3.6 Mechanics: Forces and Newton's Laws Depth: 1-hour Pack

Total Marks

EDEXCEL 9MA0 · Calculator allowed · about 60 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 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 1 is 2 marks)

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2 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 2 is 2 marks)

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3 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 3 is 1 mark)

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4 Two forces, (5i - j) N and (-2i + 4j) 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 4 is 2 marks)

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5 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 5 is 2 marks)

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6 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 6 is 5 marks)

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7 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 7 is 4 marks)

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8 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 8 is 7 marks)

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9 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 9 is 9 marks)

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10 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 10 is 9 marks)

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11 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 11 is 10 marks)

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Mark scheme · 3.6 Mechanics: Forces and Newton's Laws Depth: 1-hour Pack

Question 1

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

1200 N cao **A1**

Answer: 1200 N

Question 2

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

awrt 14.7 N **A1**

Answer: 14.7 N (3 s.f.)

Question 3

awrt 0.577 **B1**

Answer: 0.577 (3 s.f.)

Question 4

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 5

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

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

Answer: 3.92 m/s^2

Question 6

(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 7

(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 8

(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 9

(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 10

(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)

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Question 11

(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)

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