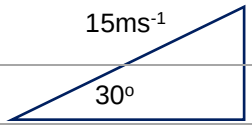
Projectile Questions (Answers) for A-level Physics

Basic Concepts

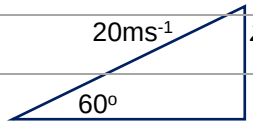
1. A stone is thrown at an angle of 30° with an initial velocity of 15 ms^{-1}. Calculate the horizontal and vertical components of its velocity.



Horizontal component: 15 cos 30° = **13ms^{-1}**

Vertical component: 15 sin 30° = **7.5ms^{-1}**

2. A football is kicked with a velocity of 20 ms^{-1} at an angle of 60° to the horizontal. Calculate the time of flight before the football hits the ground.

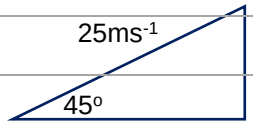


Vertical component: a = v-u / t so t = v-u / g

t = 20 sin 60° / 9.81 = 1.77 seconds

2 x t = **2.5 seconds**

3. A projectile is launched at a speed of 25 ms^{-1} at an angle of 45°. Calculate the range of the projectile (assuming no air resistance).



Vertical component:	Horizontal component:
t = v-u /g	s = v t
= 25 sin 45° /9.81	= 25 cos 45° x 3.6
= 1.8 s so total time = 3.6 s	= **63.6 metres**

4. A ball is thrown horizontally at 10 ms^{-1} from a cliff that is 20 meters high. How long does it take for the ball to reach the ground?

Vertical component only: $s = ut + \frac{1}{2} at^2$

$20 = 0 + (\frac{1}{2} \times 9.81 \times t^2)$

$(20 \times 2) / 9.81 = t^2$

$\sqrt{4.077} = t$ = **2.0 seconds**

5. A rock is thrown vertically with a speed of 18 ms^{-1}. How high does it go before it starts falling back down?

Vertical component only: $v^2 = u^2 + 2as$

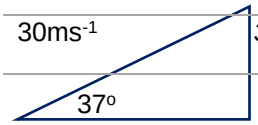
$0 = 18^2 + (2 \times (-)9.81 \times s)$

$s = 18^2 / (2 \times 9.81)$ *[negative signs cancel]*

= **16.5 metres**

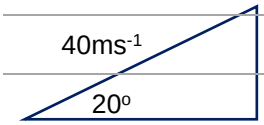
Intermediate Questions

6. A projectile is launched at a speed of 30 ms^{-1} at an angle of 37° from the horizontal. Calculate both the total time of flight and the range.



Vertical component:	Horizontal component:
t = v-u / g	s = v t
= 30 sin 37° / 9.81 = 1.84	= 30 cos 37° x 3.68
2 x t = 3.68 = **3.7 seconds**	= **88 ms^{-1}**

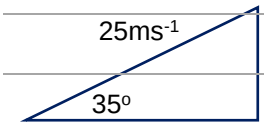
7. A tennis ball is served with an initial velocity of 40 ms^{-1} at an angle of 20° to the horizontal. Calculate the maximum height reached by the ball.



Vertical component: $v^2 = u^2 + 2as$

0 = (40 sin 20°) + (2 x (-)9.81 x s)
187.2 / (2 x 9.81) = s
= **9.5 metres**

8. A projectile is fired from the ground with an initial velocity of 25 ms^{-1} at an angle of 35°. If the projectile is in the air for 3.2 seconds, calculate its range.



Horizontal component: s = v t

= 25 x cos 35° x 3.2
= 65.5 = **66 metres**

9. A projectile is fired horizontally from a height of 50 meters with an initial speed of 20 ms^{-1}. Calculate its speed just before it hits the ground.

Horizontal speed : 20ms^{-1}

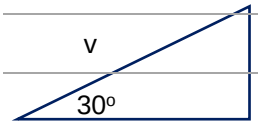
To find vertical speed: $v^2 = u^2 + 2as$ $= 0 + (2 \times 9.81 \times 50)$ $= 981$

$v = \sqrt{981}$ $= 31.3\ ms^{-1}$

Use Pythagoras to find total speed: $speed^2 = 20^2 + 31.3^2 = 1381$ $speed = \sqrt{1381}$ = **37 ms^{-1}**

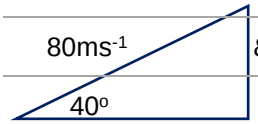
10. A projectile is launched at an angle of 30° and reaches a maximum height of 45 meters. What was its initial velocity?

Vertical component: $v_y^2 = u_y^2 + 2as$



	$0 = u^2 + (2 \times (-)9.81 \times 45)$
	$u = \sqrt{2 \times 9.81 \times 45}$ = 29.71ms^{-1}
v cos 30°	so: v sin 30° = 29.71 v = 29.71 / sin 30° = **59 ms^{-1}**

11. A cannonball is launched with an initial velocity of 80 ms^{-1} at an angle of 40°. Calculate both the time taken to reach its maximum height and the speed at that point.



Vertical component:	Horizontal component:
t = v-u / g	(*there is no vertical speed at the apex)*
= 80 sin 40° / 9.81	v = 80 cos 40°
= **5.2(4) seconds**	= **61(.3) ms^{-1}**

Advanced Applications

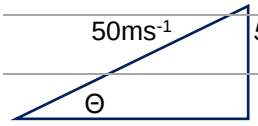
12. An airplane flying horizontally at 120 ms^{-1} releases a package from a height of 500 m. How far horizontally from the point of release does the package land?

Find the time to fall: $s = ut + ½ at^2$

$500 = 0 + (½ \times 9.81 \times t^2)$	find the distance: $s = v t$
$t^2 = 500 / (½ \times 9.81)$	$= 120 \times 10.1$
$t = \sqrt{101.94}$	= 1212 m
= 10.1 seconds	= **1.2 km**

13. A projectile is launched with a speed of 50 ms^{-1}. At what angle should it be launched to achieve a range of 200 meters?

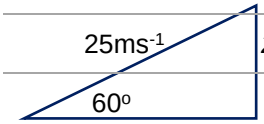
[we are going to work backwards – starting with the using the range to find the time]



Horizontal component:	$t = s / v$	$= 200 / 50\cos\theta$
Vertical component:	$½ t = v-u / g$ so	$t = 2 \times 50 \sin\theta / 9.81$
substituting for t:	$\frac{200}{50\cos\theta} = 2 \times \frac{50\sin\theta}{9.81}$ so	$\frac{200 \times 9.81}{50 \times 50} = 2\sin\theta\cos\theta$
[trig identity 2 sinθ cosθ = sin 2θ]	$\frac{200 \times 9.81}{50 \times 50} = \sin 2\theta$	$2\theta = 51.702°$ $\theta =$ **26°**

14. A ball is thrown from a height of 5 meters at an initial velocity of 25 ms^{-1} at an angle of 60°. Calculate its speed when it hits the ground.

Calculate time to reach apex: $t = v-u / g = 25 \sin 60^o / 9.81 = 2.207$ seconds



25sin60° Calculate the total heigh reached: $s = ut + ½ at^2$

$= (25 \sin 60^o \times 2.207) + (½ \times 9.81 \times 2.207) = 47.78 + 10.83 = 58.61$

25cos60° It falls 5 metres further so total drop is: 58.61 + 5 = 63.6 m

To find vertical speed as it hits the ground: $v^2 = u^2 + 2as = 2 \times 9.81 \times 63.6 = 1248$

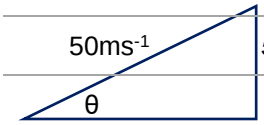
$v = \sqrt{1248} = 35.3\ ms^{-1}$

Using Pythagoras to find total speed: $speed^2 = 35.3^2 + (25 \cos 60^o)^2$

Speed = **37 ms^{-1}**

15. A projectile is launched at 50 ms^{-1} from the ground and must hit a target 100 meters away at the same level. At what two angles can the projectile be launched to achieve this?

Time to target: $t = s / v = 100 / 50 \cos \theta$



50sinθ Time to apex: $½ t = v-u / g$ so $t = 2 \times 50 \sin \theta / 9.81$

Equating these: $\frac{100}{50 \cos \theta} = 2 \times \frac{50 \sin\theta}{9.81}$ so: $\frac{100 \times 9.81}{50 \times 50} = 2 \sin\theta \cos\theta$

50cosθ *[trig identity 2 sinθ cosθ = sin 2θ]* $\frac{100 \times 9.81}{50 \times 50} = \sin 2\theta$ $2\theta = 23.10^o$ or 156.90^o

$\theta = \mathbf{12^o}$ **or** $\mathbf{78^o}$