3.1 Mechanics: Quantities, Units and Kinematics: Test Pack

Total Marks

EDEXCEL 9MA0 · Calculator allowed · about 95 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question concerns quantities and units used in mechanics.

(a) State the SI unit used to measure (i) mass, (ii) time, (iii) displacement. **(3)**

(b) A runner completes a distance of 3.2 km in a time of 11 minutes 40 seconds, moving at a constant speed. Calculate the runner's average speed in m/s, giving your answer correct to 3 significant figures. **(3)**

(c) The mass of a small ball bearing is 4.5 grams. Express this mass in kilograms, giving your answer in standard form. **(2)**

(Total for Question 1 is 8 marks)

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2 This question concerns quantities, units and unit conversions used in mechanics.

(a) State the SI unit used to measure (i) force, (ii) velocity, (iii) acceleration. **(3)**

(b) A quantity has units kg m s^{-2}. State what physical quantity this represents. **(1)**

(c) A cricket ball is bowled at a speed of 89 mph. Given that 1 mile = 1609 m, find this speed in m/s, giving your answer to 3 significant figures. **(3)**

(d) A student is asked to convert 54 km/h into m/s and writes: '54 km/h = 54 / 1000 / 3600 = 1.5 x 10^{-5} m/s'. Identify the error in the student's method, and hence find the correct value of 54 km/h in m/s. **(2)**

(Total for Question 2 is 9 marks)

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3 State the SI unit of acceleration.

(Total for Question 3 is 1 mark)

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4 Convert a speed of 90 km/h into m/s.

(Total for Question 4 is 1 mark)

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5 A go-kart moves along a straight track with constant acceleration. The table below shows its velocity v m/s at time t seconds after it passes a marker post P.

t (s): 0, 4, 8, 12
v (m/s): 3, 11, 19, 27

(a) Show that the go-kart's acceleration is constant, and state its value. **(3)**

(b) Using the go-kart's speed at P (t = 0), calculate the distance it travels from P to the point where t = 12. **(3)**

(c) After t = 12, the go-kart decelerates uniformly, coming to rest 6 seconds later. Find the magnitude of this deceleration. **(2)**

(d) Find the total distance travelled by the go-kart from P until it comes to rest. **(3)**

(Total for Question 5 is 11 marks)

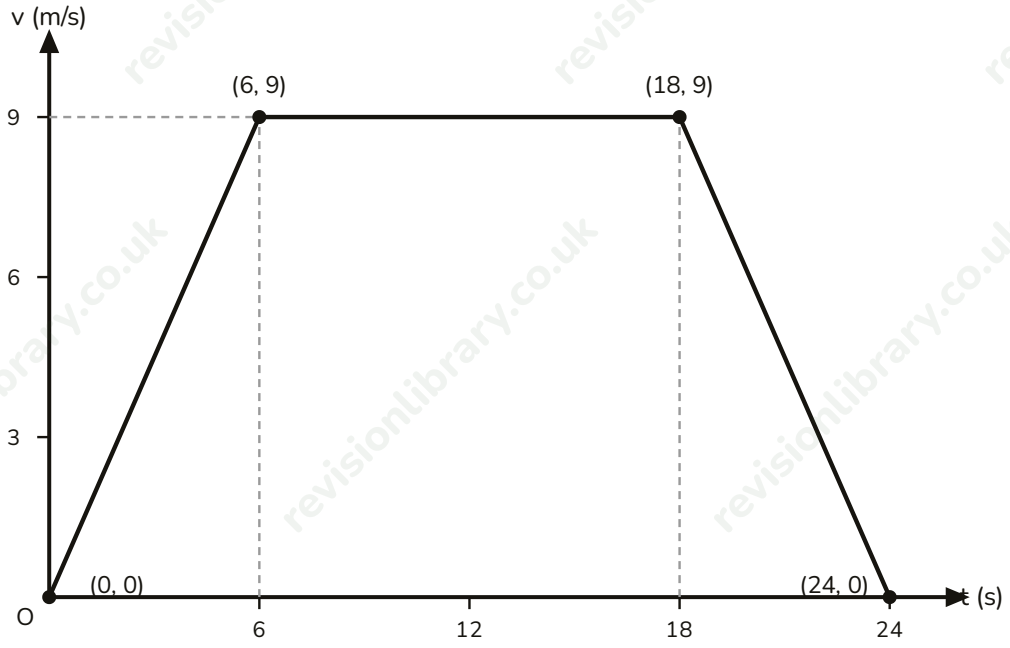
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6 A stone is dropped from rest and takes 2 seconds to reach the ground. Using $g = 9.8\ m/s^2$, find the height fallen.

(Total for Question 6 is 2 marks)

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7 The velocity-time graph for a cyclist's journey along a straight road consists of three straight line segments joining the points (0,0), (6,9), (18,9) and (24,0), where t is time in seconds and v is velocity in m/s.



(a) State what feature of a velocity-time graph represents the cyclist's acceleration. **(1)**

(b) Find the acceleration of the cyclist during the interval $0 \leq t \leq 6$. **(2)**

(c) Find the acceleration of the cyclist during the interval $18 \leq t \leq 24$. **(2)**

(d) Using the graph, calculate the total distance travelled by the cyclist. **(3)**

(e) Find the average speed of the cyclist for the whole journey. **(2)**

(Total for Question 7 is 10 marks)

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8 A ship S has position vector $(2\mathbf{i} + 5\mathbf{j})$ km relative to a lighthouse L at the instant $t = 0$, where time is measured in hours and i and j are unit vectors due east and due north respectively. The ship moves with constant velocity $(6\mathbf{i} - 3\mathbf{j})$ km/h.

(a) Find the position vector of S, relative to L, at $t = 2$. **(2)**

(b) Find the speed of the ship, giving your answer to 3 significant figures. **(2)**

(c) Find the time at which the ship is due east of the lighthouse. **(2)**

(d) At $t = 3$, a rescue boat sets off from the lighthouse L and travels directly towards the ship's position at that instant, at a constant speed of 25 km/h. Find, to the nearest minute, how long the rescue boat takes to reach that position. **(4)**

(Total for Question 8 is 10 marks)

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9 A cyclist rides from a depot D to a shop S, a distance of 4.5 km, at a constant average speed of 15 km/h. She stays at the shop for 6 minutes, then cycles back to D along the same route at a constant average speed of 12 km/h.

(a) Find the total time for which the cyclist is actually moving (that is, excluding the 6-minute stop), giving your answer in minutes. **(2)**

(b) Find her average speed for the whole 9 km round trip, using only the time she is actually moving, giving your answer in km/h to 3 significant figures. **(2)**

(c) State the value of her average velocity for the whole round trip (from leaving D to returning to D), including the time spent at the shop, and explain your answer. **(2)**

(d) Explain why the average speed found in part (b) is not equal to the mean of her two average speeds, 15 km/h and 12 km/h. **(2)**

(Total for Question 9 is 8 marks)

10 A student is asked to find the distance travelled by a particle that decelerates uniformly from 20 m/s to 8 m/s over 6 seconds. Their working is shown below:

$s = (u + v)t$

$s = (20 + 8) \times 6$

$s = 168$

Identify the error in the student's working, and find the correct value of s.

(Total for Question 10 is 3 marks)

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11 At time t = 0, a cyclist passes a fixed point O with constant speed 6 m/s, travelling in a straight line. At the same instant, a runner sets off from rest from O, moving in the same direction with constant acceleration 1.5 m/s^2. Find the time at which the runner catches up with the cyclist, and the distance from O at which this happens.

(Total for Question 11 is 4 marks)

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12 A particle P moves in a straight line with constant acceleration. It passes through three points A, B and C, in that order, where B is the midpoint of AC. The speeds of P at A, B and C are p m/s, q m/s and r m/s respectively, where p, q, r > 0.

(a) Show that $2q^2 = p^2 + r^2$. **(4)**

(b) Given that p = 3 and q = 5, find the value of r. **(3)**

(Total for Question 12 is 7 marks)

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Mark scheme · 3.1 Mechanics: Quantities, Units and Kinematics: Test Pack

Question 1

(a) kilogram (kg) for mass **B1**

(a) second (s) for time **B1**

(a) metre (m) for displacement **B1**

(a) Answer: (i) kilogram, kg (ii) second, s (iii) metre, m

(b) convert 3.2 km to 3200 m and 11 min 40 s to 700 s **M1**

(b) speed = distance / time = 3200 / 700 oe **M1**

(b) awrt 4.57 m/s **A1**

(b) Answer: 4.57 m/s (3 s.f.)

(c) divide by 1000 (1 g = 10^{-3} kg) **M1**

(c) 4.5 x 10^{-3} kg cao **A1**

(c) Answer: 4.5 x 10^{-3} kg

Question 2

(a) newton (N) for force **B1**

(a) metre per second (m/s) for velocity **B1**

(a) metre per second squared (m/s^2) for acceleration **B1**

(a) Answer: (i) newton, N (ii) metre per second, m/s (iii) metre per second squared, m/s^2

(b) force (since F = ma has units kg x m/s^2) **B1**

(b) Answer: Force.

(c) convert 89 miles to metres: 89 x 1609 = 143201 **M1**

(c) divide by 3600 to convert per hour to per second **M1**

(c) awrt 39.8 m/s **A1**

(c) Answer: 39.8 m/s (3 s.f.)

(d) identify the error: to convert km/h to m/s you multiply by 1000 (km to m) and divide by 3600 (per hour to per second); the student divided by 1000 instead of multiplying **M1**

(d) 15 m/s cao **A1**

(d) Answer: The student divided by 1000 instead of multiplying; the correct value is 15 m/s.

Question 3

m/s^2 (or m s^{-2}) oe **B1**

Answer: m/s^2

Question 4

25 cao **B1**

Answer: 25 m/s

Question 5

(a) calculate at least two of the gradients between consecutive readings, e.g. (11-3)/4 and (19-11)/4 **M1**

(a) cso: all three gradients equal 2, confirming constant acceleration **A1**

(a) a = 2 m/s^2 **B1**

(a) Answer: Constant acceleration confirmed; a = 2 m/s^2.

(b) use s = ut + 1/2 a t^2 with u = 3, a = 2 (ft from (a)), t = 12 **M1**

(b) s = 3(12) + 0.5(2)(12^2) correctly evaluated **M1**

(b) 180 m cao **A1**

(b) Answer: 180 m

(c) a = (0 - 27)/6 **M1**

(c) 4.5 m/s^2 (deceleration) cao **A1**

(c) Answer: 4.5 m/s^2

(d) distance during deceleration phase = 1/2(27+0)(6), ft from (c) **M1**

(d) add to the distance found in part (b), ft **M1**

(d) 261 m cao **A1**

(d) Answer: 261 m

Question 6

s = ut + 1/2 a t^2 with u=0, a=9.8, t=2 **M1**

19.6 m cao **A1**

Answer: 19.6 m

Question 7

(a) the gradient (slope) of the graph **B1**

(a) Answer: The gradient of the velocity-time graph.

(b) gradient = (9-0)/(6-0) **M1**

(b) 1.5 m/s^2 cao **A1**

(b) Answer: 1.5 m/s^2

(c) gradient = (0-9)/(24-18) **M1**

(c) -1.5 m/s^2, i.e. a deceleration of 1.5 m/s^2 cao **A1**

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

(d) area of triangle (0 to 6) + rectangle (6 to 18) + triangle (18 to 24) **M1**

(d) 0.5*6*9 + 12*9 + 0.5*6*9 correctly evaluated **M1**

(d) 162 m cao **A1**

(d) Answer: 162 m

(e) average speed = total distance/total time, ft from (d) **M1**

(e) 6.75 m/s cao **A1**

(e) Answer: 6.75 m/s

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Question 8

(a) r = r0 + vt applied with t=2 **M1**

(a) (14i - j) km cao **A1**

(a) Answer: (14i - j) km

(b) speed = $\sqrt{6^2 + 3^2}$ **M1**

(b) awrt 6.71 km/h **A1**

(b) Answer: 6.71 km/h (3 s.f.)

(c) set the j-component of the position vector equal to 0: 5-3t=0 **M1**

(c) t = 5/3 hours oe (1 hour 40 minutes), with the i-component positive confirming due east **A1**

(c) Answer: t = 5/3 hours (1 hour 40 minutes)

(d) find the position vector at t=3: 20i - 4j **M1**

(d) find the magnitude of this vector: $\sqrt{20^2 + 4^2}$ **M1**

(d) divide by 25 and convert the time from hours to minutes **M1**

(d) awrt 49 minutes **A1**

(d) Answer: 49 minutes (nearest minute)

Question 9

(a) time out = 4.5/15, time back = 4.5/12 (in hours or minutes) **M1**

(a) 40.5 minutes cao **A1**

(a) Answer: 40.5 minutes

(b) average speed = total distance/moving time, ft from (a) **M1**

(b) awrt 13.3 km/h **A1**

(b) Answer: 13.3 km/h (3 s.f.)

(c) 0 km/h **B1**

(c) because her overall displacement is zero, as she returns to her starting point D (oe) **B1**

(c) Answer: 0 km/h, because her overall displacement is zero (she finishes back at D).

(d) the mean of 15 and 12 is 13.5 km/h, which does not equal the 13.3 km/h found in (b) **B1**

(d) because average speed (total distance/total time) weights each leg by the time spent travelling it, and she spends unequal times on the two equal-length legs since her speeds differ (oe) **B1**

(d) Answer: The simple mean (13.5 km/h) ignores that she spends different amounts of time on each leg; average speed is weighted by time, not by simply averaging the two speeds.

Question 10

identifies that the student has omitted the factor of 1/2 (used s=(u+v)t instead of s=1/2(u+v)t) **B1**

correct method: s = 1/2(20+8)(6) **M1**

84 m cao **A1**

Answer: The student omitted the factor of 1/2 in the formula; the correct distance is s = 84 m.

Question 11

runner's distance from O is $1/2(1.5)t^2 = 0.75t^2$, using s = ut + 1/2 a t^2 with u=0 **M1**

set $0.75t^2 = 6t$ and solve, rejecting t=0 **M1**

t = 8 s cao **A1**

distance = 48 m cao **A1**

Answer: t = 8 s, at a distance of 48 m from O

Question 12

(a) let AB=BC=d and constant acceleration a; use $v^2=u^2+2as$ for A to B: $q^2=p^2+2ad$ **M1**

(a) use $v^2=u^2+2as$ for B to C: $r^2=q^2+2ad$ **M1**

(a) eliminate 2ad by equating $q^2-p^2 = r^2-q^2$ **M1**

(a) cso: rearrange to $2q^2 = p^2+r^2$ **A1**

(a) Answer: $2q^2 = p^2 + r^2$ (shown)

(b) substitute p=3, q=5 into $2q^2=p^2+r^2$, ft from (a) **M1**

(b) $r^2 = 50-9 = 41$ **M1**

(b) awrt 6.40 m/s **A1**

(b) Answer: r = 6.40 m/s (3 s.f.)

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