86) for weight Arrows and labels needed (can replace W with 2 correct components)
(b)	$R = 0.7g\cos 22^\circ$	M1		component of weight attempted
		A1		all correct, including signs
	$R = 6.36$ N	A1	3	CAO
(c)	$F = 0.25 \times 6.36$	M1		
	$F = 1.59$N	A1	2	CAO
(d)	$5.6 - 0.7g\sin 22^\circ - 1.59 = 0.7a$	M1		4 terms with weight component attempted
		A2		A marks -1 each error, accept $\pm 0.7a$
	$a = 2.06\text{ms}^{-2}$	A1F	4	FT one error, accept $\pm$
	Total		**10**	

8. Jan 2007

3(a)	$F = \sqrt{6^2 + 5^2}$	M1A1		Obtaining an equation for F with square or root. Correct equation
	$= \sqrt{61} = 7.81$	A1	3	Correct force
	Alt			
	$\alpha = \tan^{-1}\left(\frac{5}{6}\right) = 39.8^\circ$			
	$F = \frac{6}{\cos 39.8} = 7.81$ or	(M1A1)		Equation for F with a value for α. Correct equation
	$F = \frac{5}{\sin 39.8} = 7.81$	(A1)		Correct force
(b)	$\alpha = \tan^{-1}\left(\frac{5}{6}\right)$ or $\cos^{-1}\left(\frac{6}{7.81}\right)$ or $\sin^{-1}\left(\frac{6}{7.81}\right)$	M1		Obtaining an equation for α using trigonometry.
		A1		Correct equation (using their F)
	$= 39.8^\circ$	A1	3	Correct angle
	Alt			Accept values between 39.7 and 39.9
	$\frac{\sin\alpha}{5} = \frac{\sin 90^\circ}{\sqrt{61}}$			
	$\alpha = 39.8^\circ$			
	Total		**6**	

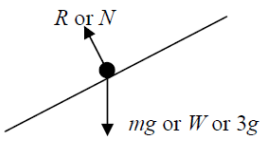
9. Jan 2007

6(a)		B1	1	Correct diagram with arrows and labels Must not use F instead of P Condone resistance instead of P
(b)	$P = 100 \times 9.8 \sin 4°$ $= 68.4$	M1 M1 A1	3	Resolving weight (must see 100) Using $\sin 4°$ or $\cos 86°$ **AG** Correct P from correct working
(c)	$100a = 100 \times 9.8 \sin 5° - 100 \times 9.8 \sin 4°$ $a = \dfrac{100 \times 9.8 \sin 5° - 100 \times 9.8 \sin 4°}{100}$ $= 0.171$	M1 A1 A1 A1	4	Three term equation of motion Weight resolved correctly Correct equation Correct a. (Accept 0.170 or 0.17)
(d)	You would expect P to vary with the speed of the car.	B1	1	Correct explanation
			9	

10. June 2007

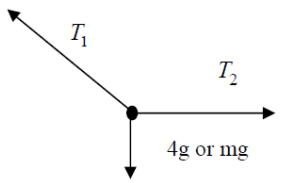
3(a)	$T_1 \sin 35° = T_2 \sin 35°$ $T_1 = T_2$ **OR** $T_1 \cos 55° = T_2 \cos 55°$ $T_1 = T_2$	M1 A1	2	Resolving two forces and forming an equation, with different tensions for each string Correct result from correct working
(b)	$T_1 \cos 35° + T_2 \cos 35° = 2 \times 9.8$ $T_1 \cos 35° + T_1 \cos 35° = 2 \times 9.8$ $T_1 = \dfrac{2 \times 9.8}{2 \cos 35°} = 12.0$ N (to 3sf)	M1 A1 A1 dM1 A1	5	Resolving forces to form a three term vertical equation Correct equation T_1 or T_2 eliminated correctly Solving for T_1 or T_2 Correct tension Accept 12 N or 11.9 N
(c)	$2 \times 40 \cos 35° = 9.8m$ $m = \dfrac{80 \cos 35°}{9.8} = 6.69$ kg **OR** $m = \dfrac{40}{11.96} \times 2$ $= 6.69$ kg	M1 A1 A1 (M1) (A1) (A1)	3	Forming an equation with two tensions to find m Correct equation Correct mass Accept 6.68
	Total		**10**	

11. June 2007

6(a)(i)		B1	1	Correct diagram with arrows and labels

(ii)	$3a = 3g\sin 30°$ $a = g\sin 30° = 4.9\ \text{ms}^{-2}$	M1 A1	 2	Two term equation of motion AG Correct acceleration from correct working (Allow $a = g\sin 30°$)
(b)(i)	$5 = \frac{1}{2}a \times 2^2$ $a = 2.5\ \text{ms}^{-2}$	M1 A1	 2	Constant acceleration equation with $u = 0$ AG Correct answer from correct working. (Use of $v = 5$ must be justified)
(ii)	$3 \times 2.5 = 3g\sin 30° - F$ $F = 3g\sin 30° - 7.5$ $= 7.20$ N (to 3 sf)	M1 A1 A1	 3	Three term equation of motion Correct equation Correct F Accept 7.2 N
(iii)	$R = 3g\cos 30°$ (= 25.46) $7.2 = \mu \times 3g\cos 30°$ $\mu = \frac{7.2}{3g\cos 30°} = 0.283$	M1 A1 M1 A1F A1F	 5	Accept 7.2 N Resolving perpendicular to the slope to find R Correct R Use of $F = \mu R$ Correct expression Correct μ Accept 0.282 (Follow through from incorrect F from above, but not an incorrect R)
(iv)	Reduce a, as the air resistance would reduce the magnitude of the resultant force or because the air resistance increases as the velocity increases towards its terminal value	B1 B1	 2	Reduces Explanation Second B1 dependent on the first B1 mark
	Total		**15**	

12. Jan 2008

3.(a)		B1	1	Diagram with three forces, labels and arrow heads. Different variables must be used for each tension
(b)	$T_1 \sin 30° = 4 \times 9.8$ $T_1 = \frac{4 \times 9.8}{\sin 30°} = 78.4$ N **AG**	M1 A1 A1	 3	Two term equation from resolving vertically. Must see a sin or cos term for M1 Correct equation Correct tension form correct working.
(c)	$T_2 = 78.4\cos 30° = 67.9$ N	M1 A1	 2	Two term equation from resolving horizontally. Correct tension.
	Total		**6**	

13. Jan 2008

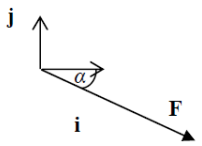
5(a)(i)	$0.2a = -0.2 \times 9.8\sin 20°$ **AG** $a = -9.8\sin 20° = -3.35\ \text{ms}^{-2}$	M1 A1 A1	 3	Two term equation of motion with weight resolved Correct equation Correct acceleration from correct working SC No negative sign but otherwise correct award M1A1A0 Allow $a = -g\sin 20°$

(a)(ii)	$0 = 4^2 + 2\times(-3.35)s$	M1		Use of constant acceleration equation with $v = 0$ and $u = 4$
		A1		Correct equation
	$s = \frac{16}{6.7} = 2.39$ m	A1	3	Correct distance
(a)(iii)	The puck slides back down the slope as the puck is at rest and the resultant force is now acting down the slope / no friction / smooth slope.	B1		Slides back down
		E1	2	Acceptable explanation

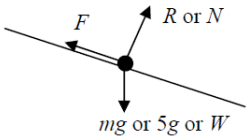
(b)(i)	$R = 0.2\times 9.8\cos 20°$ **AG**	M1		Finding normal reaction by resolving. Must see a trig term.
	$F = 0.5\times 0.2\times 9.8\cos 20°$	M1		Use of $F = \mu R$
	$= 0.921$ N	A1	3	Correct friction from correct working.
(b)(ii)	$0.2a = -0.921 - 0.2\times 9.8\sin 20°$	M1		Three term equation of motion with the weight resolved
		A1		Correct equation
	$a = -7.96$ ms^{-2}	A1	3	Correct acceleration (with or without the minus sign, applied to both A1 marks)
(b)(iii)	The puck stays at rest because the friction has a maximum of 0.921 and the component of the weight down the slope is less (0.670)	B1		Stays at rest
		dE1	2	Acceptable explanation
	Total		**16**	

14. June 2008

2(a)	$\mathbf{F} = 5\mathbf{j} + 8\mathbf{i} - 7\mathbf{j} = 8\mathbf{i} - 2\mathbf{j}$	M1		Adding the two forces. For incorrect answers, evidence of adding must be seen
		A1	2	Correct resultant
(b)	$F = \sqrt{8^2 + 2^2} = \sqrt{68} = 8.25$ N	M1		Finding magnitude (must see addition and not subtraction)
		A1F	2	Correct magnitude Accept $2\sqrt{17}$, $\sqrt{68}$ or AWRT 8.25 (eg 8.246)

(c)		B1		Diagram with force in the correct quadrant and with correct direction shown by an arrow.
	$\tan\alpha = \frac{2}{8}$	M1		Using trig to find angle: if tan, 8 in denominator; if sin or cos, 8.25 or their answer to part (b) in denominator
	$\alpha = 14.0°$	A1	3	Correct angle Accept 14.1 or 14 or AWRT 14.0 (eg 14.04) M1 and A1 not dependent on B1
	Total		**7**	

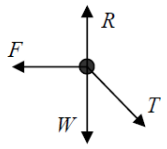
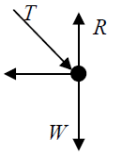
15. June 2008

6(a)		B1	1	Correct force diagram with labels and arrows Accept components of the weight if shown in a different notation with the weight also shown. B0 if components are shown instead of the weight.
(b)	$(R=)5\times9.8\cos40°=37.5$ N **AG**	M1 A1	2	Attempt at resolving perpendicular to the slope (eg 49sin40°) Correct value from correct working
(c)	$5\times0.8=5\times9.8\sin40°-\mu\times5\times9.8\cos40°$	B1 M1 A1 A1		Use of $F=\mu R$ at any stage and with any F but with $R=37.5$ OE Three term equation of motion from resolving parallel to the slope with weight component, friction and ma term. Correct terms seen (may be as 31.5, 37.5μ (or F) and 4) Correct signs
	$\mu=\dfrac{5\times9.8\sin40°-5\times0.8}{5\times9.8\cos40°}=0.733$	m1 A1	6	Solving for μ A1: Correct value for μ Allow 0.732 but not $\frac{11}{15}$ unless converted to a decimal
(d)	There is less friction so the coefficient of friction must be less.	B1 B1	2	Less friction Smaller coefficient of friction If the answer and explanation contradict each other, award no marks
	Total		**11**	

16. Jan 2009

3(a)	$4a=4g\sin40°$ $a=g\sin40°=6.30$ ms^{-2} **AG**	M1 A1 A1	3	M1: Resolving and application of Newton's second law. Allow cos40°. A1: Correct expression. A1: Correct result from correct working. Must see 6.30 not 6.3. Just seeing $g\sin40°=6.30$ ms^{-2} scores full marks. Use of $g=9.81$ gives 6.31, M1A1A0, but don't penalise again on the same script.
(b)	$0.9=0+\frac{1}{2}\times a\times0.6^2$ $a=\dfrac{0.9\times2}{0.6^2}=5$ ms^{-2}	M1 A1 A1		M1: Use of a constant acceleration equation to find a, with $s=0.9$, $u=0$ and $t=0.6$. A1: Correct equation A1: Correct acceleration
	ALT Method $0.9=\frac{1}{2}(0+v)\times0.6$ $v=3$ $3=0+0.6a$ $a=5$ ms^{-2}	(M1A1) (A1)	3	No marks at this stage. M1: Constant acceleration equation with $u=0$ and $t=0.6$. A1: Correct equation A1: Correct acceleration.
(c)	The acceleration is reduced because of air resistance or the fact that there is friction.	B1	1	B1: Must mention air resistance/resistive forces or friction. Do not allow air friction.
	Total		**7**	

17. Jan 2009

5(a)	 **OR** 	B1	1	B1: Diagram with four forces showing arrow heads and labelled. Allow mg or $8g$. Allow T or 40 or other reasonable notation. Allow μR. Direction of friction must be to the left. Any components must be shown in a different style.
(b)	$8g + 40\sin 30° (= R)$ $(R =)98.4$ N **AG**	M1 A1 A1	3	M1: Expression for normal reaction, with mg or $8g$ and 40sin30° or 40cos30°. Allow incorrect signs. A1: Correct expression with correct signs. A1: Correct value from correct working. Use of $g = 9.81$ gives 98.5 N. Do not penalise if you have already done so earlier in the script. Otherwise penalise by 1 mark.
(c)	$F = 40\cos 30° = 34.6$ N	M1 A1	2	M1: Use of 40cos30° or 40sin30°. Award M0 if any extra terms. A1: Correct value for friction. Don't need to see F.
(d)	$40\cos 30° \le \mu \times 98.4$ $\mu \ge \frac{40\cos 30°}{98.4}$ $\mu \ge 0.352$	M1 A1F A1F	3	M1: Use of $F \le \mu R$ (or $F = \mu R$). Must use $R = 98.4$ and a positive value for F. A1F: Correct inequality or equation Allow use of $F = \mu R$ throughout. A1F: Correct minimum value. For follow through must use $R = 98.4$ and their value for F from part (c). For example use of sin 30° in part (c) gives 0.203.
	Total		**9**	

18. Jan 2009

6(a)	Resultant $= (6\mathbf{i} - 3\mathbf{j}) + (3\mathbf{i} + 15\mathbf{j})$ $= 9\mathbf{i} + 12\mathbf{j}$	M1 A1	2	M1: Summing the two vectors A1: Correct resultant
(b)	Magnitude $= \sqrt{9^2 + 12^2}$ $= 15$ N	M1 A1F	2	M1: Finding magnitude with an addition sign. A1F: Correct magnitude based on their answer to part (a).
(c)	$1.5m = 9$ or $2m = 12$ $m = 6$ kg $m = 6$ kg	M1 A1F	2	M1: Applying Newton's second law to one or both of the components. A1F: Correct mass, follow through their answer to part (a). Do not award this mark if vector division with 2 components has been used, eg $\frac{9\mathbf{i} + 12\mathbf{j}}{1.5\mathbf{i} + 2\mathbf{j}} = 6$ or $6\mathbf{i} + 6\mathbf{j}$ etc without a correct previous statement gives M0A0

(d)(i)	$\mathbf{r}=\frac{1}{2}(1.5\mathbf{i}+2\mathbf{j})t^2$	M1 A1	 2	M1: Using a constant acceleration equation to find the position vector with $\mathbf{u}=0\mathbf{i}+0\mathbf{j}$ A1: Correct position vector.
(d)(ii)	$\mathbf{r}=\frac{1}{2}(1.5\mathbf{i}+2\mathbf{j})\times 2^2=3\mathbf{i}+4\mathbf{j}$ $d=\sqrt{(3)^2+(4)^2}$ $=\sqrt{25}=5$	M1 A1	 2	M1: Finding the position vector when $t=2$. ($\mathbf{r}=(1.5\mathbf{i}+2\mathbf{j})\times 2=3\mathbf{i}+4\mathbf{j}$ scores M0 unless it is clear how the 2 was obtained, possibly by a correct formula in (d) (i)) A1: Correct distance
	Total		**10**	

19. June 2009

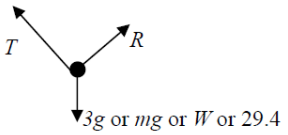
3(a)	Resultant Force = 3000 – 600 = 2400 N	M1 A1	 2	M1: Difference between the two forces. A1: Correct magnitude of resultant force. Must be a positive answer. (600 – 3000 = –2400 scores M1A0)
(b)	$2400=1200a$ $a=\frac{2400}{1200}=2\text{ ms}^{-2}$	M1 A1	 2	M1: Use of Newton's second Law to find acceleration. A1: Correct acceleration ($a=\frac{-2400}{1200}=-2\text{ ms}^{-2}$ scores M1A0)
	Total		**4**	

20. June 2009

8(a)(i)	$20\times 9.8=R+60\sin 30°$ $(R=)20\times 9.8-60\sin 30°=166\text{ N}$ AG	M1 A1 A1	 3	M1: Equation or expression for normal reaction with mg or $20g$ or 196 and $60\sin 30°$ or $60\cos 30°$. A1: Correct equation or expression with correct signs. A1: Correct value from correct working. Must be positive. Don't penalise use of g = 9.81 if already done earlier on script. Should still get 166, but from 166.2.
(ii)	$166\mu=60\cos 30°$ $\mu=\frac{60\cos 30°}{166}$ $=0.313$	M1 M1A1 A1	 4	M1: Use of $F=\mu R$, with R = 166 or 166.2. Do not allow inequalities here. M1: Resolving horizontally with $\cos 30°$ or $\sin 30°$ oe. A1: Correct equation Examples: $166\mu=60$ M1M0A0 $166\mu=-60\cos 30°$ M1M1A0 A1: Correct coefficient of friction.
(b)	$20\times 0.8=T\cos 30°-0.313(20\times 9.8-T\sin 30°)$ $T=\frac{20\times 0.8+0.313\times 20\times 9.8}{\cos 30°+0.313\sin 30°}=75.6\text{ N}$	B1 M1 A1F dM1 A1F	 5	B1: $20g-T\sin 30°$ oe seen. M1: Three term equation of motion, where normal reaction is dependent on T. A1F: Correct equation dM1: Solving for T including factorisation.

				A1F: Correct tension. AWRT 75.6 Follow through incorrect values of μ from part (a). Don't penalise use of $g = 9.81$ if already done earlier on script. Should get 75.7. Allow 75.8 if intermediate values rounded.
	Total		**12**	

21. Jan 2010

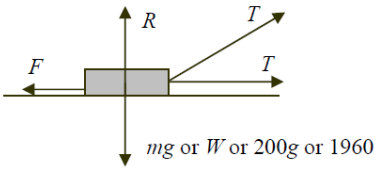
3(a)		B1	1	B1: Correct force diagram with arrows and sensible labels. If R is shown as vertical award B0. If F is included, award B0 Accept a reflection of the diagram in a vertical line. Ignore components if shown with a different notation, eg dotted lines.
(b)	$(R =)3g\cos 60°$	M1		M1: Resolving perpendicular to the slope. Must see cos60° or sin30° or cos30° or sin60° and $3g$ or 29.4. NOTE: $\frac{3g}{2} = 14.7$ or equivalent without
	$(R =)14.7$ **AG**	A1	2	A1: Correct value from correct working. NOTE: If candidates use $g = 9.81$, deduct one mark here. If candidates obtain 14.7 from 14.715 they will have used $g = 9.81$. Note: "$R =$" does not need to be seen.
(c)	$(T =)3g\sin 60°$	M1		M1: Resolving parallel to the slope. Must see cos60° or sin30° or cos30° or sin60° and $3g$ or 29.4.
	$(T =)25.5$	A1	2	A1: Correct value. AWRT 25.5 or truncation to 25.4. NOTE: If candidates use $g = 9.81$ again, do not penalise. Use of $g = 9.81$ gives 25.5 for the tension. Note: "$T =$" does not need to be seen.
	Total		**5**	

22. Jan 2010

6(a)		B1	1	B1: Force diagram with two arrows clearly in opposite directions. Must see 300 and one other label (a letter) or 550. Do not penalise if vertical forces included, even if wrong.
(b)	$T_1 - 300 = 500 \times 0.5$ $(T_1 =)\ 300 + 250$ $= 550$ N **AG**	M1 A1	 2	M1: Three term equation of motion. A1: Correct force from correct working. Examples:

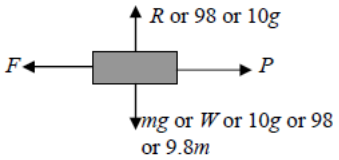
				$T_1 = 300 + 250 = 550$ N scores M0A0 $T_1 - 300 = 250$, $T_1 = 550$ N scores M1A1 $T_1 = 300 + 500 \times 0.5 = 550$ N scores M1A1 Just $300 + 500 \times 0.5 = 550$ N scores M0A0 $700 + T_1 = 2500 \times 0.5$, $T_1 = 550$ scores M0A0
(c)	$T_2 - 550 - 300 = 500 \times 0.5$ $T_2 = 550 + 300 + 250 = 1100$ N **OR** $T_2 - 600 = 1000 \times 0.5$ $T_2 = 600 + 500 = 1100$ N	M1A1 A1 (M1) (A1) (A1)	 3 (3)	M1: Four term equation of motion for Carriage 1 including 550 and 300 with mass 500 A1: Correct equation. A1: Correct force M1: Three term equation of motion for Carriages 1 and 2 together including 300 twice or 600 with mass 1000. A1: Correct equation. Accept $T_2 = 600 + 500$ or similar. A1: Correct tension
(d)	$P - 1100 - 400 = 2000 \times 0.5$ $P = 1100 + 400 + 1000 = 2500$ **OR** $P - 1000 = 3000 \times 0.5$ $P = 1000 + 1500 = 2500$	M1 A1F A1F (M1) (A1F) (A1F)	 3 (3)	M1: Four term equation of motion for engine with mass 2000, a force of 400 and their answer to part (c). A1F: Correct equation. A1F: Correct force M1: Three term equation of motion for whole train with mass 3000 and 1000 (OE) force. A1F: Correct equation. A1F: Correct force Follow through from incorrect T_2 in part (c). Don't penalise candidates who use a letter other than P.
	Total		**9**	

23. Jan 2010

8(a)		B1 B1	 2	B1: F, R and mg (or equivalent) with arrows and labels. B1: Two **equal** tension forces with arrows and labels. Ignore components if shown with a different notation, eg dotted lines.
(b)	$R + T\sin 20° = 1960$ **OR** $R + T\sin 20° = 200g$	M1A1		M1: Resolving vertically with three terms. Must include sin20° or cos20° or sin 70° or cos70° with T and 200g or 1960. A1: Correct equation.
	$(R =)1960 - T\sin 20°$ **OR** $(R =)200g - T\sin 20°$	A1	3	A1: Correct expression for the normal reaction. Note: If $g = 9.81$ is used for the first time deduct one mark. Should get 1962 instead of 1960.

(c)	$T\cos 20^\circ + T - F = 200\times 0.3$ $T\cos 20^\circ + T - 0.4(1960 - T\sin 20^\circ) = 200\times 0.3$	M1A1 M1		M1: Four term equation of motion. Must include sin20° or cos20° or sin 70° or cos70° with T and a second T term with no trig. A1: Correct equation M1: Use of friction law with their expression for R, provided that R has two terms. Note that this mark does not depend on any previous marks.
	$T = \dfrac{60+784}{\cos 20^\circ + 1 + 0.4\sin 20^\circ} = 406$	dM1 A1	5	Example If Candidate gives 1960 as answer to part (b), then: $F = 0.4\times 1960 = 784$ scores M0 here dM1: Solving for T. Note: This mark requires both of the previous M marks. A1: Correct tension. Accept AWFW 406 to 407. Note: If g = 9.81 is used should get 407 instead of 406.
	Total		**10**	

24. June 2010

2(a)		B1	1	B1: Correct force diagram with arrows and labels. Note: Award mark if forces drawn on the diagram in the question. Note: Do not accept 10 kg for the weight. Note: Do not accept μR or $0.5R$ for F.
(b)(i)	$(R = 10\times 9.8 =)98$ N	B1	1	B1: Correct normal reaction. Accept $10g$. No need to see the letter R or working.
(ii)	$(F \le) 0.5\times 98$ $(F \le) 49$	B1F	1	B1: Correct maximum value for friction. Accept $5g$. No need to see the letter F or any working. Ignore any inequalities. For FT, must be 0.5 of candidate's answer to (b)(i).
(iii)	$(F =)30$N	B1	1	B1: Correct friction. Allow – 30.
(c)	$80 - 49 = 10a$ $a = 3.1\text{ ms}^{-2}$	M1A1F A1F	 3	M1: Three term equation motion, containing 80, candidate's 49 and $10a$ (not $10ga$) in any combination. A1F: Correct equation including signs. A1F: Correct acceleration. FT candidate's answer to (b)(ii).
	Total		**7**	

25. June 2010

4(a)	$50\cos\theta = 60\cos 48^\circ$ **OR** $50\cos\theta = 60\sin 42^\circ$ **OR** (from vector triangle and sine rule)	M1A1 (M1) (A1)		M1: Equation for two forces, with both forces resolved horizontally in the same way. (Accept $50\sin\theta = 60\sin 48^\circ$ for M1.) A1: Correct equation.

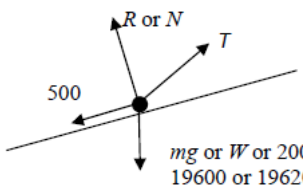
	$\frac{50}{\sin 42^\circ} = \frac{60}{\sin(90-\theta)}$ **OR** (from Lami's Theorem) $\frac{50}{\sin 138^\circ} = \frac{60}{\sin(90+\theta)}$ For example: $\theta = \cos^{-1}\left(\frac{60\cos 48^\circ}{50}\right)$ $= 36.59^\circ$ $= 36.6^\circ$ (to 3SF)	(M1) (A1) (M1) (A1) dM1 A1	 4	(M1: Use of sine rule with 50, 60 and 42°.) (A1: Correct equation.) (M1: Use of Lami's Theorem with 50, 60 and 138°.) (A1: Correct equation.) dM1: Solving for θ. A1: Correct θ. Note: Final answer of 63.1° from using resolving incorrectly with sines award M1A0dM1A0. Accept 36.5 (truncation) and 36.7 and AWRT 36.6.
(b)	$50\sin 36.59^\circ + 60\sin 48^\circ = 9.8m$ **OR** correct equivalent, for example: $50\sin 36.59^\circ + 60\cos 42^\circ = 9.8m$ **OR** (from vector triangle and sine rule) $\frac{50}{\sin 42^\circ} = \frac{mg}{\sin 84.6^\circ}$ **OR** (from Lami's Theorem) $\frac{50}{\sin 138^\circ} = \frac{60}{\sin 95.4^\circ}$ For example: $m = \frac{50\sin 36.59^\circ + 60\sin 48^\circ}{9.8} = 7.59$	M1 A1F (M1) (A1F) (M1) (A1F) (M1) (A1F) A1	 3	M1: Three term vertical equation, including mg with forces resolved vertically in the same way (accept $50\cos 36.59^\circ + 60\cos 48^\circ = 9.8m$ for M1). A1F: Correct equation. (M1: Use of vector triangle and sine rule.) (M1: Use of Lami's Theorem.) A1: Correct value for m CAO. Accept 7.58, AWRT 7.6.
	Total		7	
				Allow use of $g = 9.81$ (b) 7.58 M1A1A1

26. Jan 2011

3(b)(i)	$15 = 7 + 0.8t$ $t = \frac{15-7}{0.8} = 10$ seconds	M1A1 A1	 3	M1: Use of a constant acceleration equation to find t, with 7, 15 and 0.8. A1: Correct equation. A1: Correct time. CAO
(b)(ii)	$15^2 = 7^2 + 2\times 0.8s$ $s = \frac{15^2 - 7^2}{1.6} = 110$ m **OR** $s = \frac{1}{2}(7+15)\times 10 = 110$ m	M1A1 A1 (M1A1F) (A1F)	 3	M1: Use of a constant acceleration equation to find s, with 7, 15 and 0.8. A1: Correct equation A1: Correct distance. CAO M1: Use of a constant acceleration equation to find s, with 7, 15 and candidate's time. A1F: Correct equation. A1F: Correct distance.

				If candidates find distance first it must be stated in part (b)(ii) to gain any marks. The working does not have to be repeated if seen in part (b)(i).
(c)	Resistance forces <u>vary with speed</u> (or velocity) **OR** Speed (or velocity) changes (or increases) **OR** It accelerates	B1	1	B1: Correct explanation. Must not mention friction in main argument
	Total		**13**	

27. Jan 2011

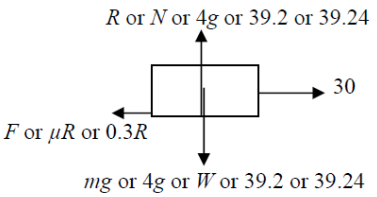
8(a)		B1 B1	2	B1: R, 500 and mg correct B1: Tension in roughly correct direction. If more than four forces shown, do not award more than one mark. Note all forces must be shown as arrows and have labels. Note some candidates may draw the force diagram in the section with the question. Components can be ignored if shown in a different notation eg dashed arrows.
(b)	$2000\times0.6 = T\cos12° - 500 - 2000\times9.8\sin5°$ $T = \dfrac{1200+500+19600\sin5°}{\cos12°}$ $\left(=\dfrac{3408.25}{\cos12°}\right)$ $(=3484.4)$ $=3480$ (to 3sf) AG	M1A1A1 dM1 A1	5	M1: Resolving parallel to the slope to obtain a four term equation of motion. The weight and tension terms must be resolved. A1: Correct terms. A1: Correct signs. dM1: Solving for T. A1: Correct tension. AWRT 3480. Allow AWRT 3490 from use of $g = 9.81$.
	Total		**7**	

28. June 2011

1(a)(i)	$0.6^2 = 0^2 + 2a\times0.9$ $a = \dfrac{0.6^2}{1.8} = 0.2\ \text{ms}^{-2}$ **AG**	M1A1 A1	3	M1: Correct use of constant acceleration equation with $u = 0$ to find a. A1: Correct equation. A1: Correct a but some intermediate working must be seen. Note that $0^2 = 0.6^2 + 2a\times0.9$ Scores M0A0A0 Verification methods require a conclusion for full marks to be awarded. Condone seeing just the second line of working.
(a)(ii)	$0.9 = \dfrac{1}{2}(0+0.6)t$ $t = \dfrac{0.9}{0.3} = 3$ seconds	M1 A1	2	M1: Correct use of constant acceleration equation with $u = 0$ (and $a = 0.2$ if needed) to find t. A1: Correct time.

	OR $0.6 = 0 + 0.2t$ $t = \frac{0.6}{0.2} = 3$ seconds **OR** $0.9 = \frac{1}{2}0.2t^2$ $t = 3$ seconds	 (M1) (A1) (M1) (A1)		Note: Do not penalise $0.9 = \frac{1}{2}(0.6+0)t$ in the first method. Note: $0 = 0.6 + 0.2t$ scores M0A0 in the second method.
(b)	$T - 800 \times 9.8 = 800 \times 0.2$ $T = 7840 + 160 = 8000$ N	M1A1 A1	3	M1: Three term equation of motion. Must have these three terms but can have incorrect signs. Must use $a = 0.2$ A1: Correct equation with correct signs. (Allow 800g) A1: Correct tension. Accept 8008 or 8010 from use of $g = 9.81$.
	Total		**8**	

29. June 2011

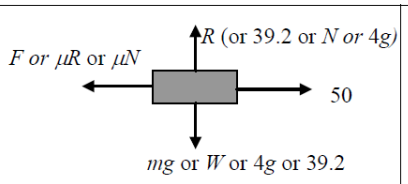
2(a)		B1	1	B1: Diagram with four forces showing arrow heads and labelled. Ignore negative signs in labels. Note: Award mark if forces drawn on the diagram in the question. Note: Do not accept 4kg for the weight. Note Accept μR for F.
(b)	$(R = 4 \times 9.8 =) 39.2$ N	B1	1	B1: Correct normal reaction. Accept 4g
(c)	$(F =) 0.3 \times 39.2 = 11.76 = 11.8$ N (to 3sf)	M1 A1	2	M1: Use of $(F =) \mu R$ A1: Correct friction. Accept 1.2g or 11.7 or 11.76 N. Do not condone further work after the value for friction has been obtained.
(d)	$4a = 30 - 11.76$ $a = \frac{30 - 11.76}{4} = 4.56$ ms^{-2}	M1A1F A1F	3	M1: Three term equation of motion. A1F: Correct equation. A1F: Correct acceleration. FT candidates F from part (c). Accept 4.55 from 11.8.
	Total		**7**	

30. June 2011

8(a)	$P\cos 80° - Q\cos 80° = 250a$ $P\sin 80° + Q\sin 80° = 250g$ $P - Q = \frac{250a}{\cos 80°}$ $P + Q = \frac{250g}{\sin 80°}$ **AG** $2P = \frac{250a}{\cos 80°} + \frac{250g}{\sin 80°}$ $P = 125\left(\frac{a}{\cos 80°} + \frac{g}{\sin 80°}\right)$	M1A1 B1 dM1 A1	5	M1: Horizontal equation of motion in the form $P\cos 80° \pm Q\cos 80° = 250a$ or $P\sin 80° \pm Q\sin 80° = 250a$ A1: Correct horizontal equation. B1: Correct vertical equation. Note: the above marks could be awarded for a correct vector equation. dM1: Solving for P with an attempt to eliminate Q. A1: Correct result from correct working. Must see an expression for $2P$ or $2P\sin 80° \cos 80°$

(b)	$P\cos 80° = 250a$ $P\sin 80° = 250g$ $\frac{1}{\tan 80°} = \frac{a}{g}$ $a = \frac{g}{\tan 80°} = 1.73$	M1 dM1 A1	 3	M1: Using $Q = 0$ into correct original equation(s) or resolving without Q. dM1: Eliminating P A1: Correct a. Note: use of $P = \pm Q$ scores M0dM0A0 Note: use of $P = 0$ can lead to ± 1.73 but scores M0dM0A0 unless fully justified by a symmetry argument.
	Total		**8**	

31. Jan 2012

2(a)		B1	1	B1: Correct force diagram with four forces with arrows and labels. Accept words eg friction instead of letters Ignore negative signs in labels. Do not accept 4 kg for the weight. Award marks if forces are drawn on the diagram in the question.
(b)	39.2 N	B1	1	B1: Correct reaction force. Accept $4g$. Do not accept 39.
(c)	$50 - F = 4 \times 3$ $F = 38$	M1A1 A1	 3	M1: Three term equation of motion with the correct terms. A1: Correct equation with correct signs. A1: Correct friction.
(d)	$38 = \mu \times 39.2$ $\mu = \frac{38}{39.2} = 0.969$	M1 A1F	 2	M1: Use of $F = \mu R$ with their answers to (b) and (c). A1F: Correct μ based on their answers to (b) and (c). Accept AWRT 0.969. Note: $F = 12$ leads to 0.306 and award M1 A1F Condone 0.97 or FT to 2sf Condone use of inequalities.
(e)	Less friction, so a smaller coefficient of friction.	B1 B1	 2	B1: Less friction. B1: Smaller μ. Note: More friction anywhere scores B0 B0 Less friction, greater μ scores B1 B0 Smaller μ with no/inexact reason B0 B1
	Total		**9**	

32. Jan 2012

5(a)	$4720 - 3R = 2200 \times 1.6$ $R = \frac{4720 - 3520}{3} = 400$ OR $4720 - R - T = 1200 \times 1.6$ $T - 2R = 1000 \times 1.6$ $4720 - 3R = 3520$ $R = 400$	M1A1 A1 A1 (M1A1) (A1) (A1)	 4	M1: Three term horizontal equation of motion with mass of 2200 kg and $3R$ (or $2R$ and R). A1: All terms correct (4720, $3R$ and 2200×1.6). A1: Correct signs. A1: Correct value for R. M1: Forming an equation for each body and adding to eliminate T. A1: Two correct equations. A1: Correct equation in R. A1: Correct value for R.

	OR $4720 - T - 400 = 1200 \times 1.6$ $T = 4720 - 400 - 1920 = 2400$ N	 (M1) (A1F) (A1F)		for R from part (a). A1F: Correct tension. Follow through from part (a) using $T = 1600 + 2R$ M1: Four term equation of motion for car with 4720, T, R and 1200×1.6. A1F: Correct equation, with their value for R from part (a) A1F: Correct tension. Follow through from part (a) using $T = 2800 - R$ Note: do not follow through if a negative value is used for R.
	Total		**7**	

33. June 2012

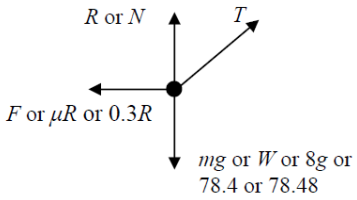
3(a)(i)	$10^2 = 20^2 + 2 \times a \times 75$ $a = \frac{100 - 400}{150} = -2$ ms^{-2}	M1A1 A1	 3	M1: Use of a constant acceleration equation to find a, with $v = 10$ and $u = 20$. $20^2 = 10^2 + 2 \times a \times 75$ scores M0 A1: Correct equation. A1: Correct acceleration. For two equation methods award no marks until an equation for a is obtained.
(ii)	$0 = 20 - 2t$ $t = 10$ seconds	M1 A1	 2	M1: Using a constant acceleration equation, with $u = 20$ and $v = 0$, to find t using their acceleration from (a) even if positive. Using $s = 75$ scores M0 A1: Correct time from correct working CSO.
(iii)	$F = 1400 \times 2$ $= 2800$ N	M1 A1F	 2	M1: Use of $F = ma$ with ± their acceleration and mass of 1400. A1F: Correct force. Follow through the magnitude of their acceleration. Answer must be positive. Sign changes do not need to be justified.
(b)	$F = 2800 - 200 = 2600$ N	B1F	1	B1F: The magnitude of their force minus 200. Do not award if M1 not awarded in (a)(iii). Final answer must be positive. Follow through only if their answer to (a)(iii) is greater than 200.
	Total		**8**	

34. June 2012

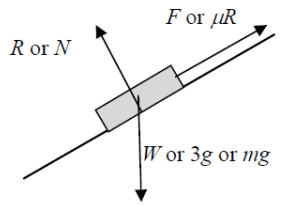
4(a)	$20\cos\theta = 10$ $\cos\theta = \frac{1}{2}$ $\theta = 60°$	M1A1 A1	 3	M1: Resolving horizontally. Accept $\sin\theta$ or $\cos\theta$ with the 20. A1: Correct equation. A1: Correct angle. Accept $\frac{\pi}{3}$ or 1.05 (radians). Allow 59.9 or better if they find W first
(b)	$(W =)20\sin 60°$ $= 17.3$ N Or $(W =)\sqrt{20^2 - 10^2} = 17.3$ N	M1 A1 (M1) (A1)	 2	M1: Resolving vertically. Accept $\sin\theta$ or $\cos\theta$ with the 20, where θ is their answer to part (a) or 90 minus their answer to part (a). A1: Correct weight CSO

				Accept $10\sqrt{3}$ or AWRT 17.3
(c)	$m = \dfrac{20\sin 60°}{9.8}$ $= 1.77$ kg	M1 A1F	2	M1: Their answer to part (b) divided by 9.8. A1F: Correct mass. Follow through their answer to part (b). Accept 1.76 or 1.8. Accept 2 sig figs in follow through. Note: Using $g = 9.81$ gives the answer 1.77, also accept 1.76.
	Total		**7**	

35. June 2012

6(a)		B1	1	B1: Diagram with **exactly four** forces showing arrow heads and labelled. If components are also shown and they use a different style, eg dashed lines, they can be ignored. Note: Award mark if forces drawn on the diagram in the question. Note: Do not accept 8 kg for the weight. Note Accept μR or $0.3R$ for F.
(b)	$R + T\sin 30° = 8 \times 9.8$ $(R =)\,78.4 - T\sin 30°$ $(R =)\,78.4 - 0.5T$	M1A1 A1	3	M1: Resolving vertically to obtain a three term equation, with R, T sin or cos(30° or 60°) and $8g$ oe. A1: Correct equation A1: Correct expression for R.
				Accept $(R =)\,8g - T\sin 30°$ Note if using $g = 9.81$ accept $R = 78.48 - 0.5T$ or $R = 78.5 - 0.5T$
(c)	$T\cos 30° - F = 8 \times 0.05$ $F = 0.3(78.4 - T\sin 30°)$ $T\cos 30° - 0.3(78.4 - T\sin 30°) = 0.4$ $T = \dfrac{23.52 + 0.4}{\cos 30° + 0.3\sin 30°} = 23.5$ N Or	M1A1 M1A1 dM1A1	6	M1: Horizontal equation of motion with F, T sin or cos(30° or 60°) and 8×0.05 oe. A1: Correct equation. M1: Using $F = 0.3R$ with their R from part (b), provided it includes a term in T. A1: Correct expression for friction. dM1: Solving for T. Must see $(\cos 30° \pm 0.3\sin 30°)$ or similar in the denominator. (Dependent on both previous M marks.) A1: Correct T. Accept 23.6 or AWRT 23.5
	$T\cos 30° - F = 8 \times 0.05$ $T\cos 30° - 0.3R = 8 \times 0.05$ $R + T\sin 30° = 8 \times 9.8$ solving simultaneously gives $T = 23.5$	(M1A1) (M1A1) (dM1A1)		M1: Horizontal equation of motion with F, T sin or cos(30° or 60°) and 8×0.05 oe. A1: Correct equation. M1: Using $F = 0.3R$ A1: Two correct equations involving only T and R. dM1: Solving for T. A1: Correct T. Accept 23.6 or AWRT 23.5 Note using $g = 9.81$ gives 23.6, also accept 23.5.
	Total		**10**	

36. Jan 2013

3(a)		B1	1	Diagram with exactly three forces showing arrow heads and labelled. If components are also shown they must use a different style e.g. dashed lines then they can be ignored. Friction must be up the slope.
(b)	$(R =)3\times 9.8\cos 40° = 22.5$ N	M1A1	2	M1: Resolving perpendicular to the slope. Can use sin40° or cos50° for method mark, with g or 9.8. A1: Correct normal reaction. Accept AWRT 22.5 (Note use of 9.81 still gives 22.5 N.)
(c)	$(F =)0.2R = 4.50$ N	M1A1F	2	M1: Use of $F = \mu R$. A1F: Correct friction. Accept 4.5 N or AWRT 4.50. (Accept 4.51 N from the use of 9.81.)
(c)	$(F =)0.2R = 4.50$ N	M1A1F	2	M1: Use of $F = \mu R$. A1F: Correct friction. Accept 4.5 N or AWRT 4.50. (Accept 4.51 N from the use of 9.81.) Follow through incorrect normal reaction from part (b).
(d)	$3a = 3\times 9.8\sin 40° - 4.504$ $a = 4.80$ m s^{-2}	M1A1F A1F	3	M1: Three term equation of motion with correct terms, with $3a$, either component of weight and their answer to part (c) for F. A1F: Equation of motion with correct terms and signs. A1F: Correct acceleration. Accept 4.8 or AWRT 4.80. (Note that using 9.81 still gives 4.80 m s^{-2}). Follow through friction from part (c).
(e)	No air resistance force acting or No other forces acting on the box. or They (forces in the diagram) are the only forces that act. **OR** No turning effect (due to forces). or Forces are concurrent. OE	B1	1	B1: Correct assumption. Ignore irrelevant comments
	Total		**9**	

37. Jan 2013

4(a)	$5900 \times 0.2 = 2500 - 800 - R$ $(R =) 2500 - 1180 - 800 = 520$ N	M1A1 A1	 3	M1: Equation of motion for tractor and trailer as a single particle, with 2500, 800, R (which might be implied by seeing 1180 and 1700 or 1180 and 3300) and 5900 × 0.2 OE, with any signs. A1: Correct equation. A1: Correct R. If tension found first, do not award any marks until an equation for R is obtained. Award M1 for $3500 \times 0.2 = \pm 2500 \pm R \pm 1280$.
(b)	$T - 800 = 2400 \times 0.2$ $(T =) 800 + 480 = 1280$ N **OR**	M1A1 A1	 3	M1: Equation for trailer with 2400 and 800. A1: Correct equation. A1: Correct tension.
	$3500 \times 0.2 = 2500 - 520 - T$ $(T =) 2500 - 700 - 520 = 1280$ N	(M1A1F) (A1F)	 (3)	M1: Equation for tractor with 3500, 2500 and 520. A1F: Correct equation. A1F: Correct tension. Follow through incorrect R from part (a). If the tension has been found in part (a) it only needs to be stated here.
(c)	1280 N	B1F	1	B1F: Same answer as part (b). Do not accept –1280
	Total		**7**	

38. Jan 2012

6(a)(i)	$10^2 = 4^2 + 2 \times a \times 50$ $a = \frac{100 - 16}{100} = 0.84 \text{ ms}^{-2}$	M1A1 A1	 3	M1: Use of a constant acceleration equation to find a, with v and u substituted correctly. For example $4^2 = 10^2 + 100a$ scores M0A0A0. A1: Correct constant acceleration equation. A1: Correct a. Note if t found first award M1 for use of $v = u + at$ or $s = ut + \frac{1}{2}at^2$.

(ii)	$50 = \frac{1}{2}(4+10)t$ $t = \frac{50}{7} = 7.14\text{ s}$ OR $10 = 4 + 0.84t$ $t = \frac{6}{0.84} = 7.14\text{ s}$ OR $50 = 4t + \frac{1}{2} \times 0.84t^2$ $0.42t^2 + 4t - 50 = 0$ $t = 7.14$ (or $t = -16.6$)	M1A1 A1 (M1A1F) (A1) (M1A1F) (A1)	3	M1: Use of a constant acceleration equation to find t. A1F: Correct constant acceleration equation with their acceleration from (a)(i) seen. A1: Correct t. Accept $\frac{50}{7}$ or $7\frac{1}{7}$ or AWRT 7.14. If t has been found in part (a) the working does not have to be repeated, but value of t must be stated. Do not follow through incorrect values of a.
(c)(i)	$58.8 = 70 \times 9.8 \sin\alpha$ $\sin\alpha = \frac{58.8}{70 \times 9.8} = 0.08571$ $\alpha = 4.92°$	M1A1F A1F	3	M1: Resolving parallel to the slope must see 70g or mg OE with sin α or cos α and their answer to part (b). A1F: Correct equation. Follow through their answer to part (b) provided sin α < 1 A1F: Correct angle. Follow through their answer to part (b). Accept 4.91° provided sin α < 1.
6(c)(ii)	$70 \times 9.8 \sin\alpha - 30 = 58.8$ $\sin\alpha = 0.12945$ $\alpha = 7.44°$	M1A1F A1F	3	M1: Three term equation of motion. must see 70g or mg OE with sin α or cos α. A1F: Correct equation. Follow through their answer to part (b) provided sin α < 1 A1F: Correct angle. Follow through their answer to part (b) provided sin α < 1. Accept 7.43°. Accept 7.41° from 0.129.
(d)	The air resistance force will increase (vary or change) with speed.	B1	1	B1: Correct statement.
	Total		**15**	