3.4 Mechanics: Projectiles and Further Kinematics: 30-minute Pack

Total Marks

EDEXCEL 9MA0 · Calculator allowed · about 30 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A particle is projected at an angle above horizontal ground and moves freely under gravity. State the vertical component of the particle's acceleration during the flight, using $g = 9.8$ m/s^2.

(Total for Question 1 is 1 mark)

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2 A particle is projected with speed 30 m/s at an angle of 40 degrees above the horizontal. Find the initial horizontal component of its velocity, giving your answer to 3 significant figures.

(Total for Question 2 is 1 mark)

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3 A particle is projected horizontally with speed 18 m/s from the top of a vertical cliff 78.4 m above the sea, modelled as a horizontal plane. Using $g = 9.8$ m/s^2, find the horizontal distance from the base of the cliff to the point where the particle lands.

(Total for Question 3 is 3 marks)

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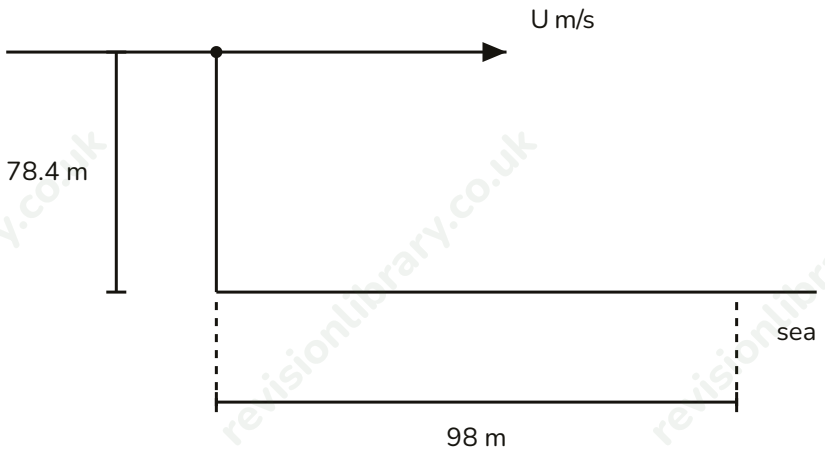
4 At time $t = 0$, a delivery drone A has position vector $(2\mathbf{i} + 6\mathbf{j})$ m and moves with constant velocity $(3\mathbf{i} - 1\mathbf{j})$ m/s. At the same time, a second drone B has position vector $(10\mathbf{i} + 2\mathbf{j})$ m and moves with constant velocity $(-1\mathbf{i} + 2\mathbf{j})$ m/s. Find the value of t at which the distance between A and B is least.

(Total for Question 4 is 3 marks)

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5 A particle is projected horizontally with speed U m/s from a point on top of a vertical cliff. The point of projection is 78.4 m above the sea, modelled as a horizontal plane, and the particle lands in the sea at a horizontal distance of 98 m from the base of the cliff. The particle is modelled as moving freely under gravity. Use $g = 9.8$ m/s^2.

Diagram NOT accurately drawn



(a) Find the time taken for the particle to reach the sea. **(3)**

(b) Find the value of U. **(2)**

(c) Find the speed of the particle immediately before it enters the sea, giving your answer to 3 significant figures. **(3)**

(d) Find the angle the velocity makes with the horizontal immediately before impact, to the nearest degree. **(2)**

(Total for Question 5 is 10 marks)

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6 A particle is projected from a point O on horizontal ground with speed 20 m/s at an angle θ above the horizontal, where $0 < \theta < 90$. Relative to O, the particle passes through the point with horizontal distance 15 m and height 5 m above the ground. Use $g = 9.8$ m/s^2.

(a) State the equation of the trajectory of a projectile launched from the origin with speed u at angle θ to the horizontal, in terms of x, y, u, θ and g. **(2)**

(b) Given that $u = 20$ m/s and the particle passes through the point (15, 5), show that $441 \tan^2(\theta) - 2400 \tan(\theta) + 1241 = 0$. **(4)**

(c) Hence find the two possible values of θ, giving each to 1 decimal place. **(5)**

(Total for Question 6 is 11 marks)

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Mark scheme · 3.4 Mechanics: Projectiles and Further Kinematics: 30-minute Pack

Question 1

9.8 m/s^2 downwards oe (i.e. -9.8 m/s^2 vertically)	**B1**

Answer: 9.8 m/s^2 downwards (i.e. -9.8 m/s^2 vertically)

Question 2

awrt 23.0 m/s	**B1**

Answer: 23.0 m/s (3 s.f.)

Question 3

find time of flight using s = 1/2 g t^2 with s=78.4	**M1**
t = 4 s, then horizontal distance = 18 x 4	**M1**
72 m cao	**A1**

Answer: 72 m

Question 4

find the position vector of A relative to B as a function of t: (4t-8)i + (4-3t)j oe	**M1**
form (distance)^2 = (4t-8)^2 + (4-3t)^2 = 25t^2 - 88t + 80 and minimise (differentiate and set to 0, or use t=-b/2a)	**M1**
t = 1.76 s cao	**A1**

Answer: t = 1.76 s

Question 5

(a) use s = ut + 0.5at^2 vertically with u = 0, s = 78.4 (oe)	**M1**
(a) rearrange to t^2 = 16	**M1**
(a) t = 4 (cao)	**A1**

(a) Answer: 4 s

(b) U = 98/4 (oe)	**M1**
(b) U = 24.5 m/s (cao)	**A1**

(b) Answer: 24.5 m/s

(c) v_y = gt = 9.8 x 4 = 39.2 (oe)	**M1**
(c) speed = $\sqrt{24.5^2 + 39.2^2}$	**M1**
(c) awrt 46.2 m/s	**A1**

(c) Answer: 46.2 m/s (3sf)

(d) tan(θ) = 39.2/24.5 = 1.6 (oe)	**M1**
(d) θ = awrt 58 degrees	**A1**

(d) Answer: 58 degrees below the horizontal

Question 6

(a) y = x tan(θ) - ... term with correct x tan(θ) component	**B1**
(a) correct full trajectory equation y = x tan(θ) - (g x^2 (1+tan^2(θ)))/(2u^2) (oe, e.g. using sec^2(θ))	**B1**

(a) Answer: y = x tan(θ) - (g x^2 (1 + tan^2(θ))) / (2u^2)

(b) substitute x=15, y=5, u=20, g=9.8 into trajectory equation	**M1**
(b) use 1+tan^2(θ) = sec^2(θ) and simplify the coefficient 9.8x225/(2x400) = 2.75625 (oe)	**M1**
(b) rearrange into a quadratic in tan(θ) and clear decimals	**M1**
(b) 441 tan^2(θ) - 2400 tan(θ) + 1241 = 0 (cso, or exact equivalent unsimplified form with correct working)	**A1**

(b) Answer: 441 tan^2(θ) - 2400 tan(θ) + 1241 = 0 (shown)

(c) use the quadratic formula to solve for tan(θ)	**M1**
(c) tan(θ) = awrt 4.86 or 0.579 (both values, ft from (b))	**A1**
(c) use arctan to find θ for each value	**M1**
(c) θ = awrt 78.4 degrees	**A1**
(c) θ = awrt 30.1 degrees	**A1**

(c) Answer: θ = awrt 30.1 degrees or θ = awrt 78.4 degrees

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