3.2 Mechanics: Forces and Newton's Laws

EDEXCEL 9MA0 · Calculator allowed · about 235 minutes · Write-in edition

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A particle of mass 3 kg hangs in equilibrium, suspended from a fixed point by a light inextensible string. Take $g = 9.8$ m/s^2. Find the tension in the string.

(Total for Question 1 is 1 mark)

2 A resultant force of 12 N acts on a particle of mass 3 kg. Find the acceleration of the particle.

(Total for Question 2 is 1 mark)

3 A particle of mass 2 kg rests in equilibrium on a horizontal table. Take $g = 9.8$ m/s^2. Find the normal reaction between the particle and the table.

(Total for Question 3 is 1 mark)

4 Two forces, of magnitude 8 N and 5 N, act on a particle in the same direction along a straight line. Find the magnitude of the resultant force.

(Total for Question 4 is 1 mark)

---

5 State Newton's third law of motion.

(Total for Question 5 is 1 mark)

---

6 State what is meant by modelling a surface in mechanics as "smooth".

(Total for Question 6 is 1 mark)

---

7 A resultant force of 15 N acting on a particle produces an acceleration of 2.5 m/s^2. Find the mass of the particle.

(Total for Question 7 is 1 mark)

---

8 A parcel has mass 12 kg. Take $g = 9.8\ m/s^2$. Find the weight of the parcel.

(Total for Question 8 is 1 mark)

9 Two forces, of magnitude 17 N and 6 N, act on a particle in opposite directions along the same straight line. Find the magnitude of the resultant force.

(Total for Question 9 is 1 mark)

10 A car of mass 1000 kg experiences a driving force of 2400 N and a constant resistance force of 400 N as it moves along a straight horizontal road. Find the acceleration of the car.

(Total for Question 10 is 2 marks)

11 A box of mass 6 kg is pushed along smooth horizontal ground by a horizontal force of 18 N. Find the acceleration of the box.

(Total for Question 11 is 2 marks)

12 Two forces of magnitude 20 N and 8 N act on a particle of mass 3 kg in opposite directions along the same straight line. Find the acceleration of the particle.

(Total for Question 12 is 2 marks)

13 A block of mass 5 kg rests on rough horizontal ground. The coefficient of friction between the block and the ground is 0.2. Take $g = 9.8\ m/s^2$. Find the maximum possible friction force before the block slips.

(Total for Question 13 is 2 marks)

---

14 Two forces, F1 = (3i - 2j) N and F2 = (-1i + 5j) N, act on a particle, where i and j are perpendicular unit vectors. Find the resultant force acting on the particle, giving your answer in the form (ai + bj) N.

(Total for Question 14 is 1 mark)

---

15 Two forces act on a particle at right angles to each other, of magnitude 9 N and 12 N. Find the magnitude of the resultant force.

(Total for Question 15 is 2 marks)

16 A block of mass 5 kg rests on rough horizontal ground. The maximum frictional force before the block slips is found to be 14.7 N. Take $g = 9.8$ m/s^2. Find the coefficient of friction between the block and the ground.

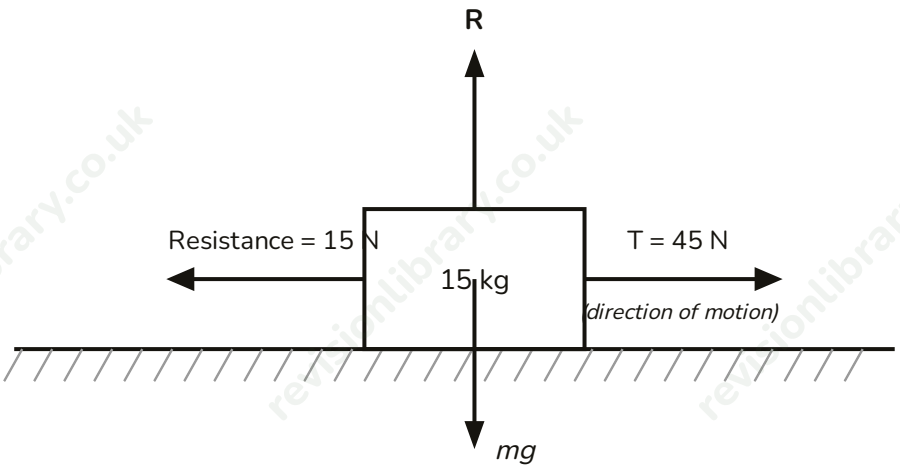
(Total for Question 16 is 2 marks)

---

17 A block of mass 10 kg rests on rough horizontal ground. The coefficient of friction between the block and the ground is 0.5. A horizontal force of magnitude 35 N is applied to the block, which remains in equilibrium. Take $g = 9.8$ m/s^2. Find the frictional force acting on the block.

(Total for Question 17 is 2 marks)

18 A box of mass 15 kg is pulled in a straight line along rough horizontal ground by a light rope which is horizontal, attached to the box with tension 45 N. The resistance to motion from the ground is modelled as a constant force of 15 N. The box is modelled as a particle. Take $g = 9.8$ m/s^2.



(a) State the four forces acting on the box while it is moving. **(2)**

(b) Use Newton's second law to find the acceleration of the box. **(3)**

(c) Find the magnitude of the normal reaction between the box and the ground. **(2)**

(d) Given that the box starts from rest, find the distance it travels in the first 6 seconds of motion. **(3)**

(Total for Question 18 is 10 marks)

19 A block of mass 12 kg is placed on a rough plane inclined at an angle α to the horizontal, where $\sin \alpha = 3/5$. 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 particle A of mass 5 kg lies on a rough horizontal table. It is attached to a particle B of mass 4 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 0.2. Take $g = 9.8$ m/s^2.

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

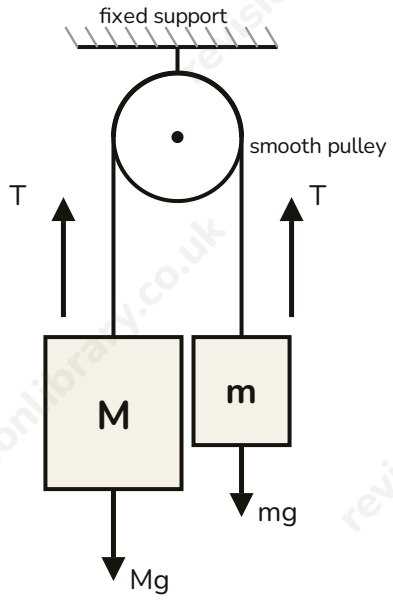
(b) Hence find the acceleration of the system and the tension in the string, each to 2 significant figures. **(4)**

(c) B is 1.0 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 20 is 12 marks)

21 Two particles, of mass M kg and m kg (M > m), 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 are released from rest. Take $g = 9.8\ m/s^2$.



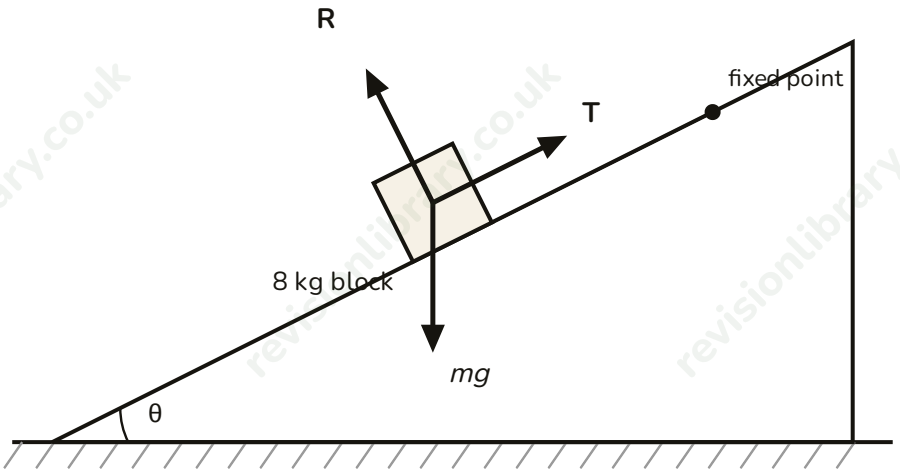
(a) By writing separate equations of motion for each particle, show that the acceleration of the system is $a = g(M - m)/(M + m)$. **(4)**

(b) Given that M = 5 kg and m = 3 kg, find the acceleration of the system and the tension in the string. **(4)**

(c) State two modelling assumptions used in this problem, and explain the effect on the acceleration if the pulley were not smooth. **(2)**

(Total for Question 21 is 10 marks)

22 A block of mass 8 kg rests in equilibrium on a smooth plane inclined at angle θ to the horizontal, held by a light inextensible string parallel to the line of greatest slope, attached to a fixed point higher up the plane. Take $g = 9.8$ m/s^2.



(a) Given that θ = 20 degrees, find the tension in the string. **(3)**

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

(c) The plane is replaced by one inclined at 35 degrees (all else unchanged). Find the new tension in the string. **(2)**

(d) Explain why the normal reaction decreases as the angle of the incline increases. **(2)**

(Total for Question 22 is 10 marks)

---

23 Two blocks A (mass 4 kg) and B (mass 2 kg) are connected by a light inextensible string and lie on smooth horizontal ground. A horizontal force of 18 N pulls block A, with B connected behind it, so both move with the same acceleration. Find the acceleration of the system.

(Total for Question 23 is 2 marks)

---

24 Two blocks connected by a light inextensible string move with acceleration 3 m/s^2. Block B, of mass 2 kg, has no horizontal force acting on it other than the tension in the string. Find the tension in the string.

(Total for Question 24 is 2 marks)

25 A block of mass 10 kg rests in equilibrium on a smooth plane inclined at 25 degrees to the horizontal, held by a light inextensible string parallel to the line of greatest slope. Take g = 9.8 m/s^2. Find the tension in the string, giving your answer to 3 significant figures.

(Total for Question 25 is 2 marks)

---

26 A block of mass 6 kg rests in equilibrium on a smooth plane inclined at 40 degrees to the horizontal, held by a light inextensible string parallel to the line of greatest slope. Take g = 9.8 m/s^2. Find the normal reaction between the block and the plane, giving your answer to 3 significant figures.

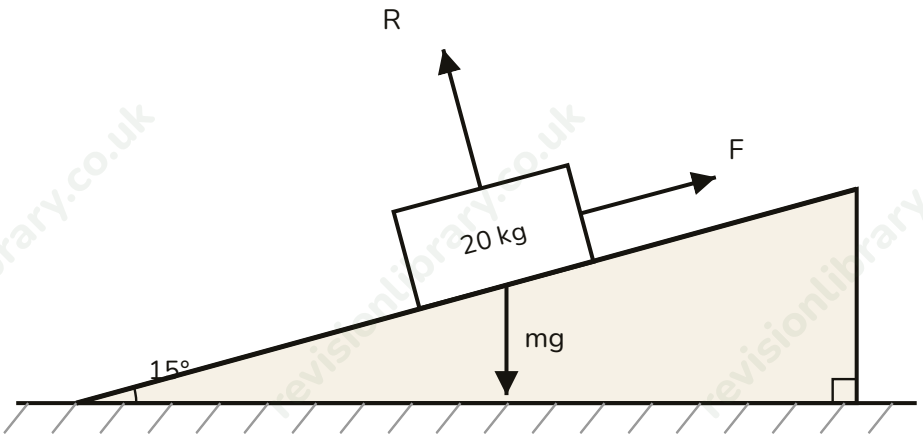
(Total for Question 26 is 2 marks)

---

27 A crate of mass 8 kg is pulled along smooth horizontal ground by a force of magnitude 25 N acting at 40 degrees above the horizontal. Find the acceleration of the crate, giving your answer to 3 significant figures.

(Total for Question 27 is 3 marks)

28 A crate of mass 20 kg rests on a rough plane inclined at 15 degrees to the horizontal. The coefficient of friction between the crate and the plane is 0.35. The crate is modelled as a particle. Take $g = 9.8\ m/s^2$.



(a) Show that the crate remains in equilibrium on the plane. **(3)**

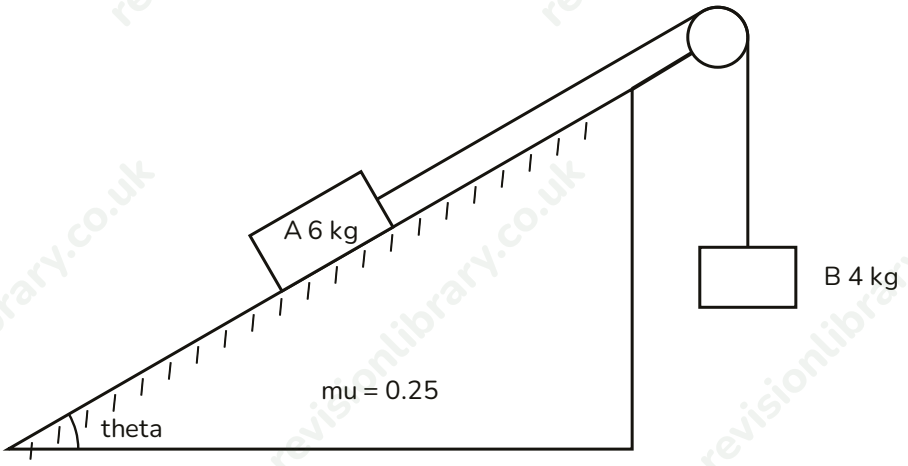
(b) Find the magnitude of the friction force acting on the crate while it is at rest. **(2)**

(c) A force P is now applied to the crate, parallel to and directed up the line of greatest slope. Find the minimum value of P required to move the crate up the plane. **(4)**

(d) State one assumption made about the crate in this model. **(1)**

(Total for Question 28 is 10 marks)

29 Particle A, of mass 6 kg, lies on a rough plane inclined at angle θ to the horizontal. A is connected by a light inextensible string, passing over a smooth light pulley fixed at the top of the plane, to particle B, of mass 4 kg, which hangs freely below the pulley. The coefficient of friction between A and the plane is 0.25. The system is released from rest. Take $g = 9.8$ m/s^2.



(a) Given that θ = 30 degrees, show that the system remains in equilibrium. **(4)**

(b) The plane is instead inclined at 60 degrees (all else unchanged). Show that the system does not remain in equilibrium, and find the resulting acceleration of the system. **(6)**

(Total for Question 29 is 10 marks)

30 A particle P of mass 2 kg moves on a smooth horizontal plane under the action of two constant forces, F1 = (3i + 5j) N and F2 = (-i + 2j) N, where i and j are perpendicular unit vectors in the plane. The weight of P and the normal reaction from the plane are not considered further, as they act perpendicular to the plane of motion.

(a) Find the resultant force acting on P, giving your answer in the form (π + qj) N. **(2)**

(b) Find the acceleration of P, in the form (π + qj) m/s^2. **(2)**

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

(d) Given that P starts at rest, find the speed of P after 4 seconds, giving your answer to 3 significant figures. **(3)**

(e) Find, to the nearest degree, the angle the direction of motion after 4 seconds makes with the vector i. **(2)**

.....

(Total for Question 30 is 11 marks)

---

31 A particle of mass 4 kg is pulled along rough horizontal ground by a horizontal force of 30 N. The resistance to motion is modelled as a constant frictional force of magnitude 0.25 times the normal reaction between the particle and the ground. Take $g = 9.8$ m/s^2. Find the acceleration of the particle.

(Total for Question 31 is 3 marks)

---

32 Particles A and B, of mass 6 kg and 2 kg respectively, are connected by a light inextensible string which passes over a smooth fixed pulley. The particles hang at rest on either side of the pulley and are released from rest. Take $g = 9.8$ m/s^2. Find the acceleration of the system and the tension in the string.

(Total for Question 32 is 4 marks)

33 A student attempts to find the tension in the cable of a lift of mass 900 kg accelerating upwards at 0.5 m/s^2. Take $g = 9.8\ m/s^2$. The student's working is shown below, but the final answer is incorrect.

$T - mg = ma$
$T = m(g - a)$
$T = 900 \times (9.8 - 0.5)$
$T = 8370$

(a) Identify the error in the student's working. **(1)**

(b) Find the correct value of the tension. **(1)**

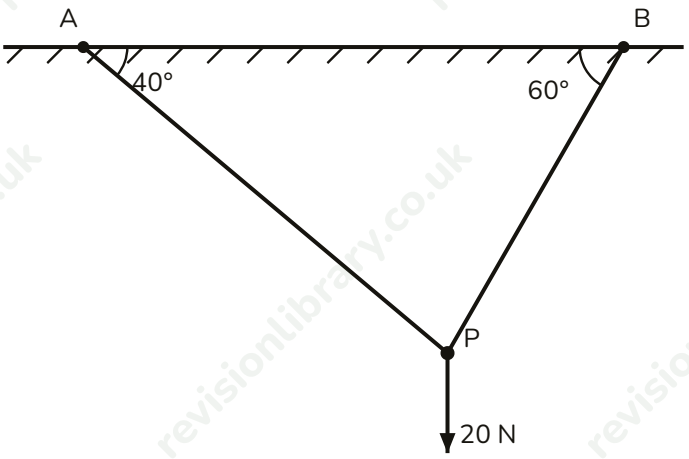
(Total for Question 33 is 2 marks)

---

34 A box of mass 6 kg is pulled along rough horizontal ground by a force of magnitude 40 N acting at 25 degrees above the horizontal. The coefficient of friction between the box and the ground is 0.3. Take $g = 9.8\ m/s^2$. Find the acceleration of the box, giving your answer to 3 significant figures.

(Total for Question 34 is 4 marks)

35 A particle P, of weight 20 N, hangs in equilibrium, held by two light inextensible strings attached to a fixed horizontal ceiling, as shown in the diagram. String PA makes an angle of 40 degrees with the horizontal ceiling and string PB makes an angle of 60 degrees with the horizontal ceiling, on the opposite side of P.

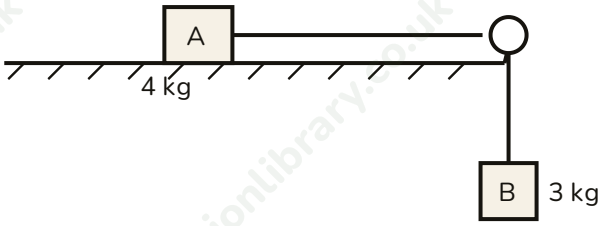


(a) Find the tension in string PA, giving your answer to 3 significant figures. **(2)**

(b) Find the tension in string PB, giving your answer to 3 significant figures. **(2)**

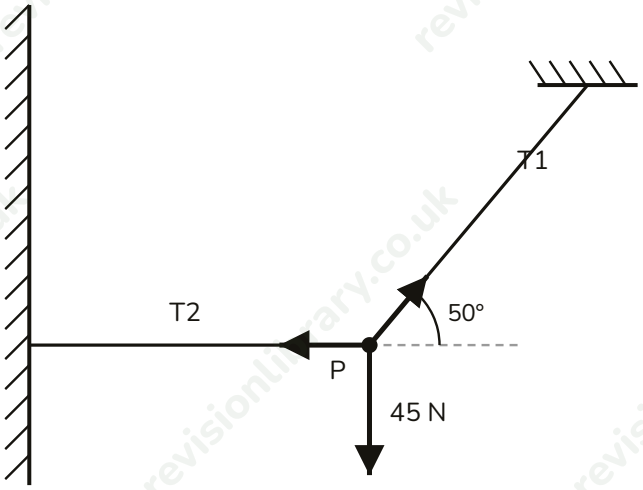
(Total for Question 35 is 4 marks)

36 Particle A, of mass 4 kg, lies on a rough horizontal table. The coefficient of friction between A and the table is 0.2. A light inextensible string attached to A passes over a smooth pulley fixed at the edge of the table and hangs vertically, carrying particle B, of mass 3 kg, freely at its other end, as shown in the diagram. The system is released from rest. Take $g = 9.8\ m/s^2$. Find the acceleration of the system and the tension in the string.



(Total for Question 36 is 3 marks)

37 A particle P of weight 45 N is held in equilibrium by two light inextensible strings. One string is inclined at 50 degrees to the horizontal and is attached to a fixed point above and to one side of P; the other string is horizontal, attached to a fixed point on a wall.



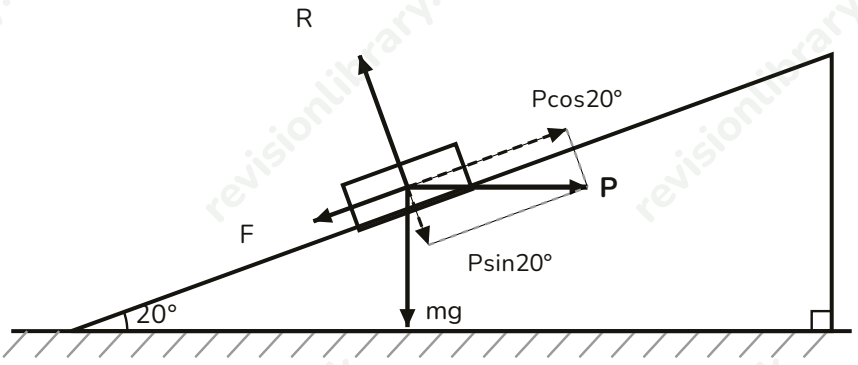
(a) Find the tension T1 in the inclined string. **(3)**

(b) Find the tension T2 in the horizontal string. **(3)**

(c) The horizontal string is cut. Find the angle the remaining string now makes with the horizontal, and the new tension in it, for P to hang in equilibrium. **(3)**

(Total for Question 37 is 9 marks)

38 A block of mass 10 kg rests on a rough plane inclined at 20 degrees to the horizontal. The coefficient of friction between the block and the plane is 0.4. A horizontal force of magnitude P newtons is applied to the block, directed into the slope, so that it has a component acting up the line of greatest slope. Take $g = 9.8$ m/s^2.

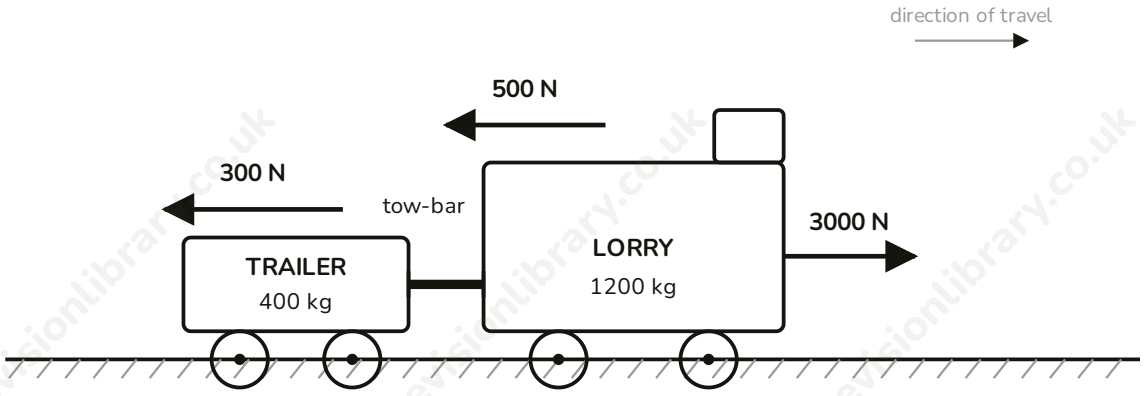


(a) Given that $P = 0$, show that the block remains in equilibrium. **(3)**

(b) Find, to 3 significant figures, the minimum value of P required to move the block up the plane. **(6)**

(Total for Question 38 is 9 marks)

39 A lorry of mass 1200 kg tows a trailer of mass 400 kg along a straight horizontal road, connected by a light rigid horizontal tow-bar. The lorry's engine produces a driving force of 3000 N. The resistances to motion are 500 N on the lorry and 300 N on the trailer. Both vehicles are modelled as particles, and the tow-bar as a light rod. Take $g = 9.8$ m/s^2 (not required numerically in this question).



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

(b) Find the force in the tow-bar, stating whether it is a tension or a thrust. **(3)**

(c) The engine is switched off while both vehicles are moving, so the driving force becomes zero; the resistances are unchanged. Find the new deceleration of the system and the new force in the tow-bar, stating whether it is a tension or a thrust. **(4)**

(d) State an assumption made about the tow-bar in this model, and explain why it allows the lorry and trailer to have the same acceleration. **(2)**

(Total for Question 39 is 12 marks)

40 A block of mass 8 kg rests on a rough plane inclined at 30 degrees to the horizontal. The coefficient of friction between the block and the plane is 0.3. A force P, acting parallel to the plane and directed up the line of greatest slope, is applied to the block so that it is on the point of sliding up the plane. Take $g = 9.8\ m/s^2$. Find the value of P, giving your answer to 3 significant figures.

(Total for Question 40 is 4 marks)

---

41 A particle P of mass 4 kg moves on a smooth horizontal plane under the action of two constant forces, F1 = (5i - 2j) N and F2 = (1i + 6j) N, where i and j are perpendicular unit vectors in the plane. Given that P starts at rest, find the speed of P after 3 seconds, giving your answer to 3 significant figures.

(Total for Question 41 is 4 marks)

42 A car of mass 1200 kg tows a trailer of mass 400 kg along a straight horizontal road using a light rigid tow-bar. The car's engine provides a driving force of 2800 N. The resistance to the motion of the car is 300 N and the resistance to the motion of the trailer is 100 N.

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

(b) Find the tension in the tow-bar. **(2)**

(Total for Question 42 is 5 marks)

43 A particle Q, of mass 2 kg, moves on a smooth horizontal plane under the action of three constant forces, F1 = (3i - 5j) N, F2 = (-1i + 2j) N and F3 = (4i + 1j) N, where i and j are perpendicular unit vectors in the plane. Given that Q starts at rest, find the speed of Q after 5 seconds, giving your answer to 3 significant figures.

(Total for Question 43 is 4 marks)

Mark scheme · 3.2 Mechanics: Forces and Newton's Laws

Question 1

29.4 cao **B1**

Answer: 29.4 N

Question 2

4 cao **B1**

Answer: 4 m/s^2

Question 3

19.6 cao **B1**

Answer: 19.6 N

Question 4

13 cao **B1**

Answer: 13 N

Question 5

if body A exerts a force on body B, then body B exerts a force of the same magnitude but in the opposite direction on body A (oe) **B1**

Answer: If A exerts a force on B, then B exerts an equal and opposite force on A.

Question 6

it exerts no friction (the frictional force is negligible / zero) (oe) **B1**

Answer: It exerts no frictional force (friction is negligible).

Question 7

6 cao **B1**

Answer: 6 kg

Question 8

117.6 cao **B1**

Answer: 117.6 N

Question 9

11 cao **B1**

Answer: 11 N

Question 10

resultant force = 2400 - 400 = 2000, then a = 2000/1000 **M1**

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

Answer: 2 m/s^2

Question 11

use F = ma with F=18, m=6 **M1**

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

Answer: 3 m/s^2

Question 12

resultant force = 20 - 8 = 12 N **M1**

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

Answer: 4 m/s^2

Question 13

friction = μ R with R = mg = 5(9.8) = 49 **M1**

9.8 N cao **A1**

Answer: 9.8 N

Question 14

(2i + 3j) cao **B1**

Answer: (2i + 3j) N

Question 15

use of Pythagoras: R^2 = 9^2 + 12^2 (oe) **M1**

15 cao **A1**

Answer: 15 N

Question 16

R = mg = 5(9.8) = 49, then μ = F/R (oe) **M1**

0.3 cao **A1**

Answer: 0.3

Question 17

recognise the block remains in equilibrium, so friction balances the applied force (not μ R) (oe) **M1**

35 cao **A1**

Answer: 35 N

Question 18

(a) weight (mg, vertically down) and normal reaction (R, vertically up) identified **B1**

(a) tension (T = 45 N, horizontal, direction of motion) and resistance (15 N, opposing motion) identified **B1**

(a) Answer: Weight, normal reaction, tension (45 N), resistance (15 N)

(b) resolving horizontally: 45 - 15 = 15a (oe) **M1**

(b) net force = 30 N found **A1**

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

(b) Answer: a = 2 m/s^2

(c) resolving vertically: R = mg (since rope is horizontal) **M1**

(c) R = 147 N cao **A1**

(c) Answer: R = 147 N

(d) correct suvat selected, s = ut + 1/2 a t^2 with u = 0, a = 2, t = 6 **M1**

(d) correct substitution s = 0.5 x 2 x 36 (oe) **A1**

(d) s = 36 m cao **A1**

(d) Answer: 36 m

Question 19

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

(a) cos α = 4/5 **A1**

(a) R = 94.1 N **A1**

(a) Answer: 94.1 N

(b) F_{max} = μ R **M1**

(b) F_{max} = 18.8 N **A1**

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

(b) 70.6 N is greater than 18.8 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 = 4.3 m/s^2 **A1**

(c) Answer: 4.3 m/s^2

Question 20

(a) for B: 4g - T = 4a **M1**

(a) for A: T - F = 5a with F = 0.2 x 5g **M1**

(a) both equations correct **A1**

(a) Answer: B: 4g - T = 4a; A: T - 0.2 x 5g = 5a

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

(b) a = 3.3 m/s^2 **A1**

(b) substitutes to find T = 4(g - a) **M1**

(b) T = 26 N **A1**

(b) Answer: a = 3.3 m/s^2, T = 26 N

(c) uses $v^2 = u^2 + 2as$ with u = 0, a = 3.267, s = 1.0 **M1**

(c) v = 2.6 m/s **A1**

(c) Answer: 2.6 m/s

(d) deceleration of A is μ g **M1**

(d) uses $v^2 = u^2 + 2as$ with final speed zero: $0 = 2.556^2 - 2(1.960)s$ **M1**

(d) s = 1.7 m **A1**

(d) Answer: 1.7 m

Question 21

(a) equation of motion for M: Mg - T = Ma **M1**

(a) equation of motion for m: T - mg = ma **M1**

(a) eliminate T by adding the two equations: Mg - mg = (M+m)a **dM1**

(a) cso: a = g(M-m)/(M+m) correctly rearranged and shown **A1**

(a) Answer: a = g(M - m)/(M + m) (given, shown)

(b) substitute M=5, m=3 into a = g(M-m)/(M+m) **M1**

(b) a = 2.45 m/s^2 (awrt 2.45) **A1**

(b) substitute into T = M(g-a) or T = m(g+a) **M1**

(b) T = 36.75 N (awrt 36.8) **A1**

(b) Answer: a = 2.45 m/s^2, T = 36.75 N

(c) assumptions stated: string is light and inextensible; pulley is smooth and light (any two) **B1**

(c) if the pulley were not smooth, friction at the pulley would resist the string's motion over it, reducing the net driving force and so the acceleration would be smaller than 2.45 m/s^2 **B1**

(c) Answer: Assumptions: light inextensible string; smooth, light pulley. A rough pulley reduces the acceleration.

Question 22

(a) resolving parallel to the plane: T = mg sin(θ) **M1**

(a) T = 8(9.8) sin20 (oe) **A1**

(a) T = 26.8 N (awrt) **A1**

(a) Answer: T = 26.8 N

(b) resolving perpendicular to the plane: R = mg cos(θ) **M1**

(b) R = 78.4 cos20 (oe) **A1**

(b) R = 73.7 N (awrt) **A1**

(b) Answer: R = 73.7 N

(c) T = 78.4 sin35 **M1**

(c) T = 45.0 N (awrt) **A1**

(c) Answer: T = 45.0 N

(d) R = mg cos(θ), and cos(θ) decreases as θ increases for $0 < \theta < 90$ degrees **B1**

(d) so the component of weight perpendicular to the plane decreases as the plane steepens, reducing R **B1**

(d) Answer: R = mg cos(θ) decreases because cos(θ) decreases as θ increases.

Question 23

whole-system equation: 18 = (4+2)a **M1**

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

Answer: 3 m/s^2

Question 24

equation of motion for B: T = ma with m=2, a=3 **M1**

6 N cao **A1**

Answer: 6 N

Question 25

resolve parallel to the plane: T = mg sin25 **M1**

awrt 41.4 N **A1**

Answer: 41.4 N (3 s.f.)

Question 26

resolve perpendicular to the plane: R = mg cos40 **M1**

awrt 45.0 N **A1**

Answer: 45.0 N (3 s.f.)

Question 27

horizontal component of the force = 25cos40 (oe) **M1**

use F=ma with the horizontal component: a = 25cos40/8 **M1**

awrt 2.39 m/s^2 **A1**

Answer: 2.39 m/s^2 (3 s.f.)

Question 28

(a) compute component of weight down the plane: mg sin15 = 50.7 N (awrt) **M1**

(a) compute maximum available friction: μ mg cos15 = 66.3 N (awrt) **M1**

(a) cso: since 50.7 < 66.3, the required friction is within the limiting value, so the crate remains in equilibrium **A1**

(a) Answer: Remains in equilibrium (50.7 N < 66.3 N)

(b) recognising friction is not limiting, so F = mg sin15 (not μ R) **B1**

(b) F = 50.7 N (awrt), acting up the plane **B1**

(b) Answer: F = 50.7 N up the plane

(c) at limiting equilibrium (about to move up), friction acts down the plane at its maximum: F = μ mg cos15 **M1**

(c) equation: P = mg sin15 + μ mg cos15 (oe) **A1**

(c) substitute values: P = 50.73 + 66.26 **M1**

(c) P = 117 N (awrt) **A1**

(c) Answer: P = 117 N

(d) the crate is modelled as a particle (a single point with no size/shape), so rotational effects are ignored **B1**

(d) Answer: The crate is modelled as a particle.

Question 29

(a) resolves perpendicular to the plane: R = mA g cos30 = 50.9 N (awrt) **M1**

(a) uses F = μ R for the maximum friction: Fmax = 0.25 x 50.9 = 12.7 N (awrt) **M1**

(a) compare tension required to hold B (T = mBg = 39.2 N) with weight component of A along plane (mA g sin30 = 29.4 N); required friction = |39.2 - 29.4| = 9.8 N **M1**

(a) cso: since 9.8 N < 12.7 N (Fmax), the required friction is available, so the system remains in equilibrium **A1**

(a) Answer: Remains in equilibrium (required friction 9.8 N < max friction 12.7 N)

(b) find new R = mA g cos60 = 29.4 N and Fmax = μ R = 7.35 N **M1**

(b) compare mA g sin60 (50.9 N, awrt) with mBg (39.2 N): difference = 11.7 N (awrt) **M1**

(b) cso: since 11.7 N > 7.35 N, friction cannot hold the system, so A slides down the plane and B rises; not in equilibrium **A1**

(b) equation of motion for whole system: mA g sin60 - mBg - Fmax = (mA+mB)a **M1**

(b) correct substitution: 50.92 - 39.2 - 7.35 = 10a **A1**

(b) a = 0.44 m/s^2 (awrt) **A1**

(b) Answer: Not in equilibrium; a = 0.44 m/s^2 (A slides down, B rises)

Question 30

(a) add components: (3-1)i + (5+2)j **M1**

(a) resultant = (2i + 7j) N cao **A1**

(a) Answer: (2i + 7j) N

(b) a = F/m = (2i+7j)/2 **M1**

(b) a = (1i + 3.5j) m/s^2 cao **A1**

(b) Answer: (i + 3.5j) m/s^2

(c) $|a| = \sqrt{1^2 + 3.5^2}$ **M1**

(c) |a| = 3.64 m/s^2 (awrt) **A1**

(c) Answer: 3.64 m/s^2

(d) v = u + at with u = 0, t = 4, using the vector acceleration **M1**

(d) v = (4i + 14j) m/s **A1**

(d) speed = |v| = 14.6 m/s (awrt) **A1**

(d) Answer: 14.6 m/s

(e) tan(angle) = 14/4 (oe, using components of v) **M1**

(e) angle = 74 degrees (awrt, nearest degree) **A1**

(e) Answer: 74 degrees

Question 31

R = mg = 4(9.8) = 39.2, friction = 0.25(39.2) = 9.8 **M1**

resultant force = 30 - 9.8, then a = resultant/4 **M1**

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

Answer: 5.05 m/s^2

Question 32

equations of motion 6g - T = 6a and T - 2g = 2a, combined to give 4g = 8a **M1**

a = 4.9 m/s^2 cao **A1**

substitute into T = 6(g-a) or T = 2(g+a) **M1**

T = 29.4 N cao **A1**

Answer: a = 4.9 m/s^2, T = 29.4 N

Question 33

(a) the student wrote T = m(g - a); since the lift accelerates upwards, T - mg = ma gives T = m(g + a), so a should be added to g, not subtracted (oe) **B1**

(a) Answer: The student subtracted a from g instead of adding it: T should equal m(g+a), not m(g-a).

(b) 9270 cao **B1**

(b) Answer: 9270 N

Question 34

resolve vertically: R + 40sin25 = mg, so R = mg - 40sin25 (oe) **M1**

friction = μ R **M1**

resolve horizontally: 40cos25 - friction = ma **M1**

awrt 3.95 m/s^2 **A1**

Answer: 3.95 m/s^2 (3 s.f.)

Question 35

(a) resolve horizontally and vertically to form simultaneous equations: $T_A \cos 40 = T_B \cos 60$ and $T_A \sin 40 + T_B \sin 60 = 20$ (oe) **M1**

(a) awrt 10.2 N **A1**

(a) Answer: 10.2 N (3 s.f.)

(b) substitute back into the simultaneous equations (ft from part (a)) **M1**

(b) awrt 15.6 N **A1**

(b) Answer: 15.6 N (3 s.f.)

Question 36

equations of motion for A and B, e.g. $T - \mu(4)(9.8) = 4a$ and $3(9.8) - T = 3a$, combined to eliminate T and find a **M1**

$a = 3.08$ m/s^2 cao **A1**

T = 20.16 N cao (ft from a) **B1**

Answer: a = 3.08 m/s^2, T = 20.16 N

Question 37

(a) resolving vertically: $T1 \sin 50 = 45$ **M1**

(a) $T1 = 45/\sin 50$ (oe) **A1**

(a) T1 = 58.7 N (awrt) **A1**

(a) Answer: T1 = 58.7 N

(b) resolving horizontally: $T2 = T1 \cos 50$ (oe, or $T2 = 45/\tan 50$) **M1**

(b) $T2 = 58.74 \cos 50$ (oe) **A1**

(b) T2 = 37.8 N (awrt) **A1**

(b) Answer: T2 = 37.8 N

(c) with only one string and the weight acting, the string must be vertical (90 degrees to horizontal) for horizontal equilibrium **B1**

(c) resolving vertically: T = 45 (weight only supported by the string) **M1**

(c) angle = 90 degrees, T = 45 N **A1**

(c) Answer: The string becomes vertical (90 degrees); T = 45 N

Question 38

(a) compare $\tan(\theta)$ with μ, or equivalently compute $mg \sin 20$ and $\mu\, mg \cos 20$ **M1**

(a) $\tan 20 = 0.364$ (awrt), or $mg \sin 20 = 33.5$ N and $\mu\, mg \cos 20 = 36.8$ N (awrt) **A1**

(a) cso: since $\tan 20$ (0.364) < μ (0.4) [equivalently 33.5 N < 36.8 N], the block remains in equilibrium **A1**

(a) Answer: Remains in equilibrium ($\tan 20 = 0.364 < 0.4$)

(b) resolving perpendicular to the plane: $R = mg \cos 20 + P \sin 20$ **M1**

(b) correct expression for R in terms of P **A1**

(b) resolving along the plane at limiting equilibrium (motion up impending, friction acting down the plane): $P \cos 20 = mg \sin 20 + \mu R$ **M1**

(b) correct equation with R substituted: $P \cos 20 = mg \sin 20 + \mu(mg \cos 20 + P \sin 20)$ **A1**

(b) rearrange to make P the subject: $P(\cos 20 - \mu \sin 20) = mg(\sin 20 + \mu \cos 20)$ **M1**

(b) P = 87.6 N (awrt) **A1**

(b) Answer: P = 87.6 N

Question 39

(a) whole system equation: $3000 - 500 - 300 = (1200+400)a$ **M1**

(a) $2200 = 1600a$ (oe) **A1**

(a) $a = 1.375$ m/s^2 cao **A1**

(a) Answer: a = 1.375 m/s^2

(b) equation of motion for trailer alone: $T - 300 = 400a$ **M1**

(b) $T = 300 + 400(1.375)$ **A1**

(b) T = 850 N cao, a tension (bar pulls trailer forward) **A1**

(b) Answer: T = 850 N (tension)

(c) whole system equation with zero driving force: $-800 = 1600a$ **M1**

(c) deceleration = 0.5 m/s^2 **A1**

(c) equation of motion for trailer: $T - 300 = 400(-0.5)$ **M1**

(c) T = 100 N cao, still a tension **A1**

(c) Answer: Deceleration = 0.5 m/s^2; T = 100 N (tension)

(d) the tow-bar is modelled as light and rigid (inextensible) **B1**

(d) because it is rigid and inextensible, the distance between the lorry and trailer cannot change, so their velocities and accelerations must be equal at all times **B1**

(d) Answer: The tow-bar is light and rigid; this fixes the separation of the two vehicles so they share the same acceleration.

Question 40

resolve perpendicular to the plane: $R = mg \cos 30$ **M1**

resolve parallel to the plane, with friction acting down the slope: $P = mg \sin 30 + \mu R$ **M1**

correct substitution $P = 39.2 + 0.3(67.9)$ (oe) **A1**

awrt 59.6 N **A1**

Answer: 59.6 N (3 s.f.)

Question 41

resultant force = $(6i + 4j)$ N **M1**

a = resultant/mass = $(1.5i + j)$ m/s^2 **M1**

v = u + at with u=0: $v = (4.5i + 3j)$ m/s **M1**

awrt 5.41 m/s **A1**

Answer: 5.41 m/s (3 s.f.)

Question 42

(a) resultant force on the whole system = driving force - (resistance on car + resistance on trailer) (oe) **M1**

(a) = (mass of car + mass of trailer) x a (oe) **M1**

(a) 1.5 m/s^2 cao **A1**

(a) Answer: 1.5 m/s^2

(b) consider the trailer alone: $T - 100 = 400(1.5)$ (oe), using a from part (a), ft **M1**

(b) 700 N cao **A1**

(b) Answer: 700 N

Question 43

resultant force = $(3-1+4)i + (-5+2+1)j = 6i - 2j$ N **M1**

a = resultant force / mass = $3i - j$ m/s^2 **M1**

v = u + at with u=0: $v = 5(3i - j) = 15i - 5j$ m/s **M1**

awrt 15.8 m/s **A1**

Answer: 15.8 m/s (3 s.f.)