Mark schemes

1 B **[1]**

2 A **[1]**

3 B **[1]**

4 C **[1]**

5 D **[1]**

6 A **[1]**

7 B **[1]**

8 C **[1]**

9 (a) km $h^{-1} \rightarrow ms^{-1}$ (27.8 m s^{-1}) or 100000/(5.8 × 3600) C1

acceleration equation or correctly substituted values C1

4.79 cao A1

3

(b) equation of motion or correctly substituted values

($s = ut + \frac{1}{2}at^2$; $s = (v + u)t/2$; $v^2 = u^2 + 2as$) C1

80.6 m e.c.f. from (a) A1

2

[5]

10 (a) correct substitution in ($v^2 = u^2 + 2as$)

or correct rearrangement g = $\frac{v^2}{2s}$ **or** $\frac{3.10^2}{2 \times 0.50}$ ✓

= 9.6 (9.61 m s^{-1}) ✓

2

(b) $g = W/m$ **or** $W = mg$ (= ma) and weight is proportional to mass/doubling the mass doubles the weight/'masses cancel'/the factor of two cancels (so g remains the same) ✓

1

(c) ball's acceleration will decrease/be less than card's **or** card's acceleration will be unaffected/nearly constant ✓

air resistance affects cards less or card is more streamlined **or** card does less work against air resistance ✓

alternative *timing/(velocity/speed/acceleration) uncertain/(inaccurate /imprecise/less reliable)* ✓

indication that full width of ball may not pass through gate/difficulty in determining 'length' of ball passing through gate ✓

2

[5]

11 (a) *states* area under graph = distance **or** clear evidence of graph use

B1

½ × 30 × 25 *seen*

B1

2

(b) accel = grad of graph **or** uses a = $\Delta v/\Delta t$

M1

30/20 = 1.5 m s^{-2}

A1

2

(c) 300 + 375 = 675 m

B1

1

(d) 675/680 m (ecf) at 30m/s takes 22.5/22.7 s

C1

but actually took 90 s

C1

so loss of time = 67.5/67.3 s

A1

3

[8]

12 (a) AB: (uniform) acceleration **(1)**
BC: constant velocity / speed or zero acceleration **(1)**
CD: negative acceleration or deceleration or decreasing speed / velocity **(1)**
DE: stationary or zero velocity **(1)**
EF ; (uniform) acceleration in opposite direction **(1)**

5

(b) area under the graph **(1)**

1

(c) distance is a scalar and thus is the total area under the graph
[or the idea that the train travels in the opposite direction] **(1)**
displacement is a vector and therefore the areas cancel **(1)**

2

[8]

13 clear attempt to use area under graph/statement that distance is equivalent to area under graph

C1

38 to 40 squares/1 square is equivalent to 0.05 m

C1

1.9 to 2.0 m

A1

[3]

14

(a) (i) $v = \frac{s}{t}$ **(1)**

t = 0.015 (s) or 15 (ms) **(1)**

0.68/0.015 **(1)** (= 45)

3

(ii) $\left(a = \frac{\Delta v}{\Delta t} = \frac{45.3}{0.015}\right)$ = 3000 (m s^{-2}) (3022) **(1)**

1

(b) (i) $s = (ut) = \frac{1}{2}gt^2$ or $t = \sqrt{\frac{2s}{g}}$ **(1)**

correct substitution seen = $\sqrt{\frac{2 \times 2.3}{9.81}}$ **(1)**

0.68 to 0.69 correct answer to more than one dp seen **(1)**

3

(ii) ($s = vt$) = 45(.3) × 0.685 or 0.7 **(1)**

= 30.6 to 32 **(1)** (m)

2

(iii) mention of air resistance or drag **(1)**

causing **horizontal** deceleration or ‘slowing down’ **(1)**

2

[11]

15 (a) a velocity divided by a time

C1

single reading from graph of v in range 54..56

C1

acceleration in range 90..93.4 ms^{-2}

A1

3

(b) clear attempt to estimate area under the curve

C1

use of correct scale factor: 1 cm^2 represents 10 × 0.2 m

C1

max height in range 80..90 m

A1

3

(c) t^2 = (2 × answer to (b))/9.8

C1

expected answer in range 4.0..4.3 s

allow ecf for height

A1

2

[8]

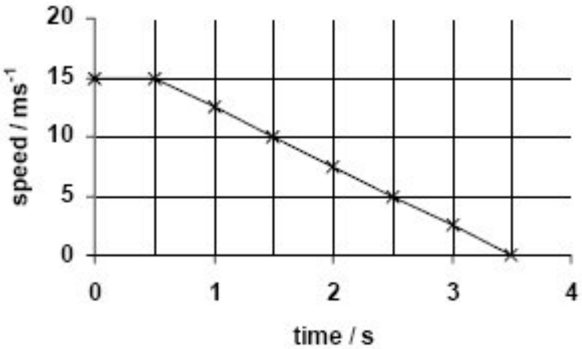
16 (a) axes labelled correctly with correct units shown **(1)**

suitable scales **(1)**

6 points plotted correctly **(1)**

all points plotted correctly **(1)**

both sections of line drawn correctly **(1)**



5

(b) (i) the gradient (of the slope section) represents the deceleration/ calculates 5 m s^{-2} **(1)**

(deceleration is uniform because) the gradient is constant/ line is straight **(1)**

(ii) distance travelled = area under line (0 to 3.5 s or 0.5 to 3.5 s) **(1)**

(= 15.0 × 0.5) = 7.5 m in first 0.5 s **(1)**

(= 0.5 × 15.0 × 3.0) or s = ½(u + v)t, etc) = 22.5 m (from 0.5s to 3.5s) **(1)**

(= ½(0.5 + 3.5) × 15 gets all three method marks)
(total distance travelled = 7.5 + 22.5) = 30m **(1)**

6

[11]

17 (a) (i) use of appropriate data from graph **(1)**

answer in acceptable range (to be decided) **(1)**

(ii) zero at 0, 0.2 0.58, 0.8 and 1 s (approx) **(1)**

reasonable attempt to show relative magnitudes **(1)**

4

(b) appreciation of area under the graph **(1)**

appropriate counting of squares **(1)**

distance per square **(1)**

correct answer in acceptable range **(1)**

4

[8]

18 (a) (i) rate of change of velocity

[or $a = \frac{\Delta v}{t}$] **(1)**

(ii) (acceleration) has (magnitude and) direction **(1)**

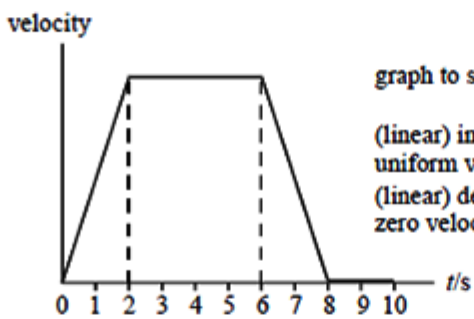
2

(b) (i) (acceleration) is the gradient (or slope) of the graph **(1)**

(ii) (displacement) is the area (under the graph)

2

(c)



graph to show:

(linear) increase to t = 2.0 ± 0.2 s ✓
uniform velocity between 2.0 s and 6.0 s ✓
(linear) decrease from 6.0 ± 0.2 s to 8.0 s ✓
zero velocity after t = 8.0 s ✓

4

[8]

19 (a) (i) car A: travels at constant speed **(1)**

(ii) car B: accelerates for first 5 secs (or up to 18 m s^{-1}) **(1)**
then travels at constant speed **(1)**

3

(b) (i) car A: distance = 5.0 × 16 **(1)**
= 80 m **(1)**

(ii) car B: (distance = area under graph)
distance = [5.0 × ½ (18 + 14)] **(1)**
= 80 m **(1)**

4

(c) car B is initially slower than car A (for first 2.5 s) **(1)**
distance apart therefore increases **(1)**
cars have same speed at 2.5 s**(1)**
after 2.5 s, car B travels faster than car A (or separation decreases) **(1)**

max 3

[10]

20 (a) the sprinter takes time to react to the starting pistol **(1)**

B1

1

(b) attempt using tangent **(1)**

C1

acceleration about 0.74 (0.68 – 0.80) **(1)**

A1

m s^{-2} **(1)**

B1

3

(c) appreciation that area under the graph **(1)**

C1

distance per square = 1m **(1)** or clear use of scale in correct approach

C1

total squares =10 – 10.8 **(1)**

C1

distance correct 10.1 – 10.6m **(1)** (unit essential)

A1

4

or alternative method using triangle and trapezium

(d) use a velocity sensor **or** record time to reach set distances **(1)**

M1

detail about frequency at which data is collected **(1)**

sensor placed so that athlete runs toward it

plot distance time graph and measure gradient at different times

A1

2

[10]

21

(a) $(s = \frac{1}{2}(u + v)t)$

Correct answer with no working gets 2 out of three.

$u = \frac{2s}{t}$ - v **OR** substitution in above equation **OR** $u = \frac{2 \times 1.5}{0.43}$ - 5.0 ✓
= 6.9767 – 5.0 ✓ = 2.0 ✓ (1.98 m s^{-1})

Full credit for use of gsin25 = acceleration down slope. This yields answer 3.22 m s^{-1}
Allow 1sf answer (2).

3

(b) (i) (F = 75 × 9.81 ×) <u>sin25</u> (°) ✓
= 310 (311, 310.94) (N) ✓

use of g = 10 not penalised here
'sin25' on its own
Use of g = 10 yields 317
Allow cos65

2

(ii) $W = Fs$
= 311 × 2.0 = 620 (622 J) ✓ ecf (2bi) × 2.0

1

(c) Idea that GPE is ultimately transferred to: internal (energy) / 'heat'/ 'thermal' (energy in the surroundings) ✓

Allow transfer of GPE to KE and then to 'thermal' etc
Do not allow reference to 'sound' on its own

Correct reference to a named resistive force: friction / drag / air resistance ✓

Don't accept implication that a resistive force is a form of energy

All GPE becomes 'heat', etc **OR** no (overall) increase in KE **OR** reference to work done against or by a resistive force ✓

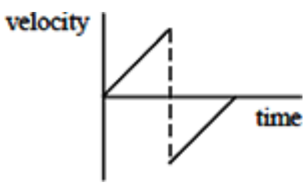
Do not allow references to loss of body heat.
Allow: '(GPE) not converted to KE'

3

[9]

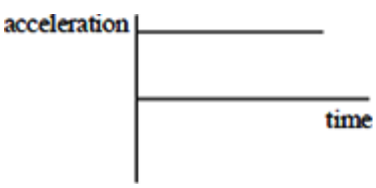
22 accept mirror image for (a) and (b)

(a)



straight line sloping up **(1)**
sudden change to negative velocity **(1)**
smaller negative velocity **(1)**
same gradient as positive line **(1)**

(b)



constant value shown **(1)**

(5)

(c) (i) vertically down at P **(1)**

(ii) vertically down at Q **(1)**

(iii) along tangent at P **(1)**

(iv) along tangent at Q **(1)**

(4)

(d) horizontal component of velocity at Q = 15 cos 50° **(1)** = 9.64 m s^{-1} **(1)**

momentum at Q = 0.15 × 9.64 = 1.45 **(1)** N s (or kg m s^{-1}) (horizontally) **(1)**

(4)

[13]

23

(a) vt_b: distance moved (at speed v) before brakes are applied [or thinking / reaction distance] **(1)**

$\frac{v^2}{2a}$: distance moved while braking [or after applying brakes] **(1)**

2

(b) (i) column B: (8.9) 13.3(5) 17.8 22.2(5) 26.7 31.1(5)
(all values correct to 2 or 3 sig. figs ± 0.2) **(1)**

(ii) column D: 1.3(5) 1.72 2.02 2.39 2.73 3.08
(all values correct to 2 or 3 sig figs ± 0.1) **(1)**

2

(c) graph of $\frac{s}{v}$ against v [or v against $\frac{s}{v}$] **(1)**

axes labelled correctly **(1)** (column D vs column B or A)
appropriate scales **(1)**
at least four points plotted correctly to 1 square **(1)**
acceptable straight line **(1)**
[note: if chosen graph gives a curve (e.g. s against v) then candidate can only score 2nd, 3rd and 4th marks]

5

(d) (i) (intercept) t_b = 0.66 s **(1)** (values in range 0.6 to 0.7 accepted)

(ii) gradient = (any triangle e.g. (3 - 1) / (30 - 4.5)) = 7.8×10^{-2} (s^2m^{-1}) **(1)**
[other answers, if consistent with graph, acceptable]
gradient = (1 / 2a) **(1)**
gives a = 6.4 m s^{-2} **(1)** (values in range 6.1 to 6.7 accepted)
(allow C.E. for value of gradient)

[if column D vs column A used, gradient = 0.022
use of conversion factor gives gradient = 0.078 (s^2m^{-1})]

[if graph of v against $\frac{s}{v}$, gradient = 12.8 m s^{-2}

= 2a for first two marks]

4

[13]

24

(a) (i) **region A**: <u>uniform</u> acceleration

(or (free-fall) acceleration = g (= 9.8(i) m s^{-2}))

force acting on parachutist is entirely his weight

(or other forces are very small) **(1)**

(ii) **region B**: speed is still increasing

acceleration is decreasing **(2)** (any two)

because frictional (drag) forces become significant (at higher speeds)

(iii) **region C**: uniform speed (50 m s^{-1})

because resultant force on parachutist is zero **(2)** (any two)

weight balanced exactly by resistive force upwards

The Quality of Written Communication marks were awarded primarily for the quality of answers to this part

(6)

(b) deceleration is gradient of the graph (at t = 13s) **(1)**

(e.g. 20/1 or 40/2) = 20 m s^{-2} **(1)**

(2)

(c) distance = area under graph **(1)**
suitable method used to determine area (e.g. counting squares) **(1)**
with a suitable scaling factor (e.g. area of each square = 5 m^2) **(1)**
distance = 335 m (±15 m) **(1)**

(4)

(d) (i) speed = $\sqrt{(5.0^2 + 3.0^2)}$ = 5.8 m s^{-1} **(1)**

(ii) $\tan\theta = \frac{3}{5}$ gives θ = 31° **(1)**

(2)

[14]

25 (a) Velocity and speed correct ✓
Distance and displacement correct ✓

	velocity	speed	distance	displacement
vector	✓			✓
scalar		✓	✓	

2

(b) (i) $v^2 = u^2 + 2as$

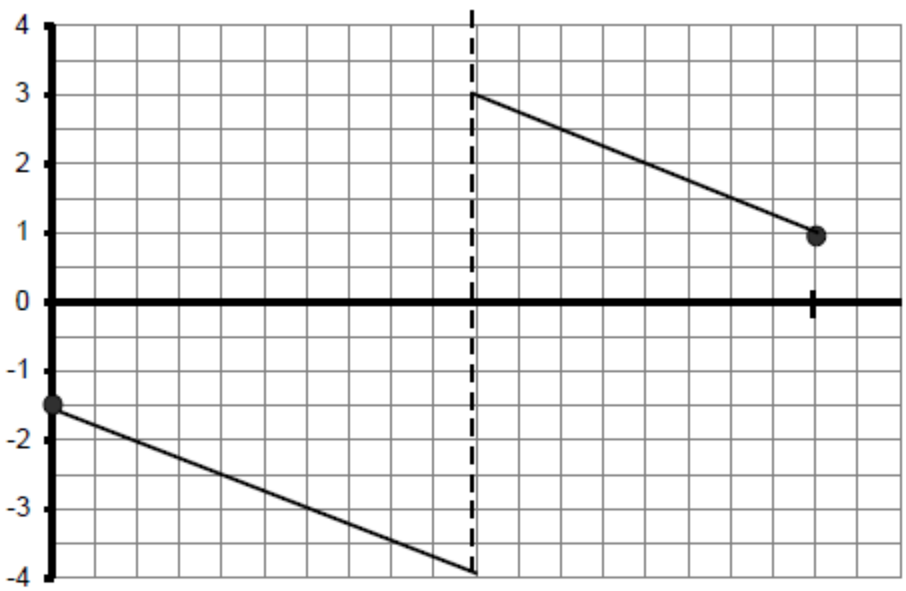
$v = \sqrt{u^2 + 2as}$ ✓ $v = \sqrt{1.5^2 + 2 \times 9.81 \times 0.65}$ ✓

= (−)3.9 (m s^{-1}) ✓two or more sig fig needed (− 3.87337 m s^{-1})

1st mark for equation rearranged to make v the subject (note sq' root may be implied by a later calculation) penalise the use of g = 10 m s^2 only on this question
2nd mark for substituting numbers into any valid equation
3rd mark for answer
Alt' approach is gainKE = lossPE
missing out u gives zero marks
answer only gains one mark [Note it is possible to achieve the correct answer by a wrong calculation]

3

(ii) **velocity / ms^{-1}**



first line descends from X to the dotted line at t_A or up to one division sooner ✓ (allow line to curve)

first line is straight and descends from X to v = −4 (m s^{-1}) ✓(allow tolerance one division)
second line has same gradient as the first, straight and descends to v = 1(m s^{-1}) ✓(tolerance ½ division)
a steep line may join the two straight lines but its width must be less than 2 divisions

3

(c) $s = ut + 1/2at^2$

$t = \sqrt{\frac{2s}{a}}$ OR correct substitution seen into either equation $t = \sqrt{\frac{2 \times 1.2}{9.81}}$ ✓

= 0.49 (s) ✓ (0.4946 s)

working must be shown for the first mark but not the subsequent marks

$v = s / t$

= 5.0 / 0.49 = 10 (m s^{-1}) ✓ (10.2 m s^{-1}) (allow CE from their time)

[note it is possible to achieve the correct answer by a wrong calculation]

3

[11]

Examiner reports

2 Students should be warned about multiple-choice questions that have an apparently very straightforward solution. Approximately the same number of students gave the incorrect response B as gave the correct response in this question. Presumably they calculated the speed for the second half of the journey, and took the average of the two speeds rather than calculating the total distance divided by the total time.

3 Being able to interpret graphs is another important skill commonly tested by multiple choice questions. 67% of students were able to spot that graph B correctly represented the variation of the gradient of the velocity-time graph with time. The most popular distractor was A, perhaps due to students eliminating C and D as being obviously incorrect, and being able to go no further.

8 This calculation proved to be very accessible, with 84% of students giving the correct answer. It should be noted that, in a written paper, students who use the suvat equations would not get the same credit as those who correctly equate GPE and KE, despite the two approaches giving the same answer.

9 (a) Most candidates were able to use an appropriate form of the equation $v = u + at$. Weaker candidates were penalised for suggesting that acceleration is velocity divided by time. A sizable number failed to convert kilometres per hour into metres per second.

(b) With error carried forward from (a) many candidates gained full marks for this part. Common errors were to use the kilometre per hour velocity a second time in the equation $s = (v + u)t/2$ or to quote the final distance to four (or more) significant figures.

10 Most candidates gained full marks in part (a). A few performed a calculation using $t = s/v$, with 3.1 as the average speed. This gave a value for g twice the required size.

In part (b) correct answers should have included 'weight is proportional to the mass and $W/m = g$', or 'doubling the mass will double the weight and g will remain the same' or similar. Many said increasing m will increase W but this was not sufficient for the mark.

A large majority of candidates seemed to be familiar with the use of a light-gate to measure velocity in part (c). Most said that air resistance would affect the ball more. However, very few then went on to explain that the increased air resistance would reduce the acceleration. Many said that air resistance 'slows down' the ball. They may be thinking, incorrectly, that the ball slows down as it falls, or they may be indicating that the ball is slower than it would be if there were no air resistance. Students therefore need to be able to describe the motion of an object in an unambiguous manner, eg 'when an object falls, the acceleration decreases due to air resistance'.

Few candidates were able to explain that the full diameter of the ball was unlikely to pass through the beam. This is a difficult idea to express. Candidates should be encouraged to include a simple sketch to help illustrate a point if they are finding it difficult to put into words. Some said that that there is more uncertainty in the measurement of the diameter of the ball. However, this would depend on the measurement technique, so credit could not be given.

11 The question told candidates to 'use the graph…'. Many failed to make it clear in any way how they did this and lost marks. Otherwise, this question was done well.
The calculation of acceleration was done well by most, but there was a smattering of incorrect units for the acceleration.
There were no major problems here apart from the few who used the distance travelled for the whole of the graph (and who had therefore failed to read the question).
Again, errors centred on the use of incorrect time periods for one or more parts of the calculation.

12 Candidates found this question quite straightforward and full marks were not uncommon, but the idea of the magnitude of velocity increasing with negative acceleration did tax some. In part (c) a significant number of candidates did have trouble explaining clearly why the distance travelled was different to the displacement. There was a tendency to offer vague answers without focusing on the fact that displacement is a vector quantity whereas distance is scalar.

13 Most candidates realised that they should determine the area under the graph. Techniques for doing this varied, but square counting tended to be most accurate and less prone to error. The standard of setting out of working was generally poor.

14 In part (a) (i), most candidates quoted the equation and correctly calculated the time. The most frequent misconception was the belief that a 'suvat' equation should be used even though the velocity is constant.

The correct answer of 3000, or 3022, was accepted in part (a) (ii) and the majority successfully produced this value.

In part (b) (i) most select and quoted the correct equation and showed the correct substitution. Some lost the mark as they did not show the answer to more than one significant figure.

Part (b) (ii) was a very easy question for over 40% of candidates who understood that the horizontal acceleration was zero. For these students, $45.3 \times 0.685 = 31$ gained two marks. However, 13% did not attempt the question and another 40% misapplied a kinematics equation to the situation often using 9.81 as the acceleration.

The vast majority of candidates identified air resistance as the key factor to part (b) (iii). However, only 7% mention that **horizontal** deceleration is caused by air resistance.

15 This proved to be a difficult question for many candidates.

An accurate calculation of average acceleration was achieved by only about half of the candidates, while rather less than that were able to calculate the correct area under the graph to find the maximum height.

Many of the candidates who gained credit for part (a) did so on the basis of error carried forward from part (b). Other candidates had the rocket falling back to Earth with an initial velocity of 69 m s^{-1}. However, there were a significant number of candidates who did achieve full marks on the question.

16 Part (a) proved to be a very easy question, with the majority of candidates correctly plotting all the points and gaining all five marks.

A large number of candidates only got one mark out of two for part (b) (i), because they did not point out that the gradient is the deceleration - though it is possible that the majority knew this. Most recognised the significance of the straight line.

For half the candidates, part (b) (ii) was a straightforward calculation of the area. However, many candidates did not recognise its simplicity. A common incorrect approach was to select a kinematics equation and substitute in 15 m/s and 3.5 s. Candidates would gain higher marks on this type of question if they routinely state the principle they are using, e.g. in this case .distance travelled = area under line..

18 Parts (a) and (b) produced good responses although a significant proportion of candidates did concern themselves with rate of change of speed rather than velocity. Part (c) was less well answered and proved to be a good discriminator as only the most able candidates were able to sketch the correct graph.

19 This question proved to be very accessible and full marks were awarded frequently. The only real confusion arose in part (c) where weaker candidates had difficulty organising their thoughts and expressing them in a logical way. Loose use of language was evident, with statements such as “accelerating at a constant speed” cropping up in a significant minority of scripts.

20 In part (a), some simply stated that the sprinter did not start at the time the gun was fired but gave no reason for this. A mention of reaction time or thinking time was required.

Part (b) was answered well. The majority of the candidates appreciated that a tangent at 3.5 s was needed and many did this accurately. The unit was well known.

Although many appreciated that the area under the graph was needed in part (c), relatively few could convert this knowledge into an accurate distance. Some treated the area as a triangle and some tried applying an equation of uniform accelerated motion.

There were many vague and/or impracticable ideas in part (d). Comments such as use a computer or attach a speedometer to the runner were not uncommon. Some answers stated the data needed (distance and time) but not how it would be obtained or how the velocity data would be obtained from it.

21 (a) This was quite well done. A few used $v = s / t$ = 1.5 / 0.43 and there was some use of a = 9.81. Those who had practiced less of these questions got confused because u was not zero. Incorrect rearranging of the equation was also quite common.

(b) A common error was to use cos25 rather than sin25 for resolving along the slope.

(c) This was very poorly answered. It was expected that candidates would realise that kinetic energy was not changing, and therefore, the transfer could be easily summed up as gravitational potential energy transferred to internal / thermal energy. Most did not pick up the more subtle points that the GPE ultimately all ends up as internal / thermal energy and the KE stays constant.

It was not enough to say that some of the GPE transfers to KE and some to heat. That doesn't answer the question and could apply to many situations. Candidates should always name the forces. 'Resistive forces' did not score the mark, 'friction' or 'drag' was needed.

Many candidates have learnt that 'loss of GPE is equal to the gain in KE' and they believe this applies to all situations.

23 Part (a) was quite straightforward and the majority of candidates gained both marks, although some marks were withheld due to candidates referring carelessly to time rather than distance.

The columns of data in part (b) were usually completed correctly, but some candidates lost marks as a result of using too many or too few significant figures. Again in part (c) many candidates scored full marks but a significant minority were unable to choose appropriate scales for their chosen graph. Others were unable to plot a suitable graph, mostly as a result of plotting s against v or v against s rather than s / v against v.

Most of candidates who plotted a straight line graph knew how to determine the value of tb in part (d). Some however failed to score this mark as a result of lack of care in plotting the graph in the previous section. In part (ii) , most candidates were able to obtain a correct value for the gradient of their straight line graph. In addition, these candidates were able to relate the gradient to the acceleration and obtained a correct value for the acceleration. On the other hand, many of the weaker candidates had plotted an unsuitable graph (e.g. s vs v) and were unable to make progress with the calculations. They were clearly unaware of the necessity of choosing variables that would produce a straight line graph.

24 In part (a) most candidates were able to interpret the graph correctly and almost all understood why the parachutist reached constant terminal speed in region C of the graph. Although many also understood and stated that the acceleration in region A was constant, few stated that this was because the drag on the parachutist was negligible or much smaller than his weight. Answers were generally well expressed and a mark of four or five was most common. A minority of candidates, however, was quite incapable of using physics terms accurately and subsequently scored few marks.

Many candidates understood that the acceleration in part (b) equalled the gradient of the line in region D of the graph and arrived at a correct answer (although the unit of acceleration was often given as $^{-1}$). Candidates who used $a = (\upsilon - u) / t$ very often chose points off the straight section of the graph and arrived at α value for a outside the acceptable range.

In part (c) many candidates ignored the graph and attempted to use an equation of uniform acceleration to find the distance travelled. The majority, however, made some attempt to relate distance to the area under the graph and most of these answers fell within the acceptable range.

Part (d) was most often correct, although in part (ii) many candidates inverted the tan function and found the angle to the horizontal rather than the vertical.

25 The equations of motion were generally understood well by most students. Problems started to emerge when it came to the graphical work in the question. The calculation in part (b)(i) was performed well but some weaker students lost marks by choosing to use the valid idea that the gain in kinetic energy is equal to the loss of potential energy but then forgot to note that the initial kinetic energy is not equal to zero. Others lost marks when they rounded $v = 3.87 \text{ m s}^{-1}$ to 3.8 m s^{-1}.

A majority of students found sketching the graph in (b)(ii) quite difficult. Even the top grade students were only confident about the first straight line drawn from X down to a time t_A. Further along the graph was drawn with random variations by most and the better students were not very careful to make the second line parallel to the first.

In (c) a majority could tackle the question in full. The weaker students did not know how to separate the vertical and horizontal components and connect them through the time of flight. Some students who did manage the first part of the calculation did not appreciate that the horizontal velocity was constant and took its initial value to be zero.