MARK SCHEME

PHYSICS

AS-Level

PROJECTILE MOTION
TEST 1

Mark schemes

1 (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]

2 (a) (i) (using sin 25° = V_V/V
$V = V_V$ / sin 25°)
=5.0/sin25° ✓
11.8 (m s^{-1}) ✓
(working and answer is required)

Look out for cos 65° = sin 25° in first mark.

Also calculating the horizontal component using cos 25° followed by Pythagoras is a valid approach.

Working backwards is not acceptable.

2

(ii) (using tan 25° = V_V / V_H)
$V_H = V_V$ /tan 25° ✓
= 5 / tan 25° =11(m s^{-1}) ✓ (10.7m s^{-1})
Or (using cos 25° = V_H / V)
$V_H = V$ cos 25° ✓ = 11.8 cos 25° = 11 (m s^{-1}) ✓ (10.7 m s^{-1})
Or (using $V_H^2 + V_V^2 = V^2$)
$V_H^2 + 5^2 = 11.8^2$ ✓ (0r 12^2)
V_H = 11 (m s^{-1}) ✓ (10.7 m s^{-1})

Note 1/cos 65° = sin 25°

and tan 25° = 1/ tan 65°

Rounding means answers between 10.7 and 11 m s^{-1} are acceptable

2

(b) (i) (using $v^2 = u^2 + 2as$ with up being positive
0 = 5.0^2 + 2 × -9.81 × s)
s = 1.3 (m) ✓ (1.27 → 1.28 m)
or (loss of KE = gain of PE
½ ~~m~~ v^2 = ~~m~~ $g\ h$
½ 5.0^2 =9.81 × h)
h = 1.3 (m) ✓ (1.27 → 1.28 m)

quoted to 2 sig figs ✓

for the sig fig mark the answer line takes priority. If a choice of sig figs given and not in answer line – no sig fig mark

Sig fig mark stands alone provided some working is shown

2

(ii) (using $s = (u + v)t/2$) or horizontal distance = speed × time)
$s = 11 \times 1.3 = 14$ (m) ✓ (using 10.7 gives the same answer)

allow CE s = (aii) × 1.3 but working must be seen

1

(c) (i) **A** marked at the point of landing or immediately before ✓

*The **A** or its marked position must not be further to the left than the 'c' in the word 'scale'*

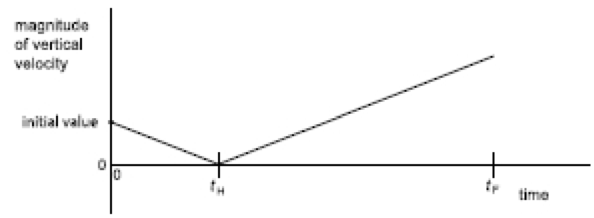
1

(ii) **B** marked at the maximum height of the path ✓

*The **B** must lie vertically between the 'r' and 'a' in the word 'resistance above figure 2.*

1

(d) <u>straight</u> line from point given down to point t_H on the axis ✓
<u>straight</u> line starting where first line stops (t_H) but with opposite gradient to the first line ✓



(A measure of accuracy for the second mark) The second line must end (t_H) between the height of the vertical axis and half this height.

Obviously straight lines drawn by hand are acceptable.

2

[11]

3 (a) (i) 720 sin 50° or 720 cos 40°
550 (552) (N)

2

(ii) 58 × 9.81 or 569 seen
19 (N)

Allow 569-(their (a)(i) for 2 marks

2

(iii) Upthrust is same as normal reaction (or same as their (a)(ii)
Newton's 2nd or 3rd Law or Archimedes' Principle reason given

2

(b) u_h = 12 cos 17° or 11.5 (m s^{-1}) seen
u_v = 12 sin 17° or 3.5 (m s^{-1}) seen
Use of $v^2 = u^2 + 2as$ with either 3.5 or 1.8 or v_v = 6.9 (m s^{-1})
13.4 (m s^{-1})

OR

Initial KE = 0.5 × 58 × 12^2 or 4176 (J) seen
ΔGPE = 58 × 9.81 × 1.8 or 1024 (J) seen
or v = √(2 × 9.81 × 1.8) or 5.9 (m s^{-1}) seen
Final KE = 5200 (J) or v = √(2.KE/m)
13.4 (m s^{-1})

Allow valid suvat arguments that use time of flight

4

[10]

4 (a) (i) $t = \sqrt{\frac{2s}{g}}$ (evidence for correct rearrangement or substitution) **(1)**

$= \sqrt{\frac{2 \times 67}{9.81}}$ (correct substitution leading to answer) **(1)**

(= **3.7** (3.696) (s))

2

(ii) $\left(v = \frac{s}{t} = \frac{150}{3.696}\right)$ = **41** (m s^{-1}) **(1)** 2sf **(1)**

2

(iii) $(v = (u+)gt =) 9.81 \times 3.696$ **(1)** = **36** **(1)** (m s^{-1})

2

(iv) $v = \sqrt{40.586^2 + 36.257^2}$ (or correct scale drawing) **(1)**

= 54 (m s^{-1}) **(1)**

ecf from (ii) (iii) [for scale drawing allow range 53 → 56]

$\tan\theta = \frac{36.257}{40.586}$ **(1)** or correct alternative

(angle from horizontal =) **42** (°) or correct alternative angle
and clear indication of direction (1)

[for scale drawing allow range 40 → 44 **(1)**
for scale drawing: quality of construction **(1)**]

4

(b) (i) (= mgh = 22 × 9.81 × 67) = 14000 (14460) (J) **(1)** 1

(ii) (G)PE → KE **(1)**

(KE to) internal/thermal/'heat' (energy) **(1)** 2

[13]

5 (a) velocity vector tangential to path and drawn from the ball, arrow in correct direction **(1)**

acceleration vector vertically downwards, arrow drawn and in line with ball **(1)** 2

(b) (i) $s = ½ gt^2$ gives $t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2 \times 24}{9.8(1)}}$ **(1)** = 2.2(1) s **(1)**

(ii) v (= s/t) = 27/2.2(1) **(1)** = 12(.2 m s^{-1}) or 12(.3) **(1)** (ecf from (b)(i))

(answer only gets both marks) 4

[6]

6 (a) (i) $v = s / t$ C1

19 (18.7) m s^{-1} A1

(ii) zero tolerate missing unit B1

(iii) $v^2 = (u^2) + 2as$ $v = u + at^2$ $s = ut + 1 / 2at^2$ C1

$v = \sqrt{(2 \times 9.8 \times 11)}$ C1

15 m s^{-1} / 14.7 m s^{-1} A1

(b) (i) use of Pythagoras C1

$18.7^2 + 14.7^2 = v^2$ **OR** $v^2 = \sqrt{(\text{their (a)(i)}^2 + \text{their (a)(iii)}^2)}$ C1

24 (23..7 or 23.8) ms^{-1} **ecf** A1

OR velocities drawn correctly to scale C1

suitable scale used and quoted M1

23 – 25 m s^{-2} A1

(ii) 38° to 39° 37° to 40° for scale drawing

ecf $\tan^{-1} \dfrac{\text{their (a)(iii)}}{\text{their (a)(i)}}$ B1

(c) when kicked / when landing has max KE B1

has no PE at this point / has max speed and KE = $\frac{1}{2}mv^2$ B1

or loses energy because of (work done against) air resistance B1

total energy greatest just after it's been kicked B1

[12]

7 C

[1]

8 A

[1]

9 B

[1]

10 A

[1]

11 C

[1]

2 (a) (i) The answers seen split clearly into two groups. The largest of which scored the mark because they could resolve a vector into its components. The smaller group did not score because they thought the question could be approached through the equations of motion.

(ii) Slightly fewer scored full marks compared to those in 2(a)(i) because, although just as many used a vector rather than an equation of motion approach, there was more opportunity for things to go wrong. There was more data to choose from with the velocity and the vertical component of velocity both available.

(b) (i) A majority of students performed well choosing the correct equation of motion to obtain the correct answer. There were a number of students who used the wrong equation and / or data. Also equal numbers scored one mark either by answering with a wrong answer given to two significant figures or by giving the correct answer but not using two significant figures.

(ii) Again the vast majority had no problem with this question especially when an error carried forward was allowed. Those who got it wrong normally wanted to include a non-zero acceleration and used the value of 'g'.

(c) These questions were generally answered very well.

(d) The overall correct shape was achieved by a majority of students. Some students did not realise that the lines on the graph needed to be straight because of the constant acceleration due to gravity. An equal number seemed to guess at the answer and had the maximum speed at the time corresponding to the maximum height.

3 (a) Part (i) was correctly answered by over 85% of students. Almost all students knew that the weight of the kite boarder was necessary in part (ii), but only half realised that it needed to be subtracted from the answer to part (i). Most students struggled with part (iii), with only about 20% of students gaining full marks. Sketched force diagrams, which would have aided the comprehension of the system, were rarely seen.

(b) This question was challenging to students, with only about 20% gaining full credit. There were two valid methods to solving this question: using suvat equations or considering energy changes.

4 The majority of candidates were successful in part (a) (i). A few worked backwards by substituting 3.7 and getting 67.15 m. This only received two marks if there was a clear statement that this showed 3.7 to be the correct time. Candidates should be encouraged to write down their answer to more than two significant figures for ‘show that’ questions like this one, although this was not penalised here.

A very large number of candidates expressed their answer to part (a) (ii) to three significant figures (eg 40.5) rather than two significant figures. Many used 67 m instead of 150 m. As a result, few gained both marks.

The majority gained two marks in part (a) (iii). A common incorrect answer was v = 67/3.7 = 18, where candidates were not aware that this was not appropriate for constantly accelerated motion.

Most candidates realised that Pythagoras' theorem was needed in part (a) (iv). However, a surprising number incorrectly used the values 150 m and 67 m, rather than their answers to parts (a) (ii) and (a) (iii). Many candidates gave bearings from north instead of an angle from the horizontal or vertical. The best way to convey direction here would be to calculate the angle and then show this on a sketch and also write 'angle from horizontal'. If there is not a clear diagram then the candidate would need to say 'from the horizontal and downwards to the right' or words to that effect.

Very few candidates had a problem with part (b) (i).

For part (b) (ii), there was some confusion about energy changes. Most candidates mentioned transfer of PE to KE but did not go beyond 'energy lost due to air resistance' and did not gain the second mark. The question asks for 'energy changes' so they needed to say *kinetic energy* changes to *internal energy* (*heat/thermal* are also accepted at AS). Some described the motion in terms of forces, velocity and acceleration – these gained no marks. Quite a few described the kinetic energy changing to gravitational as the cannonball emerges from the cannon.

5 In part (a), a large number of candidates thought that the horizontal component of velocity was to be shown rather than the instantaneous velocity at a tangent to the path. Many candidates who had the right idea still did not gain marks due to a badly drawn tangential arrow. The mark for the acceleration was gained by many candidates. Of those candidates who gained no marks in part (b) (i), many simply could not rearrange s = 1/2gt^2. Those who successfully did this picked up both marks. A majority of candidates gained two marks but some believed they had to use a 'suvat. equation and gained no marks.

6 (a) (i) Most candidates managed the first calculation correctly by simply using $s = vt$ but quite a few complicated issues by selecting other equations of motion that involved acceleration.

(ii) The majority of candidates realised that the vertical component of velocity at the highest point would be zero. Some, however, embarked on lengthy calculations.

(iii) Many candidates were successful with this calculation. This, and other calculations in this question caused many candidates to incur significant figure penalties.

(b) (i) Fewer candidates were successful by the time they reached this stage in the question. There principal problem was realising that they should find the resultant to their answers to parts (a) (i) and (a) (iii). However, many of the better candidates managed straightforward, well set out solutions to all parts of the question.

(ii) This was well done by many but a significant number used the horizontal and vertical distances given in the diagram to calculate the angle, instead of using the velocities they had calculated earlier.

(c) Most candidates could indicate the correct points at which the ball's kinetic energy would be a maximum. Clear and complete explanations about why this was the case were rarer. Candidate's explanations tended to be loose and lacking in detail or clarity. Rather than simply mentioning air resistance, for example, candidates should have commented on the work done by the ball against air resistance.

8 This question is a fairly demanding projectiles problem, requiring students to realise that at half the time of flight (2s) the ball would be at its highest point, and using $s = ut + ½ at^2$ for the remainder of the vertical motion, with $u = 0$ ms^{-1} and $a = 1.6$ ms^{-2}. Only 32% of the students were able to do this, with approximately half of the answers being B, which may have been a guess as it seemed feasible.

9 This question required an understanding of whether the accelerations in two perpendicular directions are constant or zero when a beam of electrons travels through a uniform electric field. This was well known, giving over 70% of correct responses.

10 This question had appeared in an examination previously; it tested the fairly familiar knowledge of the trajectory of charged particles in electric and magnetic fields and this time had a facility of 71%.