3.4 Mechanics: Projectiles and Further Kinematics: Test Pack

Total Marks

EDEXCEL 9MA0 · Calculator allowed · about 70 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A particle is projected horizontally with speed 12 m/s from the top of a cliff. State the initial vertical component of its velocity.

(Total for Question 1 is 1 mark)

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2 For a particle projected from and landing on horizontal ground, state the horizontal component of its velocity at the moment it lands, in terms of its initial horizontal component U.

(Total for Question 2 is 1 mark)

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3 A particle is projected horizontally with speed 10 m/s from the top of a cliff 19.6 m above the sea. Using $g = 9.8$ m/s^2, find the time taken for the particle to reach the sea.

(Total for Question 3 is 2 marks)

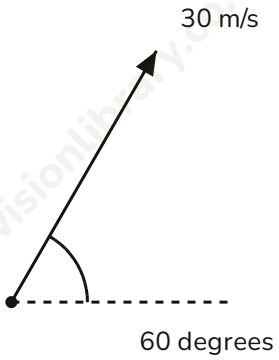
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4 A student was asked to find the horizontal component of the initial velocity of a particle projected at 30 m/s at an angle of 60 degrees above the horizontal. Their working is shown below:

Horizontal component = 30 sin60 = 26.0 m/s (3 s.f.)

Identify the error in the student's working, and find the correct value of the horizontal component, giving your answer to 3 significant figures.

Diagram NOT accurately drawn



(Total for Question 4 is 2 marks)

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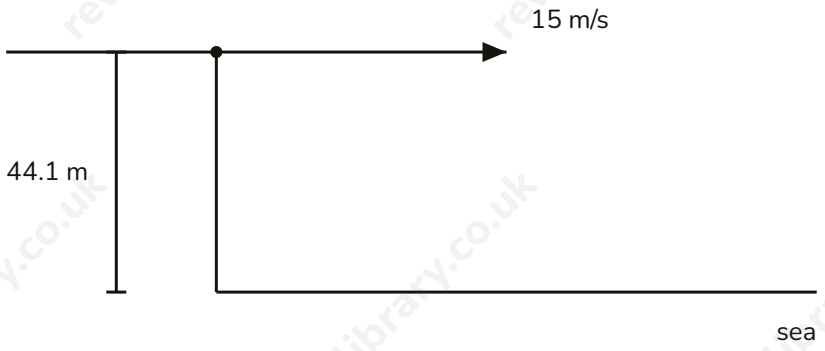
5 A particle P of mass 0.5 kg is acted on by a constant force F = (6i - 4j) N. When t = 0, P is at rest at the origin. Find the position vector of P at time t = 4 seconds.

(Total for Question 5 is 3 marks)

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6 A small stone is thrown horizontally with speed 15 m/s from the top of a vertical cliff. The point of projection is 44.1 m vertically above the sea, which may be modelled as a horizontal plane. The stone is modelled as a particle moving freely under gravity. Use $g = 9.8$ m/s^2.

Diagram NOT accurately drawn



(a) Show that the time taken for the stone to reach the sea is exactly 3 seconds. **(3)**

(b) Find the horizontal distance from the base of the cliff to the point where the stone lands. **(2)**

(c) Find the speed of the stone as it hits the sea, giving your answer to 3 significant figures. **(3)**

(d) Find the angle the velocity makes with the horizontal as the stone hits the sea, giving your answer to the nearest degree. **(2)**

(Total for Question 6 is 10 marks)

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7 A particle is projected from a point O on horizontal ground with speed U m/s at an angle α above the horizontal, where $\tan(\alpha) = 3/4$. Given that $U = 35$ m/s, use $g = 9.8$ m/s^2 throughout.

(a) Show that the initial horizontal and vertical components of the velocity are 28 m/s and 21 m/s respectively. **(2)**

(b) Find the time taken for the particle to reach its greatest height. **(2)**

(c) Find the greatest height above O reached by the particle. **(3)**

(d) Find the range of the projectile on the horizontal ground through O. **(3)**

(e) A vertical wall of height 15 m stands on the ground, in the vertical plane of the particle's motion, at a horizontal distance of 80 m from O. Determine, showing your working, whether the particle passes over the wall, strikes the wall, or lands before reaching the wall. **(5)**

(Total for Question 7 is 15 marks)

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8 A particle is projected from a point A at the top of a vertical cliff with speed 32 m/s at an angle of 25 degrees above the horizontal, in a direction away from the cliff. The point A is 55 m above the sea, modelled as a horizontal plane. The particle moves freely under gravity until it enters the sea. Use $g = 9.8$ m/s^2.

(a) Find the initial horizontal and vertical components of the velocity, each to 3 significant figures. **(2)**

(b) Find the time taken for the particle to enter the sea, giving your answer to 3 significant figures. **(4)**

(c) Find the horizontal distance from the base of the cliff to the point where the particle enters the sea, to 3 significant figures. **(2)**

(d) Find the speed of the particle as it enters the sea, to 3 significant figures. **(3)**

(Total for Question 8 is 11 marks)

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9 At time $t = 0$, a particle A has position vector $(4\mathbf{i} - 2\mathbf{j})$ m relative to a fixed origin O, and moves with constant velocity $(2\mathbf{i} + 3\mathbf{j})$ m/s. At the same time, a particle B has position vector $(-6\mathbf{i} + 10\mathbf{j})$ m and moves with constant velocity $(5\mathbf{i} - \mathbf{j})$ m/s. Positions are measured in metres and time in seconds.

(a) Find the position vector of A at time t seconds. **(2)**

(b) Find the position vector of B at time t seconds. **(2)**

(c) Show that $d^2 = 25t^2 - 156t + 244$, where d metres is the distance between A and B at time t seconds. **(3)**

(d) Hence find the minimum distance between A and B, and the value of t at which this occurs. **(4)**

(Total for Question 9 is 11 marks)

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Mark scheme · 3.4 Mechanics: Projectiles and Further Kinematics: Test Pack

Question 1

0 m/s **B1**

Answer: 0 m/s

Question 2

it equals U, unchanged, since there is no horizontal acceleration **B1**

Answer: It equals U (unchanged).

Question 3

use $s = 1/2\ g\ t^2$ with s=19.6 **M1**

2 s cao **A1**

Answer: 2 s

Question 4

identify the error: the student used sin60 (which gives the vertical component) instead of cos60 for the horizontal component **M1**

correct value: 15.0 m/s cao **A1**

Answer: Error: sin60 was used instead of cos60 (sin60 gives the vertical component, not the horizontal one). Correct horizontal component = 30cos60 = 15.0 m/s.

Question 5

use F = ma to find $a = F/m = (12i - 8j)\ m/s^2$ **M1**

use $r = r0 + ut + 1/2\ a\ t^2$ with u=0, r0=0, t=4 **M1**

(96i - 64j) m cao **A1**

Answer: (96i - 64j) m

Question 6

(a) use $s = ut + 0.5at^2$ vertically with u = 0, a = 9.8, s = 44.1 (oe) **M1**

(a) rearrange to $t^2 = 9$ **M1**

(a) t = 3 (cso) **A1**

(a) Answer: t = 3 s

(b) horizontal distance = 15 x 3 (oe) **M1**

(b) 45 m (cao) **A1**

(b) Answer: 45 m

(c) vertical speed $v_y = gt = 9.8 \times 3 = 29.4$ (oe) **M1**

(c) combine components: speed = $\sqrt{15^2 + 29.4^2}$ **M1**

(c) awrt 33.0 m/s **A1**

(c) Answer: 33.0 m/s (3sf)

(d) $\tan(\theta) = 29.4/15$ (oe) **M1**

(d) θ = awrt 63 degrees **A1**

(d) Answer: 63 degrees below the horizontal (nearest degree)

Question 7

(a) use $\sin(\alpha) = 3/5$, $\cos(\alpha) = 4/5$ (from $\tan(\alpha) = 3/4$) with U = 35 **M1**

(a) both components shown: 28 m/s and 21 m/s (cso) **A1**

(a) Answer: horizontal = 28 m/s, vertical = 21 m/s (shown)

(b) t = 21/9.8 **M1**

(b) t = 15/7 s = awrt 2.14 s **A1**

(b) Answer: 15/7 s = awrt 2.14 s

(c) use $v^2 = u^2 - 2gs$ with v = 0, u = 21 **M1**

(c) rearrange for s **M1**

(c) H = 22.5 m (cao) **A1**

(c) Answer: 22.5 m

(d) time of flight T = 2 x 15/7 = 30/7 **M1**

(d) R = 28 x T **M1**

(d) R = 120 m (cao) **A1**

(d) Answer: 120 m

(e) find time to reach horizontal distance 80: t = 80/28 = 20/7 **M1**

(e) substitute into vertical displacement equation $y = 21t - 4.9t^2$ **M1**

(e) y = 20 m at x = 80 m **A1**

(e) compare 20 m with wall height 15 m and confirm 80 m < range 120 m **M1**

(e) correct conclusion: the particle clears the wall, passing 5 m above it (cao) **A1**

(e) Answer: The particle passes over the wall (height at x=80 m is 20 m, greater than the 15 m wall; 80 m is less than the range of 120 m)

Question 8

(a) $u_x = 32\cos(25)$, $u_y = 32\sin(25)$ identified **M1**

(a) u_x = awrt 29.0 m/s and u_y = awrt 13.5 m/s **A1**

(a) Answer: u_x = 29.0 m/s, u_y = 13.5 m/s

(b) form vertical equation $-55 = 13.524t - 4.9t^2$ (oe, using unrounded u_y) **M1**

(b) rearrange to $4.9t^2 - 13.524t - 55 = 0$ (oe) **M1**

(b) solve quadratic (formula), reject negative root **M1**

(b) t = awrt 5.00 s **A1**

(b) Answer: t = awrt 5.00 s

(c) $x = u_x \times t$ (ft from (a) and (b)) **M1**

(c) x = awrt 145 m **A1**

(c) Answer: awrt 145 m

(d) vertical speed at impact $v_y = \sqrt{u_y^2 + 2 \times 9.8 \times 55}$ (oe, or $v_y = u_y - gt$) **M1**

(d) combine: speed = $\sqrt{u_x^2 + v_y^2}$ **M1**

(d) speed = awrt 45.8 m/s **A1**

(d) Answer: awrt 45.8 m/s

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Question 9

(a) $r_A = r0 + vt$ substituted **M1**

(a) $r_A = (4+2t)i + (-2+3t)j$ **A1**

(a) Answer: (4+2t)i + (-2+3t)j m

(b) $r_B = r0 + vt$ substituted **M1**

(b) $r_B = (-6+5t)i + (10-t)j$ **A1**

(b) Answer: (-6+5t)i + (10-t)j m

(c) find vector AB = $r_B - r_A$ **M1**

(c) form d^2 = (i-component)^2 + (j-component)^2 **M1**

(c) $d^2 = 25t^2 - 156t + 244$ (cso) **A1**

(c) Answer: $d^2 = 25t^2 - 156t + 244$ (shown)

(d) differentiate d^2 with respect to t and set equal to zero: $50t - 156 = 0$ **M1**

(d) t = 3.12 s (cao) **A1**

(d) substitute back to find d^2_min **M1**

(d) $d_{min} = 0.8$ m (cao) **A1**

(d) Answer: t = 3.12 s, minimum distance = 0.8 m

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