A-Level Physics

Projectile Motion

Mark Scheme

Time available: 81 minutes
Marks available: 60 marks

1.

(a) horizontal velocity = 20 cos 40° = 15.3 ✓ (m s^{-1})

Needs minimum 3 sf

For MP1 it must be clear that the horizontal velocity has been determined.

horizontal velocity (is constant) / minimum when vertical velocity = 0 ✓

2

(b) (vertical velocity) v = 20 sin 40° (= 12.9) ✓ (m s^{-1})

$s = ut + \frac{1}{2}at^2$

$-3 = -12.9t + \frac{1}{2} \times 9.81t^2$ or $3 = 12.9t - \frac{1}{2} \times 9.81t^2$ ✓

($4.91t^2 - 12.9t + 3.00 = 0$)

For second mark both suvat equation and substitution must be shown. Equation may be rearranged before substitution

2

(c) Use of quadratic formulae with +, − or ± ✓

eg $t = \frac{12.9 \pm \sqrt{(-12.9)^2 - 4 \times 4.91 \times 3.00}}{2 \times 4.91}$

0.258 s and 2.37 s✓

Two correct answers alone scores first 2 marks.

Time to reach 3 m once on the way up and once on the way down (OWTTE)✓

Larger value ✓

ecf available for last 2 marks

4

(d) $s = vt$ = 20 cos 40° × 2.37 = 36.3 m so no✓

*ecf from **(c)***

Calculation must be seen

1

(e) Gradient is the acceleration **AND**

area under graph = <u>vertical</u> distance travelled✓$_1$

Without air resistance:
comment about gradient✓$_2$
comment about area✓$_3$

With air resistance
comment about gradient✓$_4$
comment about area✓$_5$

For each comment on the graph a reason must be given not just a description.

e.g for ✓$_2$

• constant gradient = g or 9.81 m s^{-1}

e.g. for ✓$_4$

• initially steeper gradient since air resistance in same direction as weight (so a > g)

• when line crosses time axis, gradient = g /9.81 / gradient without air resistance as air resistance = 0 when v = 0 /

• After crossing time axis, gradient decreases as air resistance increases with speed

E.g. for ✓$_3$ or ✓$_5$

• total area under graph = 0 since ball starts and finishes on ground

• area between graph and axis is max height/ ***vertical*** *distance*

• without air resistance reaches a higher height as area greater

statement referring to area under both graphs gains ✓$_3$ and ✓$_5$

5

[14]

2. (a) Use of an appropriate equation of motion ✓

Where $v^2 = u^2 + 2as$ is correctly stated, condone one error in substitution e.g. sign of a

Where other equations are used it must be clear that v can be determined.

Must see v as subject and an attempt to determine t.

(v =) 0.35 (m s^{-1}) ✓

Allow more than 2 sf where correct.

2

(b) Use of tan 35 = u_v / 8.8

Or

Use of u cos 35 = 8.8 and u_v = u sin 35

and

6.2 or 6.16 with supporting a calculation ✓

Alternative: credit use of sine rule

Must see answer to at least two significant figures

1

(c) Use of an appropriate equation of motion ✓ ECF

Condone their incorrect value of u in this substitution.

Condone errors in signs in substitution Where other equations are used it must be clear how t can be determined.

Must see t as subject and an attempt to determine s.

(t=) 0.63 (s) ✓ ECF

0.61 (s) for use of u = 6 m s^{-1}

For MP2, where their value of u is used, the answer must be consistent with this value. ***Only*** *allow this use where their value of u, to 1 significant figure, = (5<u<7) m s^{-1}*

Condone 1 significant figure answer where U is 1 sig fig.

2

(d) Use of an appropriate equation of motion ✓ ECF

Where equation is correctly stated, condone one error in substitution e.g. ***one error on sign*** *of a substituted value* ***or*** *one incorrect value substituted (of course, ecf is acceptable)*

(h =) 1.9 (m) ✓ ECF

h = 1.83 m for use of u = 6 m s^{-1} allow ecf on t (check (c))

For MP2, where their value of u is used, the answer must be consistent with this value. ***Only*** *allow this use where their value of u, to 1 significant figure, = (5<u<7) m s^{-1}*

allow reverse calculation where u=0 and v = 6 m s^{-1}

2

(e) Smooth curve with maximum turning point seen, curve starts at the ball and finishes at **X** ✓

Curve should be approximately parabolic in shape.

Curve must start below the label 'golf ball' and ends within 5mm of the ball or the label ***X****. Curve must have a maximum turning point.*

1

(f) (Increase the angle to horizontal so) the ball must go higher (and increases its time in the air)

Or

(Increase the angle to horizontal so) the ball must have a greater (initial) vertical velocity ✓

(Covers the same horizontal distance over) a longer time in the air (so has a smaller horizontal velocity) ✓

Alternative:

Increased angle (to horizontal of projection) so smaller horizontal velocity ✓

must be falling towards ground to land at **X** ✓

(Increase the angle to horizontal so that) the vertical velocity greater than the horizontal / increase the vertical decreases the horizontal

2

[10]

3. (a) The <u>centre of mass</u> of the beam and box is at the pivot ✓

Idea that moments balance / sum of the moments is zero at this position ✓

OR

The anticlockwise moment (of weight of the beam) = clockwise moment (of weight of the box) ✓

Links pivot position to a consideration of moments ✓

Accept one route or the other, do not accept points from both.

Allow max 1 for "the pivot is to the right of the centre (of mass) of the beam"

'pivot' on its own does not get the first mark

Award 2 for 1.25 × weight of beam = 1.5 × weight of empty box

Confusion of moments with eg work done/forces = max 1

2

(b) Clockwise moment = 610 × 9.81 × 1.5 (= 8976 N m) ✓

Anticlockwise moment = 250 × 4 + T sin 50 × 4.0 (N m)✓

Use of clockwise = anticlockwise✓

Use of T sin 50° seen / relates vertical component to tension✓

T (= 1994/sin 50°) = 2600 (N)✓

Credit any evidence to work out a moment with one mark

Condone cos 50 in MP2.

Allow ecf for clockwise moment

Allow ecf for anticlockwise moment

Use of g = 10 N kg^{-1} gives 2990 N Omission of 4.0 m (g = 9.8) gives 10410 N. Use of cos 50 (g = 9.8) gives 3100 N

Allow max 4 for use of g = 10 N kg^{-1}.

5

(c) 7.5 = ½ g t^2 ✓

(t = 1.2 s)

(calculate distance)

s (= ut = 18 × 1.2) = 22 (m)✓

Allow ecf from incorrect t for MP2

2

(d) **(Range will be greater:)**

component of velocity upwards ✓

rock will spend longer in the air ✓

greater t ✓

therefore the range is greater ✓

OR

(Range will be smaller)

Counterweight will fall less far before projectile released ✓

Less energy transferred to rock ✓

Initial speed of rock less/horizontal velocity reduced ✓

therefore the range is smaller ✓

OR

(balanced arguments)

therefore the range is unchanged / answer is indeterminate ✓

Candidates can argue from both lists to reach a balanced view suggesting that there is no change.

Full credit can be obtained from 2 deductions from one list ✓✓+ consistent conclusion ✓

1 deduction from each list ✓✓+ consistent conclusion ✓

Do not allow an unsupported conclusion.

*Conclusion must be consistent with **correct** statements.*

Treat incorrect statements as neutral.

Do not reward arguments based on a longer time of flight.

MAX 3

[12]

4. (a) resultant force = 11 000 × 2.9 = 31900 (N) ✓

resultant force = thrust − air resistance

OR

31 900 = 230 000 – air resistance✓

198 000 (N) ✓

3

(b) Air resistance increases with speed so resultant force decreases with speed ✓

Eventually air resistance = thrust (so no acceleration)✓

2

(c) Time to reach maximum height = 2.5/9.8=0.255 s✓

maximum height = $1.5 + 4.9 \times 0.255^2 = 1.82$ m✓

Time to reach ground from maximum height = 0.61 s giving total time = 0.87 s✓

OR

$-1.5 = 2.5t - 0.5 \times 9.8 \times t^2$✓

rearrange quadratic gives $4.9t^2 - 2.5t - 1.5 = 0$ and

solution $t = \frac{2.5 \pm \sqrt{2.5^2 + 4 \times 4.9 \times 1.5}}{2 \times 4.9}$ ✓

Giving solutions 0.86 or − 0.35 hence time = 0.86 s✓

Allow credit for alternative routes

3

(d) Starts at 2.5 m s^{-1} and maximum height same but reached earlier✓

Maximum range no more than 175 m✓

2

(e) Motion unchanged vertically / maximum height of P is unchanged: air resistance decelerates P horizontally so less distance travelled. (both points needed) ✓

Air resistance increases with speed: speed is low vertically but very high horizontally (both points needed) ✓

2

[12]

5. (a) Vertical velocity = 40 sin 30

= 20 (m s^{-1}) ✓

1

(b) Line vertically downward from point X ✓

Ignore labelling unless two or more arrows drawn

1

(c) Method leading to a numerical answer

e.g. v = u + at / 0 = 20 − (9.81 × t) gives t = 2.0(4) ✓

total time of flight = 4.08 / 4.1 (s) ✓

Any alternative acceptable method allowed

Need to see one or more dp for final credit

2

(d) Straight line (of positive or negative gradient) ✓

Starting at 20 ms^{-1} (or − 20 ms^{-1}) ✓

Crossing the x axis at 2.0s approximately ✓

*Any single straight line over the 6.0s will score this mark **OR** ecf from part **(a)***

Any line which crosses at 2.0s (and only here) will score this mark

3

(e) Area under graph (between 4s and 6s) ✓

$= (20 \times 2) + \frac{1}{2}(20 \times 2)$ ✓

= 60 m ✓

Alternative to use equation of motion selecting

$s = ut + \frac{1}{2} at^2$ ✓

$s = (20 \times 2) + \frac{1}{2} (9.81 \times 2^2)$ ✓

$s = 59.6$ *m* ✓

(values with 56 − 62 acceptable from graph)

3

(f) ***MAX 2***

reaches lower height than X✓

at an earlier time✓

hits ground closer to cliff base✓

MAX 2

[12]