3.4 Forces: 1-hour Pack

AQA 8461 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 State whether the forces on an object are balanced or unbalanced when it moves at constant speed in a straight line.

(Total for Question 1 is 1 mark)

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2 Use the Physics Equations Sheet: resultant force (N) = mass (kg) x acceleration (m/s^2), i.e. F = m a. A cyclist and her bicycle have a combined mass of 78 kg.

(a) Calculate the resultant force needed to accelerate the cyclist and bicycle at 1.5 m/s^2. **(2)**

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(b) The cyclist's brakes later provide a braking force of 210 N, which is the only horizontal force acting. Calculate the deceleration produced, giving your answer to 2 significant figures. **(3)**

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(Total for Question 2 is 5 marks)

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3 A trampolinist of mass 55 kg lands on a trampoline and momentarily comes to rest after descending through a height of 0.80 m while stretching the trampoline surface. Assume all of the gravitational potential energy transferred is stored as elastic potential energy in the trampoline (ignore air resistance and other energy losses). Gravitational field strength g = 9.8 N/kg.

(a) Show that the gravitational potential energy transferred as the trampolinist descends is about 430 J. Use the Physics Equations Sheet: gravitational potential energy (J) = mass (kg) x gravitational field strength (N/kg) x height (m), i.e. GPE = m g h. **(3)**

(b) The trampoline behaves like a very stiff spring with spring constant k = 5400 N/m. Using $Ee = 0.5\ k\ e^2$ and the energy value of 431 J from part (a), calculate the extension e of the trampoline surface, giving your answer to 2 significant figures. **(3)**

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(Total for Question 3 is 6 marks)

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4 A swimmer pushes backwards against the water with their arms in order to move forwards through a pool.

(a) State Newton's Third Law. **(1)**

(b) Identify the reaction force to the swimmer's push on the water, stating its size and direction compared with the swimmer's push, and explain why the swimmer moves forwards. **(2)**

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(Total for Question 4 is 3 marks)

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5 The gravitational field strength near the Earth's surface is g = 9.8 N/kg. Use the Physics Equations Sheet if needed: weight (N) = mass (kg) x gravitational field strength (N/kg), i.e. W = m g.

(a) Calculate the weight of a shopping bag of mass 6.0 kg on Earth. **(2)**

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(b) The same bag is taken to the Moon, where the gravitational field strength is 1.6 N/kg. Calculate its weight on the Moon. **(2)**

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(c) State what happens to the mass of the bag on the Moon compared with on Earth. **(1)**

(Total for Question 5 is 5 marks)

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6 A person pushes a 12 kg box along a horizontal floor with a constant horizontal force of 50 N. The box moves at steady speed. Calculate the frictional force and state the resultant force.

(a) Calculate the frictional force acting on the box. **(2)**

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(b) State the resultant force on the box and explain your answer. **(2)**

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(Total for Question 6 is 4 marks)

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7 Explain how to calculate the average braking force exerted by the brakes. Include the relevant equation(s), the substitution with numbers and the final calculation. State any assumptions you use. This question is worth 6 marks.

(Total for Question 7 is 6 marks)

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8 A student measures stopping distances at different speeds and obtains the following average data: speed 10 m/s stopping distance 8 m; speed 20 m/s stopping distance 32 m. Suggest why stopping distance does not scale linearly with speed and use a calculation to show the relationship between kinetic energy and stopping distance, assuming braking force is constant.

(a) Explain why stopping distance is not proportional to speed. **(1)**

(b) Assuming braking force is constant, show how stopping distance scales with speed by calculating the ratio of stopping distances from the kinetic energy change between 10 and 20 m/s for a 1000 kg car. **(2)**

(Total for Question 8 is 3 marks)

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9 A student investigates terminal velocity by dropping small model parachutes from a fixed height and measuring terminal speed. One trial gave data: mass of model and parachute 0.060 kg, terminal speed 3.0 m/s. Air resistance at terminal velocity equals weight.

(a) Calculate the weight of the model. Use g = 9.8 N/kg. **(1)**

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(b) State the magnitude of the air resistance force acting on the model at terminal velocity and explain how the terminal velocity changes if the parachute area is fixed but the mass is increased slightly. **(3)**

(Total for Question 9 is 4 marks)

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10 A student applies a constant resultant force to a 0.50 kg toy for 6.0 s. The speed increases uniformly from 1.0 m/s to 7.0 m/s. Use Newton's second law and the work-energy principle.

(a) Calculate the acceleration of the toy. **(1)**

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(b) Calculate the magnitude of the resultant force applied. **(1)**

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(c) Calculate the change in kinetic energy and verify this equals the work done by the resultant force over the distance moved while accelerating. **(3)**

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(Total for Question 10 is 5 marks)

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11 A rocket of mass 2000 kg accelerates vertically upward producing a constant thrust of 60 000 N. Neglecting air resistance, calculate the net acceleration at lift-off and the velocity after 10 s.

(a) Calculate the net upward force and hence the acceleration at lift-off. Use g = 9.8 N/kg. **(2)**

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(b) Calculate the velocity after 10 s, assuming constant acceleration and starting from rest. **(2)**

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(Total for Question 11 is 4 marks)

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Mark scheme · 3.4 Forces: 1-hour Pack

Question 1

balanced cao **B1**

Answer: Balanced.

Question 2

(a) 78 x 1.5 **M1**

(a) 117 N, cao **A1**

(a) Answer: 117 N

(b) correct rearrangement: a = F / m **M1**

(b) correct substitution: a = 210 / 78 **M1**

(b) 2.7 m/s^2, awrt 2.7 **A1**

(b) Answer: 2.7 m/s^2 (2 s.f.)

Question 3

(a) correct substitution: GPE = 55 x 9.8 x 0.80 **M1**

(a) correct evaluation: 55 x 9.8 = 539, then 539 x 0.80 = 431.2 J **M1**

(a) 431 J shown, rounding to about 430 J as given, cso (answer printed in question, full working must be shown) **A1**

(a) Answer: 431 J (about 430 J)

(b) correct rearrangement: e^2 = 431 / (0.5 x 5400), ft from 19a **M1**

(b) correct evaluation: e^2 = 431 / 2700 = 0.1596, then e = $\sqrt{0.1596}$ **M1**

(b) 0.40 m, awrt 0.40 **A1**

(b) Answer: 0.40 m

Question 4

(a) whenever two objects interact, they exert equal and opposite forces on each other, oe **B1**

(a) Answer: When two objects interact, they exert equal and opposite forces on each other.

(b) the water pushes back on the swimmer's arms/hands, equal in size and opposite in direction to the swimmer's push, oe **B1**

(b) this reaction force acts forwards on the swimmer, so the swimmer accelerates/moves forwards, oe **B1**

(b) Answer: The water exerts an equal and opposite (forward) force on the swimmer, which pushes the swimmer forwards.

Question 5

(a) correct substitution: W = 6.0 x 9.8 **M1**

(a) 58.8 N, cao (allow 59 N to 2 s.f.) **A1**

(a) Answer: 58.8 N

(b) correct substitution: W = 6.0 x 1.6 **M1**

(b) 9.6 N, cao **A1**

(b) Answer: 9.6 N

(c) the mass stays the same (6.0 kg); mass does not depend on gravitational field strength, oe **B1**

(c) Answer: The mass stays the same (6.0 kg).

Question 6

(a) recognises that friction balances push when speed is constant so friction = 50 N **M1**

(a) 50 N cao **A1**

(a) Answer: 50 N

(b) states resultant force is zero **M1**

(b) explains because the horizontal forces balance so there is no acceleration, oe **A1**

(b) Answer: 0 N because the applied force is balanced by friction so the resultant force is zero.

Question 7

Level 3 A clear, logical explanation that uses the work-energy principle or energy equations correctly, substitutes the numbers, shows the calculation and gives the braking force with correct unit. Any reasonable assumption is stated. **5-6**

Level 2 Partial explanation with either correct energy change calculation or correct use of work = force x distance, and one correct substitution leading to a magnitude for force, but missing one clear link or unit. **3-4**

Level 1 Simple statements, such as giving only one equation or a qualitative answer, with minimal or incorrect use of numbers. **1-2**

Indicative content:

- Work done by braking force = change in kinetic energy
- Initial kinetic energy = 1/2 x m x v^2 = 0.5 x 60 x 8.0^2 = 0.5 x 60 x 64 = 1920 J
- Final kinetic energy = 0 J, so change in energy = 1920 J
- Work = force x distance, so force = work / distance = 1920 / 10 = 192 N
- Assumption: braking force is approximately constant over the distance; ignore frictional losses other than braking

Question 8

(a) because kinetic energy depends on speed squared so more energy to remove at higher speed, oe **B1**

(a) Answer: Stopping distance is not proportional because kinetic energy increases with speed squared, so higher speeds require disproportionately more distance to dissipate energy.

(b) calculates KE at 10 m/s and 20 m/s: 0.5 x 1000 x 10^2 = 50 000 J and 0.5 x 1000 x 20^2 = 200 000 J **M1**

(b) shows ratio 200 000 / 50 000 = 4 so stopping distance scales as speed^2, explaining 32 m vs 8 m **A1**

(b) Answer: KE10 = 50 000 J, KE20 = 200 000 J, ratio = 4 so stopping distance quadruples when speed doubles, consistent with 8 m -> 32 m.

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Question 9

(a) weight = 0.060 x 9.8 = 0.588 N (0.588 N or 0.59 N) **B1**

(a) Answer: 0.588 N

(b) air resistance equals weight at terminal velocity so 0.588 N stated **M1**

(b) explains that if mass increases slightly the weight increases, so a larger air resistance is needed to balance it and the new terminal velocity is (slightly) higher, oe (accept: terminal velocity depends on balance between weight and drag) **A1**

(b) alternative clear explanation that for a fixed area there is a specific speed where drag equals each weight, so a small increase in mass gives only a small increase in terminal velocity, oe **A1**

(b) Answer: Air resistance = 0.588 N. Terminal velocity is reached when drag equals weight; if the mass increases slightly the weight increases, so a larger drag is needed to balance it, which happens at a slightly higher speed: the terminal velocity increases slightly.

Question 10

(a) a = (7.0 - 1.0) / 6.0 = 1.0 m/s^2 cao **B1**

(a) Answer: 1.0 m/s^2

(b) F = m x a = 0.50 x 1.0 = 0.50 N cao **B1**

(b) Answer: 0.50 N

(c) calculates change in KE = 0.5 x 0.50 x (7.0^2 - 1.0^2) = 0.25 x (49 - 1) = 0.25 x 48 = 12 J **M1**

(c) calculates distance using s = ut + 0.5 a t^2 = 1.0 x 6.0 + 0.5 x 1.0 x 36 = 6.0 + 18 = 24 m **M1**

(c) work = F x s = 0.50 x 24 = 12 J so equals change in KE cao **A1**

(c) Answer: Change in KE = 12 J; distance = 24 m; work = 0.50 x 24 = 12 J, so equals change in KE.

Question 11

(a) calculates weight = 2000 x 9.8 = 19 600 N and net force = 60 000 - 19 600 = 40 400 N **M1**

(a) acceleration = 40 400 / 2000 = 20.2 m/s^2 cao **A1**

(a) Answer: 20.2 m/s^2

(b) uses v = u + at with u = 0, so v = 0 + 20.2 x 10 **M1**

(b) v = 202 m/s cao **A1**

(b) Answer: 202 m/s

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