3.6 Mechanics: Forces and Newton's Laws Depth

EDEXCEL 9MA0 · Calculator allowed · about 230 minutes · Write-in edition

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Two forces, (3i + 4j) N and (1i - 2j) N, act on a particle. Find the resultant force, giving your answer in the form (π + qj) N.

(Total for Question 1 is 1 mark)

2 A block of mass 5 kg experiences a normal reaction of 39.2 N and a maximum friction force of 15.68 N. Find the coefficient of friction between the block and the surface.

(Total for Question 2 is 1 mark)

3 State the direction in which friction acts on a block that is on the point of sliding up a rough inclined plane.

(Total for Question 3 is 1 mark)

4 A particle A of mass 3 kg lies on a smooth horizontal table and is connected by a light inextensible string, passing over a smooth pulley, to a particle B hanging freely. Given that the acceleration of the system is 3.92 m/s^2, find the tension in the string by considering particle A alone.

(Total for Question 4 is 2 marks)

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5 A car of mass 1000 kg tows a trailer of mass 500 kg along a straight horizontal road using a light, rigid tow-bar. The driving force is 3500 N and the total resistance to motion is 500 N. Find the acceleration of the car and trailer.

(Total for Question 5 is 2 marks)

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6 A trailer of mass 500 kg is towed by a car via a light rigid tow-bar, with the system accelerating at 2 m/s^2. The only horizontal forces on the trailer are the tow-bar force and a resistance of 200 N. Find the force in the tow-bar.

(Total for Question 6 is 2 marks)

7 A particle P of mass 4 kg is in limiting equilibrium on a rough plane inclined at 22 degrees to the horizontal, under gravity alone. Find the friction force acting on P, giving your answer to 3 significant figures.

(Total for Question 7 is 2 marks)

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8 Using $\mu = \tan(\theta)$, find the coefficient of friction for a plane inclined at 30 degrees, giving your answer to 3 significant figures.

(Total for Question 8 is 1 mark)

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9 A block of mass 6 kg rests on rough horizontal ground and is on the point of sliding when a horizontal force of 18 N is applied. Take $g = 9.8$ m/s^2. Find the coefficient of friction between the block and the ground, giving your answer to 3 significant figures.

(Total for Question 9 is 2 marks)

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10 Two forces, $(5\mathbf{i} - \mathbf{j})$ N and $(-2\mathbf{i} + 4\mathbf{j})$ N, act on a particle of mass 0.5 kg which is initially at rest. Find the magnitude of the acceleration of the particle, giving your answer to 3 significant figures.

(Total for Question 10 is 2 marks)

11 A particle A of mass 3 kg lies on a smooth horizontal table and is connected by a light inextensible string, passing over a smooth pulley fixed at the edge of the table, to a particle B of mass 2 kg hanging freely. The system is released from rest with the string taut and B descends. Take $g = 9.8\ m/s^2$. Find the acceleration of the system.

(Total for Question 11 is 2 marks)

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12 Two forces, $(5i - 2j)$ N and $(-3i + 6j)$ N, act on a particle P of mass 0.8 kg which is initially at rest. Take i and j as horizontal and vertical unit vectors.

(a) Find the acceleration of P, giving your answer as a vector in terms of i and j. **(3)**

(b) Find the magnitude of the acceleration of P, giving your answer to 3 significant figures. **(2)**

(Total for Question 12 is 5 marks)

13 A block of mass 5 kg lies on rough horizontal ground. A horizontal force of magnitude 14 N is applied to the block, and the block is on the point of sliding. Take $g = 9.8$ m/s^2.

(a) Find the normal reaction between the block and the ground. **(1)**

(b) Hence find the coefficient of friction between the block and the ground, giving your answer to 3 significant figures. **(3)**

(Total for Question 13 is 4 marks)

14 A person of mass 70 kg stands on the floor of a lift that is moving downward and decelerating at 1.2 m/s^2. Take g = 9.8 m/s^2. Find the normal reaction force exerted on the person by the lift floor.

(Total for Question 14 is 2 marks)

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15 Two particles, P of mass 7 kg and Q of mass 4 kg, are connected by a light inextensible string which passes over a smooth fixed pulley. The particles hang freely on either side of the pulley and the system is released from rest with the string taut. Take g = 9.8 m/s^2.

(a) Find the acceleration of the system. **(4)**

(b) Find the tension in the string. **(2)**

(c) Find the magnitude of the force exerted on the pulley by the string. **(1)**

(Total for Question 15 is 7 marks)

16 A crate of mass 14 kg is pulled along rough horizontal ground by a light rope inclined at an angle θ above the horizontal, where $\sin\theta = 12/13$. The tension in the rope is 47 N. The coefficient of friction between the crate and the ground is 0.1. The crate is modelled as a particle. Take $g = 9.8\ m/s^2$.

(a) Find the normal reaction of the ground on the crate, to 3 significant figures. **(3)**

(b) Find the frictional force, and the acceleration of the crate, to 3 significant figures. **(4)**

(Total for Question 16 is 7 marks)

17 A car of mass 800 kg is towing a trailer of mass 600 kg along a straight horizontal road. The car and trailer are connected by a light horizontal tow bar. The engine of the car produces a driving force of 2400 N. The resistance to motion of the car is 200 N and the resistance to motion of the trailer is 200 N.

(a) Find the acceleration of the car and trailer, to 3 significant figures. **(3)**

(b) Find the tension in the tow bar, to 3 significant figures. **(3)**

(c) The tow bar breaks when the speed is 15 m/s. The driving force and the resistance on the car stay the same. Find the time taken for the trailer to stop, if its resistance remains 200 N, to 3 significant figures. **(3)**

(Total for Question 17 is 9 marks)

18 A crate of mass 3 kg is pulled along rough horizontal ground by a light rope inclined at an angle θ above the horizontal, where $\sin\theta = 8/17$. The tension in the rope is 21 N. The coefficient of friction between the crate and the ground is 0.25. The crate is modelled as a particle. Take $g = 9.8\ m/s^2$.

(a) Find the normal reaction of the ground on the crate, to 3 significant figures. **(3)**

(b) Find the frictional force, and the acceleration of the crate, to 3 significant figures. **(4)**

(Total for Question 18 is 7 marks)

19 A block of mass 12 kg is placed on a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 8/17$. The coefficient of friction between the block and the plane is 0.2. The block is modelled as a particle. Take $g = 9.8$ m/s^2.

(a) Find the normal reaction between the block and the plane. **(3)**

(b) Find the maximum friction force available, and determine whether the block remains at rest if it is released from rest. **(4)**

(c) Find the acceleration of the block down the plane, to 2 significant figures. **(2)**

(Total for Question 19 is 9 marks)

20 A crate of mass 4 kg is pulled along rough horizontal ground by a light rope inclined at an angle θ above the horizontal, where $\sin\theta = 7/25$. The tension in the rope is 53 N. The coefficient of friction between the crate and the ground is 0.25. The crate is modelled as a particle. Take $g = 9.8\ m/s^2$.

(a) Find the normal reaction of the ground on the crate, to 3 significant figures. **(3)**

(b) Find the frictional force, and the acceleration of the crate, to 3 significant figures. **(4)**

(Total for Question 20 is 7 marks)

21 A particle A of mass 4 kg lies on a rough horizontal table. It is attached to a particle B of mass 6 kg by a light inextensible string that passes over a smooth light pulley at the edge of the table. B hangs freely, and the system is released from rest with the string taut. The coefficient of friction between A and the table is 0.3. Take $g = 9.8$ m/s^2.

(a) Write down equations of motion for A and for B. **(3)**

(b) Hence find the acceleration of the system and the tension in the string, each to 2 significant figures. **(4)**

(c) B is 1.5 m above the floor when released. Find the speed of B as it reaches the floor, to 2 significant figures. **(2)**

(d) After B hits the floor it does not rebound, and A continues to move along the table. Find the further distance A travels before coming to rest, to 2 significant figures, assuming the table is long enough. **(3)**

(Total for Question 21 is 12 marks)

22 A particle A of mass 3 kg lies on a smooth horizontal table. A light inextensible string connects A to a particle B of mass 2 kg which hangs freely over a smooth pulley fixed at the edge of the table, with the part of the string between A and the pulley horizontal and the part between the pulley and B vertical. The system is released from rest with the string taut and B descends. Take $g = 9.8$ m/s^2.

(a) Show that the acceleration of the system is 3.92 m s^{-2}. **(4)**

(b) Find the tension in the string. **(2)**

(c) Find the magnitude of the force exerted on the pulley by the string. **(3)**

(Total for Question 22 is 9 marks)

23 A block of mass 10 kg is placed on a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 8/17$. The coefficient of friction between the block and the plane is 0.2. The block is modelled as a particle. Take $g = 9.8$ m/s^2.

(a) Find the normal reaction between the block and the plane. **(3)**

(b) Find the maximum friction force available, and determine whether the block remains at rest if it is released from rest. **(4)**

(c) Find the acceleration of the block down the plane, to 2 significant figures. **(2)**

(Total for Question 23 is 9 marks)

24 A block of mass 3 kg is placed on a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 3/5$. The coefficient of friction between the block and the plane is 0.25. The block is modelled as a particle. Take $g = 9.8$ m/s^2.

(a) Find the normal reaction between the block and the plane. **(3)**

(b) Find the maximum friction force available, and determine whether the block remains at rest if it is released from rest. **(4)**

(c) Find the acceleration of the block down the plane, to 2 significant figures. **(2)**

(Total for Question 24 is 9 marks)

25 A particle P rests in limiting equilibrium on a rough plane inclined at 25 degrees to the horizontal, under gravity alone (no other forces act on P).

(a) Find the coefficient of friction between P and the plane, giving your answer to 3 significant figures. **(4)**

(b) The plane is now tilted further so that it is inclined at 32 degrees to the horizontal, with P resting on the same rough surface (same coefficient of friction as in part (a)). Determine, with justification, whether P remains in equilibrium at this new angle, or whether it slides. **(3)**

(Total for Question 25 is 7 marks)

26 A person of mass 68 kg stands on the floor of a lift. The lift is moving downward and decelerating at a rate of 1.5 m s^{-2} as it comes to rest at a floor. Take g = 9.8 m/s^2.

(a) Find the magnitude of the normal reaction force exerted on the person by the lift floor while it is decelerating. **(4)**

(b) Hence find the magnitude of the force that the person exerts on the floor of the lift, stating the law used. **(2)**

(Total for Question 26 is 6 marks)

27 A block of mass 8 kg rests on rough horizontal ground. The coefficient of friction between the block and the ground is 0.3. A force of magnitude P acts on the block at an angle of 25 degrees above the horizontal, pulling it so that it is on the point of sliding. Take $g = 9.8$ m/s^2. Find the value of P, giving your answer to 3 significant figures.

(Total for Question 27 is 3 marks)

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28 A person of mass 75 kg stands on the floor of a lift. The lift is moving downward and decelerating at 2 m/s^2 as it comes to rest at a floor. Take $g = 9.8$ m/s^2. Find the magnitude of the normal reaction force exerted on the person by the lift floor while it is decelerating, and hence find the magnitude of the force that the person exerts on the floor, stating the law used.

(Total for Question 28 is 4 marks)

29 A particle of mass 2 kg is projected up a line of greatest slope of a rough plane inclined at 20 degrees to the horizontal, with initial speed 8 m s^{-1}. The coefficient of friction between the particle and the plane is 0.3. Take g = 9.8 m/s^2.

(a) Show that the deceleration of the particle while it moves up the plane is 6.11 m s^{-2}, correct to 3 significant figures. **(5)**

(b) Find the distance travelled by the particle up the plane before it comes to instantaneous rest. **(3)**

(c) Determine, with justification, whether the particle remains at rest at this point or slides back down the plane. **(2)**

(Total for Question 29 is 10 marks)

30 A car of mass 900 kg is towing a trailer of mass 300 kg along a straight horizontal road using a light, rigid tow-bar which is parallel to the road. The car's engine produces a constant driving force of 3000 N. As the car and trailer move, the resistance to motion of the car is 400 N and the resistance to motion of the trailer is 200 N. The car and trailer are modelled as particles.

(a) Find the acceleration of the car and trailer. **(3)**

(b) Find the tension in the tow-bar, stating whether the tow-bar is in tension or in thrust (compression). **(4)**

(c) The tow-bar suddenly breaks. Given that the driving force on the car and the resistance to the car remain unchanged, and the resistance to the trailer remains unchanged, find the acceleration of the car and the deceleration of the trailer immediately after the tow-bar breaks. **(4)**

(Total for Question 30 is 11 marks)

31 A particle P of mass 3 kg is held at rest on a rough plane inclined at 15 degrees to the horizontal. The coefficient of friction between P and the plane is 0.35. A force of magnitude 20 N acts on P at an angle of 10 degrees to the line of greatest slope, measured so that the force has a component up the plane and a component directed away from the plane (tending to lift P off the surface). P is released from rest and moves up the plane. Take $g = 9.8\ m/s^2$.

(a) Show that the normal reaction between P and the plane is $R = 3g\cos15 - 20\sin10$, and find its value to 3 significant figures. **(4)**

(b) Show that the acceleration of P up the plane is $1.12\ m\ s^{-2}$, correct to 3 significant figures. **(6)**

(c) Find the distance travelled by P up the plane, and its speed, after 2 seconds, assuming P remains on the plane throughout. **(3)**

(Total for Question 31 is 13 marks)

32 A block A of mass 5 kg lies on a rough plane inclined at 30 degrees to the horizontal. The coefficient of friction between A and the plane is 0.3. A light inextensible string is attached to A, passes over a small smooth pulley fixed at the top of the plane, and hangs vertically down to a block B of mass 7 kg, which hangs freely. The system is released from rest with the string taut, and B moves downward, pulling A up the plane. Take $g = 9.8$ m/s^2.

(a) Show that the acceleration of the system is 2.61 m s^{-2}, correct to 3 significant figures. **(6)**

(b) Find the tension in the string. **(2)**

(c) Given that B hits the ground after descending 0.8 m, and the string then becomes slack, find the further distance A travels up the plane before it comes to instantaneous rest, assuming A does not reach the pulley. **(5)**

(Total for Question 32 is 13 marks)

Mark scheme · 3.6 Mechanics: Forces and Newton's Laws Depth

Question 1

(4i + 2j) N cao **B1**

Answer: (4i + 2j) N

Question 2

0.4 cao **B1**

Answer: 0.4

Question 3

friction acts down the plane, opposing the impending motion **B1**

Answer: Down the plane (opposing the impending motion).

Question 4

equation of motion for A: T = 3a (the table is smooth, so tension is the only horizontal force) **M1**

11.76 N cao **A1**

Answer: 11.76 N

Question 5

whole-system equation: 3500 - 500 = 1500a **M1**

2 m/s^2 cao **A1**

Answer: 2 m/s^2

Question 6

equation of motion for the trailer: T - 200 = 500(2) **M1**

1200 N cao **A1**

Answer: 1200 N

Question 7

resolve parallel to the plane: friction = mg sin22 **M1**

awrt 14.7 N **A1**

Answer: 14.7 N (3 s.f.)

Question 8

awrt 0.577 **B1**

Answer: 0.577 (3 s.f.)

Question 9

R = mg = 58.8, μ = 18/58.8 **M1**

awrt 0.306 **A1**

Answer: 0.306 (3 s.f.)

Question 10

resultant force = (3i + 3j) N, then a = resultant/mass = (6i + 6j) m/s^2 **M1**

awrt 8.49 m/s^2 **A1**

Answer: 8.49 m/s^2 (3 s.f.)

Question 11

whole-system equation: 2g = (3+2)a **M1**

3.92 m/s^2 cao **A1**

Answer: 3.92 m/s^2

Question 12

(a) finds the resultant force (5-3)i + (-2+6)j = 2i + 4j (N) (oe) **M1**

(a) uses Newton's second law a = F/m **M1**

(a) a = 2.5i + 5j (m s^{-2}) cao **A1**

(a) Answer: a = 2.5i + 5j (m s^{-2})

(b) uses Pythagoras' theorem on their a: $\sqrt{2.5^2 + 5^2}$ **M1**

(b) awrt 5.59 (m s^{-2}) **A1**

(b) Answer: 5.59 m s^{-2} (3sf)

Question 13

(a) R = mg = 49 (N) cao **B1**

(a) Answer: R = 49 N

(b) uses F = μ R with F = 14 (at limiting equilibrium) and their R **M1**

(b) μ = 14/49 oe **A1**

(b) awrt 0.286 **A1**

(b) Answer: μ = 2/7 = 0.286 (3sf)

Question 14

decelerating while moving down means the acceleration is upward: R - mg = ma with a=+1.2 **M1**

770 N cao **A1**

Answer: 770 N

Question 15

(a) equation of motion for P (down positive): 7g - T = 7a (oe) **M1**

(a) equation of motion for Q (up positive): T - 4g = 4a (oe) **M1**

(a) adds the two equations to eliminate T **M1**

(a) a = awrt 2.67 (m s^{-2}) **A1**

(a) Answer: a = 2.67 m s^{-2} (3sf)

(b) substitutes their a into either equation of motion **M1**

(b) awrt 49.9 (N) **A1**

(b) Answer: T = 49.9 N (3sf)

(c) force on pulley = 2T = awrt 99.8 (N) ft **B1**

(c) Answer: 99.8 N (3sf)

Question 16

(a) resolves vertically: R + T sin θ = mg **M1**

(a) R = 14 x 9.8 - 47 x 12/13 **A1**

(a) R = 93.8 N **A1**

(a) Answer: 93.8 N

(b) F = μ R **M1**

(b) F = 9.38 N **A1**

(b) resolves horizontally: T cos θ - F = 14a **M1**

(b) a = 0.621 m/s^2 **A1**

(b) Answer: F = 9.38 N, a = 0.621 m/s^2

Question 17

(a) applies F = ma to the whole system **M1**

(a) 2400 - 200 - 200 = 1400a **A1**

(a) a = 1.43 m/s^2 **A1**

(a) Answer: 1.43 m/s^2

(b) applies F = ma to the trailer alone **M1**

(b) T - 200 = 600 x 1.4286 **A1**

(b) T = 1060 N **A1**

(b) Answer: 1060 N

(c) deceleration of the trailer = 200/600 **M1**

(c) uses v = u + at with v = 0 **M1**

(c) t = 45.0 s **A1**

(c) Answer: 45.0 s

Question 18

(a) resolves vertically: R + T sin θ = mg **M1**

(a) R = 3 x 9.8 - 21 x 8/17 **A1**

(a) R = 19.5 N **A1**

(a) Answer: 19.5 N

(b) F = μ R **M1**

(b) F = 4.88 N **A1**

(b) resolves horizontally: T cos θ - F = 3a **M1**

(b) a = 4.55 m/s^2 **A1**

(b) Answer: F = 4.88 N, a = 4.55 m/s^2

Question 19

(a) resolves perpendicular to the plane: R = mg cos α **M1**

(a) cos α = 15/17 **A1**

(a) R = 104 N **A1**

(a) Answer: 104 N

(b) F_{max} = μ R **M1**

(b) F_{max} = 20.8 N **A1**

(b) compares with the component of weight down the plane: mg sin α **M1**

(b) 55.3 N is greater than 20.8 N, so the block slides down **A1**

(b) Answer: slides down the plane

(c) F = ma down the plane: mg sin α - μ R = ma **M1**

(c) a = 2.9 m/s^2 **A1**

(c) Answer: 2.9 m/s^2

Question 20

(a) resolves vertically: R + T sin θ = mg **M1**

(a) R = 4 x 9.8 - 53 x 7/25 **A1**

(a) R = 24.4 N **A1**

(a) Answer: 24.4 N

(b) F = μ R **M1**

(b) F = 6.09 N **A1**

(b) resolves horizontally: T cos θ - F = 4a **M1**

(b) a = 11.2 m/s^2 **A1**

(b) Answer: F = 6.09 N, a = 11.2 m/s^2

Question 21

(a) for B: 6g - T = 6a **M1**

(a) for A: T - F = 4a with F = 0.3 x 4g **M1**

(a) both equations correct **A1**

(a) Answer: B: 6g - T = 6a; A: T - 0.3 x 4g = 4a

(b) adds the two equations to eliminate T **M1**

(b) a = 4.7 m/s^2 **A1**

(b) substitutes to find T = 6(g - a) **M1**

(b) T = 31 N **A1**

(b) Answer: a = 4.7 m/s^2, T = 31 N

(c) uses v^2 = u^2 + 2as with u = 0, a = 4.704, s = 1.5 **M1**

(c) v = 3.8 m/s **A1**

(c) Answer: 3.8 m/s

(d) deceleration of A is μ g **M1**

(d) uses v^2 = u^2 + 2as with final speed zero: 0 = 3.757^2 - 2(2.940)s **M1**

(d) s = 2.4 m **A1**

(d) Answer: 2.4 m

Question 22

(a) equation of motion for A: T = 3a (oe) **M1**

(a) equation of motion for B: 2g - T = 2a (oe) **M1**

(a) adds the two equations to eliminate T, dependent on both previous M marks: 2g = 5a **dM1**

(a) a = 3.92 (m s^{-2}) cso **A1**

(a) Answer: a = 3.92 m s^{-2} (shown)

(b) substitutes a = 3.92 into either equation of motion **M1**

(b) T = 11.76 (N) cao **A1**

(b) Answer: T = 11.76 N

(c) recognises the two sections of string at the pulley act at right angles (one horizontal, one vertical), each with tension T **M1**

(c) uses Pythagoras to find the resultant force on the pulley = T*$\sqrt{2}$ **M1**

(c) awrt 16.6 (N) **A1**

(c) Answer: 16.6 N (3sf)

Question 23

(a) resolves perpendicular to the plane: R = mg cos α **M1**

(a) cos α = 15/17 **A1**

(a) R = 86.5 N **A1**

(a) Answer: 86.5 N

(b) F_{max} = μ R **M1**

(b) F_{max} = 17.3 N **A1**

(b) compares with the component of weight down the plane: mg sin α **M1**

(b) 46.1 N is greater than 17.3 N, so the block slides down **A1**

(b) Answer: slides down the plane

(c) F = ma down the plane: mg sin α - μ R = ma **M1**

(c) a = 2.9 m/s^2 **A1**

(c) Answer: 2.9 m/s^2

Question 24

(a) resolves perpendicular to the plane: R = mg cos α **M1**

(a) cos α = 4/5 **A1**

(a) R = 23.5 N **A1**

(a) Answer: 23.5 N

(b) F_{max} = μ R **M1**

(b) F_{max} = 5.88 N **A1**

(b) compares with the component of weight down the plane: mg sin α **M1**

(b) 17.6 N is greater than 5.88 N, so the block slides down **A1**

(b) Answer: slides down the plane

(c) F = ma down the plane: mg sin α - μ R = ma **M1**

(c) a = 3.9 m/s^2 **A1**

(c) Answer: 3.9 m/s^2

Question 25

(a) resolves perpendicular to the plane: R = mg cos25 (oe) **M1**

(a) resolves along the plane using limiting friction: mg sin25 = μ R (oe) **M1**

(a) combines to form μ = tan25 (oe) **M1**

(a) μ = awrt 0.466 **A1**

(a) Answer: μ = 0.466 (3sf)

(b) calculates tan32 = awrt 0.625 **M1**

(b) compares their μ (0.466) with tan32 (0.625) **M1**

(b) correct conclusion with reason: since μ < tan32, the friction available is insufficient to hold P in equilibrium, so P slides down the plane **A1**

(b) Answer: P slides down the plane, since μ (0.466) < tan32 (0.625)

Question 26

(a) identifies that the lift's acceleration is directed upward (since it decelerates while moving downward), magnitude 1.5 (m s^{-2}) **M1**

(a) equation of motion for the person (up positive): R - mg = ma (oe) **M1**

(a) substitutes R = m(g + a) **M1**

(a) R = 768.4 (N) cao **A1**

(a) Answer: R = 768.4 N

(b) states Newton's third law: the force exerted by the person on the floor is equal in magnitude and opposite in direction to the force exerted by the floor on the person **B1**

(b) 768.4 (N) ft, directed downward **B1**

(b) Answer: 768.4 N (downward), by Newton's third law

Question 27

resolve vertically: R = mg - P sin25 **M1**

resolve horizontally at limiting equilibrium: P cos25 = μ R, substitute and solve for P **M1**

awrt 22.8 N **A1**

Answer: 22.8 N (3 s.f.)

Question 28

decelerating downward motion means acceleration is upward: R - mg = ma with a=+2 **M1**

R = 885 N cao **A1**

invoke Newton's third law **B1**

force on floor = 885 N (equal magnitude, opposite direction to the force on the person) **A1**

Answer: R = 885 N; by Newton's third law, the person pushes on the floor with a force of 885 N

Question 29

(a) resolves perpendicular to the plane: R = 2g cos20 (oe) **M1**

(a) finds friction F = μ R = 0.3 * 2g cos20 (oe) **M1**

(a) resolves along the plane (up positive): -2g sin20 - F = 2a (oe) **M1**

(a) recognises mass cancels and rearranges to a = -g(sin20 + 0.3cos20), dependent on all previous M marks **dM1**

(a) deceleration = awrt 6.11 (m s^{-2}) cso **A1**

(a) Answer: deceleration = 6.11 m s^{-2} (shown)

(b) uses $v^2 = u^2 + 2as$ with v = 0, u = 8, and their a from (a) **M1**

(b) rearranges to make s the subject **M1**

(b) awrt 5.23 (m) (allow awrt 5.24 if 6.11 is used from (a)) **A1**

(b) Answer: 5.23 m (3sf)

(c) compares μ (0.3) with tan20 (awrt 0.364) **M1**

(c) correct conclusion: since μ < tan20, the particle cannot remain at rest and slides back down the plane **A1**

(c) Answer: The particle slides back down the plane, since μ (0.3) < tan20 (0.364)

Question 30

(a) total resistance = 600 (N) **B1**

(a) equation of motion for the whole system: 3000 - 600 = 1200a (oe) **M1**

(a) a = 2 (m s^{-2}) cao **A1**

(a) Answer: a = 2 m s^{-2}

(b) isolates the trailer: T - 200 = 300a (oe) **M1**

(b) substitutes a = 2 (ft from (a)) **M1**

(b) T = 800 (N) cao **A1**

(b) states the tow-bar is in tension, since T > 0 (the tow-bar must pull the trailer forward) **B1**

(b) Answer: T = 800 N; the tow-bar is in tension

(c) equation of motion for the car alone: 3000 - 400 = 900 a_{car} (oe) **M1**

(c) a_{car} = awrt 2.89 (m s^{-2}) **A1**

(c) equation of motion for the trailer alone: -200 = 300 a_trailer (oe) **M1**

(c) trailer decelerates at awrt 0.667 (m s^{-2}) **A1**

(c) Answer: car accelerates at awrt 2.89 m s^{-2}; trailer decelerates at awrt 0.667 m s^{-2}

Question 31

(a) resolves perpendicular to the plane with all relevant terms present: R + 20sin10 = 3g cos15 (oe)	**M1**
(a) R = 3g cos15 - 20 sin10 cso	**A1**
(a) substitutes numerical values	**M1**
(a) awrt 24.9 (N)	**A1**

(a) Answer: R = 3g cos15 - 20sin10 (shown); R = awrt 24.9 N

(b) resolves along the plane with all relevant terms: 20cos10 - 3g sin15 - F = 3a (oe)	**M1**
(b) uses F = μ R with their R from (a), ft	**M1**
(b) forms the full equation of motion combining all terms correctly	**M1**
(b) substitutes numerical values, dependent on all previous M marks	**dM1**
(b) unsimplified numeric value, e.g. a = 3.363/3	**A1**
(b) a = awrt 1.12 (m s^{-2}) cso	**A1**

(b) Answer: a = 1.12 m s^{-2} (shown)

(c) uses v = u + at and s = ut + 0.5at^2 (or equivalent) with their a from (b), u = 0, t = 2	**M1**
(c) v = awrt 2.24 (m s^{-1})	**A1**
(c) s = awrt 2.24 (m) ft	**A1**

(c) Answer: v = awrt 2.24 m s^{-1}; s = awrt 2.24 m

Question 32

(a) resolves perpendicular to the plane for A: R = 5g cos30 (oe)	**M1**
(a) finds friction F = 0.3 * 5g cos30 (oe)	**M1**
(a) equation of motion for A (up the plane positive): T - 5g sin30 - F = 5a (oe)	**M1**
(a) equation of motion for B (down positive): 7g - T = 7a (oe)	**M1**
(a) adds the two equations to eliminate T, dependent on all previous M marks	**dM1**
(a) a = awrt 2.61 (m s^{-2}) cso	**A1**

(a) Answer: a = 2.61 m s^{-2} (shown)

(b) substitutes their a into either equation of motion	**M1**
(b) T = awrt 50.3 (N)	**A1**

(b) Answer: T = 50.3 N (3sf)

(c) uses $v^2 = u^2 + 2as$ with u = 0, s = 0.8, and their a from (a) to find the common speed when the string becomes slack	**M1**
(c) finds the new deceleration of A once the string is slack: a2 = g(sin30 + 0.3cos30) (oe), mass cancels	**M1**
(c) a2 = awrt 7.45 (m s^{-2})	**A1**
(c) uses $v^2 = u^2 - 2(a2)d$ with their v and a2 to find the further distance d	**M1**
(c) awrt 0.281 (m) ft	**A1**

(c) Answer: further distance = 0.281 m (3sf)