3.4 Mechanics and Materials: Test Pack

AQA 7408 · Calculator allowed · about 70 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A cyclist in Durham is travelling along a straight, flat road at a constant velocity of 12 m/s when she begins to brake uniformly, coming to rest 8.0 s later. Use the Physics Equations Sheet where needed. Take g = 9.81 m/s^2.

(a) Calculate the deceleration of the cyclist while braking. **(2)**

(b) Calculate the distance the cyclist travels while braking. **(2)**

(c) Show that the same braking distance is obtained using the equation $v^2 = u^2 + 2as$. **(2)**

(d) The cyclist's reaction time before she starts to brake is 0.30 s, during which she continues at 12 m/s. Calculate the total distance travelled from the moment she first sees a hazard to when she stops. **(3)**

(Total for Question 1 is 9 marks)

---

2 This question tests core definitions in mechanics.

(a) State Newton's second law of motion in terms of the rate of change of momentum. **(1)**

(b) Define the moment of a force about a point. **(1)**

(c) State the principle of moments. **(1)**

(Total for Question 2 is 3 marks)

---

3 An electric motor is used to lift a load of mass 150 kg at a constant speed through a vertical height of 12 m in 20 s. The motor is 75% efficient. Take g = 9.81 m/s^2.

(a) Calculate the gain in gravitational potential energy of the load. **(2)**

(b) Calculate the useful power output of the motor. **(2)**

(c) Given that efficiency = (useful power output / input power) x 100%, calculate the input power supplied to the motor. **(3)**

(d) Calculate the power wasted by the motor. **(2)**

(Total for Question 3 is 9 marks)

© Revision Library | revisionlibrary.co.uk

4 A ball is kicked from level ground with an initial speed of 18 m/s at an angle of 40 degrees above the horizontal. Air resistance is negligible. Take $g = 9.81\ m/s^2$.

(a) Calculate the horizontal and vertical components of the initial velocity. **(2)**

(b) Calculate the maximum height reached by the ball above the ground. **(2)**

(c) Calculate the total time of flight before the ball returns to the ground. **(1)**

(d) Calculate the horizontal range of the ball. **(2)**

(Total for Question 4 is 7 marks)

---

5 REQUIRED PRACTICAL. A student investigates the force-extension behaviour of a metal wire of length 1.80 m and diameter 0.30 mm, using masses to apply tension and a travelling microscope to measure extension. The results, all within the elastic region, are given below.
Force (N): 10, 20, 30, 40, 50
Extension (mm): 1.27, 2.55, 3.82, 5.09, 6.37

(a) State what physical quantity is represented by the gradient of a force-extension graph in the elastic region. **(1)**

(b) Use the data for the largest force to calculate the gradient of the force-extension graph. **(3)**

(c) Calculate the cross-sectional area of the wire. **(2)**

(d) Calculate the Young modulus of the wire material, using E = (gradient x L) / A. **(3)**

(e) Calculate the elastic strain energy stored in the wire when the applied force is 40 N. **(2)**

(Total for Question 5 is 11 marks)

---

6 A student determines the density of an irregularly shaped metal alloy sample. Its mass is measured on a balance as 245.6 ± 0.1 g, and its volume is found by water displacement as $31.5 \pm 0.5\ cm^3$.

(a) Calculate the density of the alloy in kg/m^3. **(3)**

(b) Calculate the percentage uncertainty in the calculated density. **(3)**

(c) State which measurement, the mass or the volume, limits the overall precision of the density value, and explain why. **(2)**

(Total for Question 6 is 8 marks)

© Revision Library | revisionlibrary.co.uk

Mark scheme · 3.4 Mechanics and Materials: Test Pack

Question 1

(a) correct substitution into a = (v - u)/t, oe **M1**

(a) a = -1.5 m/s^2 (deceleration of 1.5 m/s^2), cao **A1**

(a) Answer: a = -1.5 m/s^2 (deceleration of 1.5 m/s^2)

(b) correct substitution into s = (u + v)t/2 or s = ut + 1/2at^2, oe **M1**

(b) s = 48 m, cao **A1**

(b) Answer: 48 m

(c) rearrange v^2 = u^2 + 2as to make s the subject, oe **M1**

(c) cso: 0 = 144 - 3s leading to s = 48 m, consistent with part (b) **A1**

(c) Answer: 48 m (shown)

(d) distance during reaction time = 12 x 0.30 = 3.6 m **M1**

(d) total distance = reaction distance + braking distance (ft from (b)) **M1**

(d) 51.6 m, cao **A1**

(d) Answer: 51.6 m

Question 2

(a) the resultant force acting on an object is equal to (proportional to) the rate of change of its momentum oe **B1**

(a) Answer: The resultant force on an object equals the rate of change of its momentum.

(b) the product of the force and the perpendicular distance from the point (pivot/line of action) to the point oe **B1**

(b) Answer: The moment of a force about a point is the product of the force and the perpendicular distance from the point to the line of action of the force.

(c) for a system in equilibrium, the sum of the clockwise moments about any point equals the sum of the anticlockwise moments about that same point oe **B1**

(c) Answer: For a body in equilibrium, the sum of the clockwise moments about any point equals the sum of the anticlockwise moments about that point.

Question 3

(a) GPE = mgh substitution **M1**

(a) 1.77 x 10^4 J (17700 J, accept 17600-17700 J), cao **A1**

(a) Answer: 1.77 x 10^4 J

(b) P = work done/time, using answer from (a), ft **M1**

(b) 883 W (accept 880-885 W, ft), awrt **A1**

(b) Answer: 883 W

(c) rearrange efficiency equation to make input power the subject **M1**

(c) correct substitution: input power = 882.9/0.75, ft from (b) **M1**

(c) 1180 W (accept 1175-1185 W, ft), awrt **A1**

(c) Answer: 1180 W

(d) wasted power = input power - useful power output, ft from (b) and (c) **M1**

(d) 294 W (accept 290-298 W, ft), awrt **A1**

(d) Answer: 294 W

Question 4

(a) vx = 18 cos(40) = 13.8 m/s **M1**

(a) vy = 18 sin(40) = 11.6 m/s cao **A1**

(a) Answer: vx = 13.8 m/s, vy = 11.6 m/s

(b) use v^2 = u^2 - 2gh with u = vy, v = 0 **M1**

(b) h = 6.82 m cao **A1**

(b) Answer: 6.82 m

(c) t = 2 vy / g = 2 x 11.57 / 9.81 = 2.36 s cao **B1**

(c) Answer: 2.36 s

(d) use range = vx x t **M1**

(d) range = 32.5 m cao **A1**

(d) Answer: 32.5 m

Question 5

(a) the stiffness (spring constant, k) of the wire oe **B1**

(a) Answer: The stiffness (spring constant) of the wire.

(b) gradient = F / x = 50 / (6.37 x 10^{-3}) **M1**

(b) convert extension to metres before dividing **M1**

(b) gradient = 7850 N/m (accept 7840-7860) cao **A1**

(b) Answer: 7850 N/m

(c) use A = π (d/2)^2 with d = 0.30 x 10^{-3} m **M1**

(c) A = 7.07 x 10^{-8} m^2 cao **A1**

(c) Answer: 7.07 x 10^{-8} m^2

(d) substitute E = (7850 x 1.80) / (7.07 x 10^{-8}) **M1**

(d) carry out the calculation **M1**

(d) E = 2.0 x 10^{11} Pa cao **A1**

(d) Answer: 2.0 x 10^{11} Pa

(e) use elastic strain energy = 1/2 F x, with x = 5.09 x 10^{-3} m **M1**

(e) energy = 0.102 J cao **A1**

(e) Answer: 0.102 J

Question 6

(a) density = mass/volume = 245.6/31.5 = 7.80 g/cm^3 **M1**

(a) convert to kg/m^3 by multiplying by 1000 **M1**

(a) density = 7.80 x 10^3 kg/m^3 cao **A1**

(a) Answer: 7.80 x 10^3 kg/m^3

(b) percentage uncertainty in mass = 0.1/245.6 x 100 = 0.041% **M1**

(b) percentage uncertainty in volume = 0.5/31.5 x 100 = 1.59% **M1**

(b) total percentage uncertainty = 1.63% (sum of the two) cao **A1**

(b) Answer: 1.6%

(c) the volume measurement limits the precision **B1**

(c) because its percentage uncertainty (about 1.6%) is far larger than that of the mass measurement (about 0.04%), so it dominates the combined uncertainty oe **B1**

(c) Answer: The volume measurement limits the precision, because its percentage uncertainty (about 1.6%) is much larger than the mass measurement's percentage uncertainty (about 0.04%), so it dominates the overall uncertainty in density.

© Revision Library | revisionlibrary.co.uk