3.8 Mechanics: Projectiles and Applications Depth: 30-minute Pack

EDEXCEL 9MA0 · Calculator allowed · about 30 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

Key results: projectile motion and combining kinematics with forces

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Unless a question states otherwise, take g = 9.8 m/s^2 and model every object as a particle moving freely under gravity once released, so that gravity is the only force acting during the flight itself. For a particle projected from a point on horizontal ground with speed U at angle alpha above the horizontal, resolve the initial velocity into a horizontal component U cos(alpha), which is constant throughout the flight, and a vertical component U sin(alpha), which reduces uniformly under gravity; the horizontal and vertical motions can then be treated independently using the suvat equations, and combined using Pythagoras' theorem and trigonometry to find the resultant speed and direction at any instant. Two standard results you may quote without proof, unless a question asks you to derive them, are the time of flight on level ground, T = 2Usin(alpha)/g, and the range on level ground, R = U^2 sin(2alpha)/g; the greatest height reached is H = U^2 sin^2(alpha)/(2g). Several questions in this worksheet combine projectile motion with forces: where a particle or block is first accelerated by gravity and/or friction while in contact with a surface (for example sliding down a rough inclined plane, or being pulled by a connected particle over a pulley), use Newton's second law, F = ma, resolving forces parallel and perpendicular to the relevant surface, to find its speed at the point where it becomes a projectile, and then apply projectile motion to the remainder of its path. Vectors are given in terms of perpendicular unit vectors i and j; a position vector r(t) for a projectile can be written in terms of t by integrating, or by using the suvat equations componentwise, with constant acceleration -gj.

1 At time t = 0 a particle P has position vector (-5j) m relative to a fixed origin O, and velocity (3i - 4j) m/s. P moves with constant acceleration (3i + 2j) m/s^2.

(a) Find the velocity of P when t = 4, and its speed, to 3 significant figures. **(3)**

(b) Find the position vector of P when t = 4. **(2)**

(Total for Question 1 is 5 marks)

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2 A stone is projected horizontally with speed 14 m/s from the top of a vertical cliff, at a point 44.1 m above horizontal ground. The motion is modelled as that of a particle moving freely under gravity. Take $g = 9.8$ m/s^2.

(a) Find the time taken to reach the ground. **(2)**

(b) Find the horizontal distance from the point of projection to the point where it lands. **(2)**

(c) Find the speed and direction of motion at the instant before it lands, to 3 significant figures and the nearest degree. **(4)**

(Total for Question 2 is 8 marks)

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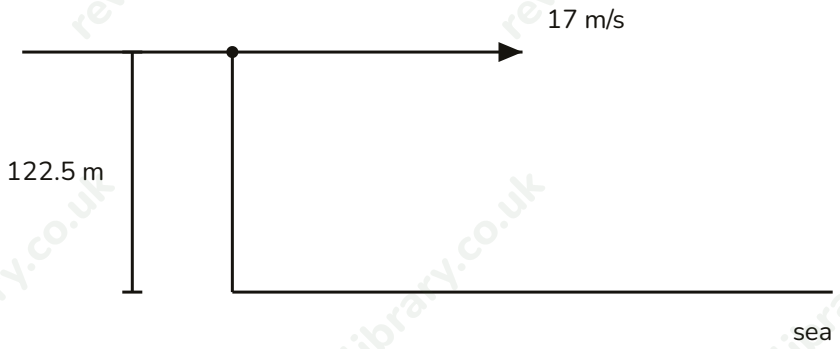
3 A particle is projected from ground level at an angle of 50 degrees above the horizontal, and lands on the same horizontal ground at a horizontal distance of 32 m from the point of projection. Take $g = 9.8$ m/s^2. You may quote the result $R = U^2 \sin(2\text{alpha})/g$ without proof. Find the initial speed U, giving your answer to 3 significant figures.

(Total for Question 3 is 2 marks)

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4 A ball is thrown horizontally with speed 17 m/s from a point at the top of a vertical cliff. The point of projection is 122.5 m vertically above the sea, which may be modelled as a horizontal plane. The ball is modelled as a particle moving freely under gravity. Take $g = 9.8$ m/s^2.

Diagram NOT accurately drawn



(a) Show that the time taken for the ball to reach the sea is exactly 5 seconds. **(3)**

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

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

(d) Find the angle the ball's velocity makes with the horizontal as it hits the sea, giving your answer to 3 significant figures. **(2)**

(Total for Question 4 is 10 marks)

5 A particle is projected from a point on horizontal ground with speed U at an angle of 20 degrees above the horizontal, and moves freely under gravity, landing on the same horizontal ground. The greatest height reached by the particle is 4.9 m. Take $g = 9.8$ m/s^2. Find the value of U, giving your answer to 3 significant figures.

(Total for Question 5 is 2 marks)

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Mark scheme · 3.8 Mechanics: Projectiles and Applications Depth: 30-minute Pack

Question 1

(a) uses $v = u + at$	**M1**
(a) $15i + 4j$	**A1**
(a) speed = 15.5 m/s	**A1**
(a) Answer: (15i + 4j) m/s, speed 15.5 m/s	
(b) uses $r = r0 + ut + (1/2)at^2$	**M1**
(b) (36i - 5j) m	**A1**
(b) Answer: (36i - 5j) m	

Question 2

(a) uses $s = ut + (1/2)at^2$ vertically: $44.1 = (1/2)(9.8)t^2$	**M1**
(a) t = 3.00 s	**A1**
(a) Answer: 3.00 s	
(b) horizontal speed is constant: distance = u t	**M1**
(b) 42.0 m	**A1**
(b) Answer: 42.0 m	
(c) vertical speed = gt = 9.8 x 3.000 = 29.400	**M1**
(c) combines the components: speed = $\sqrt{14^2 + 29.400^2}$	**M1**
(c) speed = 32.6 m/s	**A1**
(c) angle 65 degrees below the horizontal from tan(angle) = 29.400/14	**A1**
(c) Answer: 32.6 m/s at 65 degrees below the horizontal	

Question 3

rearranges $R = U^2 \sin(2\alpha)/g$ to $U^2 = Rg/\sin(2\alpha)$ and substitutes R = 32, α = 50 (oe)	**M1**
U = awrt 17.8 (m/s), cao	**A1**
Answer: U = awrt 17.8 m/s	

Question 4

(a) uses $s = ut + 0.5at^2$ vertically with u = 0, a = 9.8, s = 122.5 (oe)	**M1**
(a) rearranges to $t^2 = 25$	**M1**
(a) t = 5, cso	**A1**
(a) Answer: t = 5 s (shown)	
(b) horizontal distance = 17 x 5 (oe)	**M1**
(b) 85 (m), cao	**A1**
(b) Answer: 85 m	
(c) vertical speed at impact v_y = gt = 9.8 x 5 = 49 (oe)	**M1**
(c) combines components: speed = $\sqrt{17^2 + 49^2}$	**M1**
(c) awrt 51.9 (m/s)	**A1**
(c) Answer: 51.9 m/s (3sf)	
(d) $\tan(\theta) = 49/17$ (oe)	**M1**
(d) θ = awrt 70.9 (degrees)	**A1**
(d) Answer: 70.9 degrees below the horizontal (3sf)	

Question 5

rearranges $H = U^2 \sin^2(\alpha)/(2g)$ to $U = \sqrt{2gH}/\sin(\alpha)$ and substitutes H = 4.9, α = 20 (oe)	**M1**
U = awrt 28.7 (m/s), cao	**A1**
Answer: U = awrt 28.7 m/s	

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