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HIGHER

P5H Forces: Higher Tier Practice

AQA 8463 · Calculator allowed · about 100 minutes

Total Marks

Name: ________________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 A car drives along a straight horizontal road at constant speed. The driving force from the engine is balanced by friction and air resistance.

(a) State what is meant by an object moving at constant speed. **(1)**

(b) Explain why the driving force must equal the total resistive forces for the car to maintain constant speed. **(1)**

(Total for Question 1 is 2 marks)

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2 A student measures the extension of a spring as masses are added. The measured data are: mass 0.10 kg extends spring by 0.012 m; mass 0.20 kg extends by 0.024 m; mass 0.30 kg extends by 0.036 m.

(a) Show that the spring follows Hooke's law using the data by calculating the ratio force / extension for one row. Use g = 9.8 N/kg. **(2)**

....

(b) Calculate the spring constant k using any one row of the data and state its unit. **(1)**

....

(Total for Question 2 is 3 marks)

3 A cyclist travelling at 6.0 m/s applies the brakes and slows to 2.0 m/s over a distance of 15 m. The mass of the cyclist plus bike is 80 kg.

(a) Calculate the change in kinetic energy during braking. Use KE = 0.5 x m x v^2. **(2)**

....

(b) Calculate the average braking force assuming the work done equals the change in kinetic energy and the distance is 15 m. State the direction as 'opposite to motion'. **(1)**

....

(Total for Question 3 is 3 marks)

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4 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)**

....

(b) State the magnitude of the air resistance force acting on the model at terminal velocity and explain why terminal velocity does not change if the parachute area is fixed but mass is increased slightly. **(3)**

(Total for Question 4 is 4 marks)

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5 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)**

....

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

(Total for Question 5 is 4 marks)

6 A skydiver of mass 75 kg reaches a terminal velocity of 55 m/s. Calculate the air resistance at terminal velocity and state the energy change per second associated with the skydiver falling at that speed.

(a) Calculate the air resistance acting on the skydiver at terminal velocity. Use g = 9.8 N/kg. **(1)**

....

(b) State the rate of increase of the skydiver's kinetic energy while falling at terminal velocity. **(2)**

(Total for Question 6 is 3 marks)

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7 A student pulls a toy car along a slope. The slope is 2.0 m long and rises by 0.50 m vertically. The car moves at constant speed. Calculate the component of the car's weight acting down the slope and use it to determine the tension needed in a string pulling the car up the slope at steady speed. Mass of car 1.5 kg, g = 9.8 N/kg.

(a) Calculate the angle of the slope to the horizontal (answer to 2 s.f.). **(1)**

....

(b) Calculate the component of weight acting down the slope and hence the tension required to pull the car up the slope at constant speed. **(3)**

....

(Total for Question 7 is 4 marks)

8 A force-time graph shows a constant force of 6.0 N applied to a 2.0 kg mass for 4.0 s, then the force is removed. The mass starts from rest.

(a) Calculate the acceleration while the force is applied. **(1)**

....

(b) Calculate the speed of the mass at the moment the force is removed. **(1)**

....

(c) State the distance travelled during the 4.0 s while the force is applied. **(1)**

(Total for Question 8 is 3 marks)

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9 A collision between two trolleys on a straight track is analysed. Trolley A of mass 0.80 kg moves right at 2.0 m/s and collides elastically with trolley B of mass 1.6 kg initially at rest. Calculate the velocities after the collision.

(a) Using conservation of momentum and kinetic energy for an elastic collision, calculate the final speed of trolley A and trolley B. Positive direction is the original direction of A. **(4)**

....

(Total for Question 9 is 4 marks)

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)**

....

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

....

(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)**

....

(Total for Question 10 is 5 marks)

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11 State two factors that affect thinking distance for a driver reacting to an unexpected obstacle.

(a) Give two factors. **(2)**

(Total for Question 11 is 2 marks)

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12 Explain how a safety feature in cars, such as an airbag, reduces injuries in a collision. In your answer include reference to forces, time, momentum and energy.

Explain how an airbag reduces injuries in a head-on collision. Use physics ideas about forces, change in momentum, time interval and energy absorption. You may include sketches or equations in your explanation.

(Total for Question 12 is 6 marks)

13 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 13 is 3 marks)

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14 A student investigates motion on a rough horizontal surface. They pull a 2.5 kg block at constant speed with a horizontal force of 12 N and measure displacement of 4.0 m. Calculate the work done by the pulling force and the thermal energy increase of the block and surface. Explain any assumptions.

(a) Calculate the work done by the pulling force. **(1)**

....

(b) State the increase in thermal energy of the block and surface and explain any assumption. **(3)**

(Total for Question 14 is 4 marks)

15 A mass on a frictionless vertical spring oscillates. The spring constant is 120 N/m and the mass is 0.50 kg. Calculate the period of small oscillations. Use $T = 2\pi\sqrt{m/k}$.

(a) Calculate the period T to 3 significant figures. **(3)**

....

(b) State how the period would change if the mass were doubled, and give the new period. **(1)**

....

(Total for Question 15 is 4 marks)

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16 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)**

....

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

....

(Total for Question 16 is 4 marks)

Mark scheme · P5H Forces: Higher Tier Practice

Question 1

- (a) **B1** speed stays the same (no change in magnitude of velocity) cao
- **(a) Answer: The speed stays the same; there is no change in the magnitude of velocity.**
- (b) **B1** resultant force is zero when forces are balanced, so there is no acceleration, oe
- **(b) Answer: Because when driving force equals resistive forces the resultant force is zero, so the car does not accelerate.**

Question 2

- (a) **M1** calculates force = mass x g for a mass, eg 0.20 x 9.8 = 1.96 N
- (a) **A1** shows ratio F/x = 1.96 / 0.024 = 81.7 N/m (or similar consistent value) cao
- **(a) Answer: For mass 0.20 kg: F = 0.20 x 9.8 = 1.96 N. F/x = 1.96 / 0.024 = 81.7 N/m.**
- (b) **B1** k = 81.7 N/m (to 3 s.f.) and unit N/m cao
- **(b) Answer: 81.7 N/m**

Question 3

- (a) **M1** substitutes KE change = 0.5 x 80 x (6.0^2 - 2.0^2) or computes initial and final KE then difference
- (a) **A1** Δ KE = 0.5 x 80 x (36 - 4) = 0.5 x 80 x 32 = 1280 J cao
- **(a) Answer: 1280 J**
- (b) **B1** force = 1280 / 15 = 85.3 N (to 3 s.f.) and direction opposite to motion cao
- **(b) Answer: 85.3 N opposite to motion**

Question 4

- (a) **B1** weight = 0.060 x 9.8 = 0.588 N (0.588 N or 0.59 N)
- **(a) Answer: 0.588 N**
- (b) **M1** air resistance equals weight at terminal velocity so 0.588 N stated
- (b) **A1** explains that if mass increases slightly weight increases so new terminal velocity will adjust; or if mass change is negligible then drag balance remains, oe (accept: terminal velocity depends on balance between weight and drag)
- (b) **A1** alternative clear explanation that for a fixed area there is a specific speed where drag equals weight so small changes may not change terminal velocity much, oe
- **(b) Answer: Air resistance = 0.588 N. Terminal velocity exists because drag equals weight; if mass increases slightly the weight changes and terminal velocity will change until drag equals new weight, but for very small mass change the speed change is small.**

Question 5

- (a) **M1** recognises that friction balances push when speed is constant so friction = 50 N
- (a) **A1** 50 N cao
- **(a) Answer: 50 N**
- (b) **M1** states resultant force is zero
- (b) **A1** explains because the horizontal forces balance so there is no acceleration, oe
- **(b) Answer: 0 N because the applied force is balanced by friction so the resultant force is zero.**

Question 6

- (a) **B1** air resistance = weight = 75 x 9.8 = 735 N (735 N)
- **(a) Answer: 735 N**
- (b) **M1** states power from gravity equals weight x velocity: 735 x 55 = 40 425 W or recognises no net gain in kinetic energy so rate is zero and explains choice
- (b) **A1** correct conclusion: kinetic energy does not increase so rate = 0 W; if using power argument must explain that at terminal velocity work done by gravity is dissipated by air resistance so no net KE gain
- **(b) Answer: 0 W**

Question 7

- (a) **B1** angle = arcsin(rise / hypotenuse) = arcsin(0.50 / 2.0) = 14.48 degrees => 14.5 degrees (2 s.f.)
- **(a) Answer: 14.5 degrees**
- (b) **M1** calculates component = mg sin(θ) = 1.5 x 9.8 x sin(14.48 degrees) or equivalent using rise/run approx
- (b) **M1** recognises tension must balance this component at steady speed
- (b) **A1** gives numerical tension = 1.5 x 9.8 x 0.25 = 3.675 N => 3.68 N (3 s.f.) cao
- **(b) Answer: 3.68 N**

Question 8

- (a) **B1** a = F/m = 6.0 / 2.0 = 3.0 m/s^2 cao
- **(a) Answer: 3.0 m/s^2**
- (b) **B1** v = u + at = 0 + 3.0 x 4.0 = 12 m/s cao
- **(b) Answer: 12 m/s**
- (c) **B1** s = ut + 0.5 a t^2 = 0 + 0.5 x 3.0 x 16 = 24 m cao
- **(c) Answer: 24 m**

Question 9

- (a) **M1** sets up momentum: 0.80 x 2.0 + 1.6 x 0 = 0.80 vA + 1.6 vB
- (a) **M1** uses elastic collision relation or conservation of KE: 0.5 x 0.80 x 2.0^2 = 0.5 x 0.80 vA^2 + 0.5 x 1.6 vB^2 or uses relative speed method
- (a) **A1** vA = -0.667 m/s (to 3 s.f.) cao
- (a) **A1** vB = 1.33 m/s (to 3 s.f.) cao
- **(a) Answer: vA = -0.667 m/s, vB = 1.33 m/s**

Question 10

- (a) **B1** a = (7.0 - 1.0) / 6.0 = 1.0 m/s^2 cao
- **(a) Answer: 1.0 m/s^2**
- (b) **B1** F = m x a = 0.50 x 1.0 = 0.50 N cao
- **(b) Answer: 0.50 N**
- (c) **M1** 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
- (c) **M1** 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
- (c) **A1** work = F x s = 0.50 x 24 = 12 J so equals change in KE cao
- **(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) **B1** driver reaction time (eg tiredness) or alcohol or distractions, oe
- (a) **B1** vehicle speed cao
- **(a) Answer: Driver reaction time (eg tiredness, distraction, alcohol) and vehicle speed.**

Question 12

- **Level 3** (5-6): Detailed explanation linking change in momentum to force and time, and describing energy absorption. Includes an equation or quantitative statement and explains how the airbag increases time and reduces peak force, and how energy is absorbed to reduce injury.
- **Level 2** (3-4): Clear explanation that mentions that airbags increase the time over which momentum changes and thus reduce force, and that energy is absorbed, with some correct physics but missing one link.
- **Level 1** (1-2): Simple statements such as 'airbag cushions the head' or 'reduces speed' without linking to momentum, force and time, or with incomplete physics.
- **Indicative content:**
  - Change in momentum: Delta p = m Delta v, so for a given Delta p reducing force requires increasing time (F = Delta p / Delta t).
  - Airbag increases the time over which the head slows by cushioning the impact, so peak force on the head is lower.
  - Lower peak force reduces stress on body tissues and decreases risk of serious injury.
  - Airbag material and folding absorb some kinetic energy (energy transferred to the airbag, heat and deformation), reducing energy transferred to passenger.
  - Mention that the airbag spreads force over a larger area and prevents contact with hard surfaces, lowering pressure.
  - Quantitative statement could show example numbers or reference to reducing force by factor if time is increased, eg if time doubles force halves, all else equal.

Question 13

- (a) **B1** because kinetic energy depends on speed squared so more energy to remove at higher speed, oe
- **(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) **M1** 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
- (b) **A1** shows ratio 200 000 / 50 000 = 4 so stopping distance scales as speed^2, explaining 32 m vs 8 m
- **(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.**

Question 14

- (a) **B1** work = F x s = 12 x 4.0 = 48 J cao
- **(a) Answer: 48 J**
- (b) **M1** states thermal energy increase equals work done if kinetic energy unchanged, so 48 J
- (b) **A1** gives value 48 J cao
- (b) **A1** states assumption that block moves at constant speed so no change in kinetic energy and no other energy transfers (eg sound) significant, oe
- **(b) Answer: Increase in thermal energy = 48 J, assuming constant speed so no change in kinetic energy and negligible other energy losses.**

Question 15

- (a) **M1** substitutes $T = 2\pi\sqrt{m/k} = 2\pi\sqrt{0.50 / 120}$
- (a) **M1** evaluates inside sqrt = 0.0041667 and sqrt = 0.06455
- (a) **A1** T = 2 x π x 0.06455 = 0.406 s (0.406 s to 3 s.f.) cao
- **(a) Answer: 0.406 s**
- (b) **B1** period increases by factor $\sqrt{2}$; new T = 0.406 x $\sqrt{2}$ = 0.406 x 1.414 = 0.574 s (0.574 s)
- **(b) Answer: 0.574 s**

Question 16

- (a) **M1** calculates weight = 2000 x 9.8 = 19 600 N and net force = 60 000 - 19 600 = 40 400 N
- (a) **A1** acceleration = 40 400 / 2000 = 20.2 m/s^2 cao
- **(a) Answer: 20.2 m/s^2**
- (b) **M1** uses v = u + at with u = 0, so v = 0 + 20.2 x 10
- (b) **A1** v = 202 m/s cao
- **(b) Answer: 202 m/s**