3.6 Mechanics: Forces and Newton's Laws Depth: Test Pack

Total Marks

EDEXCEL 9MA0 · Calculator allowed · about 60 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A block of mass 4 kg rests on rough horizontal ground. Take $g = 9.8$ m/s^2. Find the normal reaction between the block and the ground.

(Total for Question 1 is 1 mark)

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2 A particle is in limiting equilibrium on a rough plane inclined at angle θ to the horizontal, under gravity alone (no other forces act). State the relationship between the coefficient of friction μ and θ at this angle.

(Total for Question 2 is 1 mark)

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3 A block of mass 6 kg rests on rough horizontal ground. The coefficient of friction between the block and the ground is 0.35. A horizontal force of P newtons is applied to the block. Take $g = 9.8$ m/s^2. Find the minimum value of P required to make the block start to move, giving your answer to 3 significant figures.

(Total for Question 3 is 3 marks)

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4 A car of mass 800 kg is towing a trailer of mass 400 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 400 N and the resistance to motion of the trailer is 150 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 150 N, to 3 significant figures. **(3)**

(Total for Question 4 is 9 marks)

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5 A particle A of mass 5 kg lies on a rough horizontal table. It is attached to a particle B of mass 3 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 0.1. 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 5 is 12 marks)

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6 A particle A of mass 4 kg lies on a rough horizontal table, where the coefficient of friction between A and the table is 0.25. A light inextensible string connects A to a particle B of mass 3 kg which hangs freely over a smooth pulley fixed at the edge of the table, with the string between A and the pulley horizontal. 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 and the tension in the string.

(Total for Question 6 is 4 marks)

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7 A block of mass 10 kg rests on rough horizontal ground. The coefficient of friction between the block and the ground is 0.4. A force of magnitude P newtons acts on the block at an angle of 20 degrees above the horizontal, pulling the block so that it is on the point of sliding along the ground. Take $g = 9.8\ m/s^2$.

(a) Show that $P = 10g\ \mu / (\cos 20 + \mu \sin 20)$. **(5)**

(b) Hence find the value of P, giving your answer to 3 significant figures. **(2)**

(Total for Question 7 is 7 marks)

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8 Two particles A and B, of masses m and km respectively, where $k > 1$, are connected by a light inextensible string which passes over a smooth pulley fixed at the top of a smooth plane inclined at angle α to the horizontal. Particle A lies on the inclined plane and particle B hangs freely, vertically below the pulley. The system is released from rest with the string taut, and B moves downward, pulling A up the plane.

(a) Show that the acceleration of the system is $a = g(k - \sin(\alpha)) / (k + 1)$. **(5)**

(b) State one physical assumption made about the string in this model. **(1)**

(Total for Question 8 is 6 marks)

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9 A block A of mass 4 kg lies on a rough plane inclined at 25 degrees to the horizontal. The coefficient of friction between A and the plane is 0.2. A light inextensible string is attached to A, passes over a smooth pulley fixed at the top of the plane, and hangs vertically down to a block B of mass 6 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. Find the acceleration of the system and the tension in the string, giving each answer to 3 significant figures.

(Total for Question 9 is 4 marks)

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

Question 1

39.2 cao	**B1**

Answer: 39.2 N

Question 2

$\mu = \tan(\theta)$	**B1**

Answer: $\mu = \tan(\theta)$

Question 3

$R = mg = 58.8$	**M1**
maximum friction = $\mu R = 0.35(58.8)$	**M1**
awrt 20.6 N	**A1**

Answer: 20.6 N (3 s.f.)

Question 4

(a) applies $F = ma$ to the whole system	**M1**
(a) $2400 - 400 - 150 = 1200a$	**A1**
(a) $a = 1.54$ m/s^2	**A1**

(a) Answer: 1.54 m/s^2

(b) applies $F = ma$ to the trailer alone	**M1**
(b) $T - 150 = 400 \times 1.5417$	**A1**
(b) $T = 767$ N	**A1**

(b) Answer: 767 N

(c) deceleration of the trailer = 150/400	**M1**
(c) uses $v = u + at$ with $v = 0$	**M1**
(c) $t = 40.0$ s	**A1**

(c) Answer: 40.0 s

Question 5

(a) for B: $3g - T = 3a$	**M1**
(a) for A: $T - F = 5a$ with $F = 0.1 \times 5g$	**M1**
(a) both equations correct	**A1**

(a) Answer: B: $3g - T = 3a$; A: $T - 0.1 \times 5g = 5a$

(b) adds the two equations to eliminate T	**M1**
(b) $a = 3.1$ m/s^2	**A1**
(b) substitutes to find $T = 3(g - a)$	**M1**
(b) $T = 20$ N	**A1**

(b) Answer: $a = 3.1$ m/s^2, $T = 20$ N

(c) uses $v^2 = u^2 + 2as$ with $u = 0$, $a = 3.062$, $s = 1.0$	**M1**
(c) $v = 2.5$ m/s	**A1**

(c) Answer: 2.5 m/s

(d) deceleration of A is μg	**M1**
(d) uses $v^2 = u^2 + 2as$ with final speed zero: $0 = 2.475^2 - 2(0.980)s$	**M1**
(d) $s = 3.1$ m	**A1**

(d) Answer: 3.1 m

Question 6

whole-system equation: $3g - \mu(4)g = 7a$, with friction = $0.25(4)(9.8)$	**M1**
2.8 m/s^2 cao	**A1**
equation of motion for B: $T = 3(g - a)$	**M1**
21 N cao	**A1**

Answer: $a = 2.8$ m/s^2, $T = 21$ N

Question 7

(a) resolves vertically: $R = 10g - P \sin 20$ (oe)	**M1**
(a) resolves horizontally (limiting equilibrium): $P \cos 20 = F$ (oe)	**M1**
(a) uses $F = \mu R$ (limiting)	**M1**
(a) combines and rearranges to make P the subject, dependent on all previous M marks	**dM1**
(a) $P = 10g\mu / (\cos 20 + \mu \sin 20)$ cso	**A1**

(a) Answer: $P = 10g\mu / (\cos 20 + \mu \sin 20)$ (shown)

(b) substitutes $\mu = 0.4$, $g = 9.8$ into the formula from (a)	**M1**
(b) awrt 36.4 (N)	**A1**

(b) Answer: P = 36.4 N (3sf)

Question 8

(a) equation of motion for B (down positive): $kmg - T = kma$ (oe)	**M1**
(a) equation of motion for A (up the plane positive, smooth plane so no friction): $T - mg \sin(\alpha) = ma$ (oe)	**M1**
(a) adds the two equations to eliminate T, dependent on both previous M marks	**dM1**
(a) $mg(k - \sin(\alpha)) = ma(k + 1)$ (oe), unsimplified	**A1**
(a) $a = g(k - \sin(\alpha)) / (k + 1)$ cso	**A1**

(a) Answer: $a = g(k - \sin(\alpha)) / (k + 1)$ (shown)

(b) any correct modelling assumption, e.g. the string is inextensible so A and B have the same magnitude of acceleration (oe); or the string is light so the tension is the same throughout its length; or the pulley is smooth so it does not affect the tension in the string	**B1**

(b) Answer: e.g. the string is inextensible, so A and B always have the same speed and the same magnitude of acceleration

Question 9

whole-system equation: $6g - 4g \sin 25 - \mu(4)g \cos 25 = 10a$ (weight component and friction both oppose A moving up the plane)	**M1**
awrt 3.51 m/s^2	**A1**
equation of motion for B: $T = 6(g - a)$	**M1**
awrt 37.7 N	**A1**

Answer: $a = 3.51$ m/s^2, $T = 37.7$ N (both 3 s.f.)

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