Q1.

2 (a) (i) distance from a (fixed) point M1
in a specified direction A1
(Allow 1 mark for 'distance in a given direction')

(ii) (displacement from start is zero if) car at its starting position ..... B1 [3]

(b) (i)1 $v^2 = u^2 + 2as$
$28^2 = 2 \times a \times 450$ (use of component of 450 scores no marks) C1
a = 0.87 m s^{-2} .... A1 [2]
(-1 for 1 sig. fig. but once only in the question)

(i)2 $v = u + at$ or any appropriate equation
28 = 0.87*t* or appropriate substitution C1
t = 32 s .... A1 [2]

Q2.

3 (a) (i) scatter of points (about the line) B1
(ii) intercept (on t^2 axis) B1 **[2]**
(note that answers must relate to the graph)

(b) (i) gradient = $\Delta y / \Delta x$ = (100 – 0)/(10.0 – 0.6) C1
gradient = 10.6 (cm s^{-2}) *(allow ±0.2)* A1 **[2]**
(Read points to within $\pm\frac{1}{2}$ square. Allow 1 mark for 11 cm s^{-2}
i.e. 2 sig fig, -1. Answer of 10 scores 0/2 marks)

(ii) $s = ut + \frac{1}{2}at^2$ B1
so acceleration = 2 x gradient B1
acceleration = 0.212 m s^{-2} B1 **[3]**

Total [7]

Q3.

(c) horizontal velocity = 18 m s^{-1} B1 [1]

(d) (i) correct shape of diagram
(two sides of right-angled triangle with correct orientation) B1

(ii) angle = 41° → 48° (allow trig. solution based on diagram) A2 [3]
(for angle 38° → 41° or 48° → 51°, allow 1 mark)

Q4.

2 (a) 2.4 s .... A1 [1]

(b) in (b) and (c), allow answers as (+) or (–)
recognises distance travelled as area under graph line C1
height = (½ × 2.4 × 9.0) – (½ × 1.6 × 6.0) C1
= 6.0 m (*allow 6 m*) .... A1 [3]
(*answer 15.6 scores 2 marks*
answer 10.8 or 4.8 scores 1 mark)

alternative solution: $s = ut - \frac{1}{2}at^2$
$= (9 \times 4) - \frac{1}{2} \times (9 / 2.4) \times 4^2$
$= 6.0$ m
(*answer 66 scores 2 marks*
answer 36 or 30 scores 1 mark)

Q5.

2 (a) scalar B1
scalar B1
vector .... B1 [3]

(b) (i) 1 gradient (of graph) is the speed/velocity (*can be scored here or in* **2**)........ B1
initial gradient is zero .... B1 [2]

2 gradient (of line/graph) becomes constant .... B1 [1]

(ii) speed = (2.8 ± 0.1) m s^{-1} .... A2 [2]
(*if answer > ±0.1 but ≤ ±0.2, then award 1 mark*)

(iii) curved line never below given line and starts from zero B1
continuous curve with increasing gradient B1
line never vertical or straight .... B1 [3]

Q6.

2 (a) e.g. initial speed is zero
constant acceleration
straight line motion
(*any two, one mark each*) .... B2 [2]

(b) (i) $s = \frac{1}{2}a\,t^2$
$0.79 = \frac{1}{2} \times 9.8 \times t^2$ C1
t = 0.40 s allow 1 SF or greater A1
2 or 3 SF answer .... A1 [3]

(ii) distance travelled by end of time interval = 90 cm C1
$0.90 = \frac{1}{2} \times 9.8 \times t^2$
t = 0.43 s allow 2 SF or greater C1
time interval = 0.03 s .... A1 [3]

(c) (air resistance) means ball's speed/acceleration is less M1
length of image is shorter .... A1 [2]

Q7.

3	(a)	evidence of use of area below the line	B1	
		distance = 39 m (*allow* ±0.5*m*)	A2	[3]
		(*if* > ±0.5*m but* ≤ 1.0 *m, then allow 1 mark*)		

Q8.

1	(a)		scalar has only magnitude	B1	
			vector has magnitude and direction	B1	[2]
	(b)		kinetic energy, mass, power all three underlined	B1	[1]
	(c)	(i)	$s = ut + ½ at^2$		
			$15 = 0.5 \times 9.81 \times t^2$	C1	
			$T = 1.7$ s	A1	[2]
			if g = 10 is used then –1 but only once on paper		
		(ii)	vertical component v_v:		
			$v_v^2 = u^2 + 2as = 0 + 2 \times 9.81 \times 15$ or $v_v = u + at = 9.81 \times 1.7(5)$		
			v_v =17.16	C1	
			resultant velocity: $v^2 = (17.16)^2 + (20)^2$	C1	
			$v = 26$ m s^{-1}	A1	[3]
			If u = 20 is used instead of u = 0 then 0/3 Allow the solution using: initial (potential energy + kinetic energy) = final kinetic energy		
		(iii)	distance is the actual path travelled	B1	
			displacement is the straight line distance between start and finish points (in that direction) / minimum distance	B1	[2]

Q9.

2	(a)	(i)	base units of D:		
			force: $kg\,m\,s^{-2}$	B1	
			radius: m velocity: $m\,s^{-1}$	B1	
			base units of D: $[F / (R \times v)]$ $kg\,m\,s^{-2} / (m \times m\,s^{-1})$	M1	
			$= kg\,m^{-1}\,s^{-1}$	A0	[3]
		(ii)	1. $F = 6\pi \times D \times R \times v = [6\pi \times 6.6 \times 10^{-4} \times 1.5 \times 10^{-3} \times 3.7]$		
			$= 6.9 \times 10^{-5}$ N	A1	[1]
			2. $mg - F = ma$ hence $a = g - [F / m]$		
			$m = \rho \times V = \rho \times 4/3\,\pi\,R^3 = (1.4 \times 10^{-5})$	C1	
			$a = 9.81 - [6.9 \times 10^{-5}] / \rho \times 4/3\,\pi \times (1.5 \times 10^{-3})^3$ $(9.81 - 4.88)$	M1	
			$a = 4.9(3)\ m\,s^{-2}$	A1	[3]
	(b)	(i)	$a = g$ at time $t = 0$	B1	
			a decreases (as time increases)	B1	
			a goes to zero	B1	[3]
		(ii)	Correct shape below original line	M1	
			sketch goes to terminal velocity earlier	A1	[2]

Q10.

2	(a)	(i)	$v = u + at$	C1	
			$= 4.23 + 9.81 \times 1.51$	M1	
			$= 19.0(4)\ m\,s^{-1}$ (Allow 2 s.f.)	A0	[2]
			(Use of $-g$ max 1/2. Use of $g = 10$ max 1/2. Allow use of 9.8. Allow 19 $m\,s^{-1}$)		
		(ii)	either $s = ut + ½\,at^2$ (or $v^2 = u^2 + 2as$ etc.)		
			$= 4.23 \times 1.51 + 0.5 \times 9.81 \times (1.51)^2$	C1	
			= 17.6 m *(or 17.5m)*	A1	[2]
			(Use of $-g$ here wrong physics (0/2))		

Q11.

2	(a)	(i)	$v^2 = u^2 + 2as$		
			$= (8.4)^2 + 2 \times 9.81 \times 5$	C1	
			$= 12.99\ m\,s^{-1}$ *(allow 13 to 2 s.f. but not 12.9)*	A1	[2]
		(ii)	$t = (v - u) / a$ or $s = ut + ½at^2$		
			$= (12.99 - 8.4) / 9.81$ or $5 = 8.4t + ½ \times 9.81t^2$	M1	
			$t = 0.468$ s	A0	[1]
	(b)		reasonable shape	M1	
			suitable scale	A1	
			correctly plotted 1st and last points at (0,8.4) and (0.88 – 0.96,0)		
			with non-vertical line at 0.47 s	A1	[3]

Q12.

2 (a)	(i)	1. distance of path / along line AB	B1	[1]
		2. shortest distance between AB / distance in straight line between AB or displacement from A to B	B1	[1]
	(ii)	acceleration = rate of change of velocity	A1	[1]
(b)	(i)	distance = area under line or $(v/2)t$ or $s = (8.8)^2 / (2 \times 9.81)$	C1	
		$= 8.8 / 2 \times 0.90 = 3.96$ m or $s = 3.95$ m $= 4(.0)$ m	A1	[2]
	(ii)	acceleration $= (-4.4 - 8.8) / 0.50$	C1	
		$= (-)\ 26(.4)$ m s^{-2}	A1	[2]
(c)	(i)	the accelerations are constant as straight lines	B1	
		the accelerations are the same as same gradient or no air resistance as acceleration is constant or change of speed in opposite directions (one speeds up one slows down)	B1	[2]
	(ii)	area under the lines represents height or KE at trampoline equals PE at maximum height	B1	
		second area is smaller / velocity after rebound smaller hence KE less	B1	
		hence less height means loss in potential energy	A0	[2]

Q13.

3 (a)	$v^2 = u^2 + 2as$ OR use of triangle etc	C1	
	$4.0^2 = 2 \times 9.8 \times s$ OR $s = ½ \times 4.0 \times 0.4$		
	$s = 0.82$ m OR 0.80 m	A1	[2]
(b)	$\Delta p = m(v - u)$ OR $p = mv$	C1	
	speeds are 4.2 m s^{-1} and 3.6 m s^{-1}	C1	
	$\Delta p = 0.045\ (4.2 + 3.6)$ (2/4 only if speeds not added)	C1	
	$= 0.35$ N s	A1	[4]
	(1 mark only if only one speed used)		
(c)	any time between 0.14 s and 0.17 s	C1	
	force $= \Delta p / \Delta t = 0.35 / 0.14$ (allow e.c.f.)		
	$= 2.5$ N	A1	[2]

Q14.

1 (a) (i) acceleration (allow a definition of acceleration). B1

(ii) the velocity is decreasing or force/acceleration is in negative direction – accept 'body is decelerating'/'slowing down' .... B1 [2]

(b) (i) e.g. separation of dots becomes constant/does not continue to increase (must make a reference to the diagram) B1

(ii)1 distance = 132 cm.. B1

(ii)2 at constant speed, distance travelled in 0.1 s = 25 cm (allow ± 1 cm).. C1
distance = 132 + (4 x 25)
= 232 cm .... A1 [4]

(c) $s = ut + ½at^2$
$1.6 = ½ \times 9.8 \times t^2$ (allow $g = 10\ \text{m s}^{-2}$ C1
$t = 0.57$ s... C1
hence 6 photographs ('bald' answer scores 2 marks only)........... A1 [3]

Q15.

3 (a) constant gradient/straight line — B1 [1]

(b) (i) 1.2 s — A1

(ii) 4.4 s — A1 [2]

(c) *either* use of area under line *or* *h* = average speed x time — C1

h = ½ x (4.4 – 1.2) x 32 — C1

= 51.2 m — A1 [3]

(allow 2/3 marks for determination of *h* = 44 m or *h* =58.4 m
allow 1/3 marks for answer 7.2 m)

(d) $\Delta p = m\Delta v$ OR $p = mv$ — C1

= 0.25 x (28 + 12) — C1

= 10 N s — A1 [3]

(answer 4 N s scores 2/3 marks)

3	**(e)**	**(i)**	total/sum momentum before = total/sum momentum after	**B1**	
			in any closed system	**B1**	**[2]**
		(ii)	*either* the system is the ball and Earth	**B1**	
			momentum of Earth changes by same amount	**B1**	
			but in the opposite direction	**B1**	
			or Ball is not an isolated system/there is a force on the ball	(B1)	
			Gravitational force acts on the ball	(B1)	
			causes change in momentum/law does not apply here	(B1)	**[3]**
			(if explains in terms of air resistance, allow first mark only)		

Q16.

3	**(a)**	change in velocity/time (taken)	B1	**[1]**
	(b)	velocity is a vector/velocity has magnitude & direction	B1	
		direction changing so must be accelerating	B1	**[2]**

Q17.

4	**(a)**	**(i)**	use of tangent at time t = 0	B1	
			acceleration = 42 ± 4 cm s^{-2}	A1	**[2]**
		(ii)	use of area of loop	B1	
			distance = 0.031 ± 0.001 m	B2	**[3]**
			allow 1 mark if 0.031 ± 0.002 m)		

Q18.

2	**(a)**		uses a tangent (anywhere), not a single point	C1	
			draws tangent at correct position	B1	
			acceleration = 1.7 ± 0.1	A2	[4]
			(*outside 1.6 → 1.8 but within 1.5 → 1.9, allow 1 mark*)		
	(b)	**(i)**	because slope (of tangent of graph) is decreasing	M1	
			acceleration is decreasing	A1	[2]
		(ii)	e.g. air resistance increases (with speed)		
			(angle of) slope of ramp decreases	B1	[1]
	(c)	**(i)**	scatter of points about line	B1	[1]
		(ii)	intercept / line does not go through origin	B1	[1]

Q19.

2	(a) 3.5 T	B1	[1]
	(b) (i) distance = average speed × time (however expressed)	C1	
	= 14 m	A1	[2]
	(ii) distance = 5.6 × (T – 5) (*or* 3.5T – 14)	A1	[1]
	(c) 3.5T = 14 + 5.6(T – 5)	C1	
	T = 6.7 s	A1	[2]
	(d) (i) acceleration = (5.6 / 5 =) 1.12 m s^{-2}	C1	
	force = ma	C1	
	= 75 N	A1	[3]
	(ii) power = (force × speed =) {75 + 23} × 4.5	C1	
	= 440 W	A1	[2]
	(*allow 1/2 for 234 W, 0/2 for 338 W or 104 W*)		

Q20.

2	(a) (i) $v^2 = 2as$		
	$v^2 = 2 \times 0.85 \times 9.8 \times 12.8$	C1	
	v = 14.6 m s^{-1}	A1	[2]
	(ii) time = 29.3 / 14.6	C1	
	= 2.0 s	A1	[2]
	(*any acceleration scores 0 marks; allow 1 s.f.*)		
	(b) *either* 60 km h^{-1} = 16.7 m s^{-1}		
	or 14.6 m s^{-1} = 53 km h^{-1}		
	or 22.1 m s^{-1} = 79.6 km h^{-1}	M1	
	so driving within speed limit	A1	
	but reaction time is too long / too slow	B1	[3]

Q21.

2 (a) (i) (air) resistance increases with speed M1
resultant / accelerating force decreases .... A1 [2]

(ii) *either* (air) resistance is zero
or weight / gravitational force is only force .... B1 [1]

(b) use of gradient of a tangent M1
acceleration = 1.9 ± 0.2 m s^{-2} .... A2 [3]
(*for values* > ± *0.2 but* ≤ *0.4, allow 1 mark*)
(*answer 3.3 m* s^{-2} *scores no marks*)

(c) (i) **1** weight = 90 × 9.8 = 880 N .... A1 [1]
(*use of g = 10 m* s^{-2} *then deduct mark but once only in the Paper*)
2 accelerating force = 90 × 1.9 = 170 N ...(*allow ecf*) .... A1 [1]

(ii) resistive force = 880 – 170 = 710 N .... A1 [1]
(*allow ecf but only if resistive force remains positive*)

[Total: 9]

Q22.

3 (a) (i) speed = 4.0 m s^{-1} ...(*allow 1 s.f.*) .... A1 [1]

(ii) $v^2 = 2gh$
$= 2 \times 9.8 \times 1.96$ M1
$v = 6.2$ m s^{-1} .... A0 [1]
(*use of g = 10 m* s^{-2} *loses the mark*)

(b) correct basic shape with correct directions for vectors M1
speed = (7.4 ± 0.2) m s^{-1} A1
at (33 ± 2)° to the vertical .... A1 [3]
(*for credit to be awarded, speed and angle must be correct on the diagram – not calculated*)

(c) (i) *either* $v^2 = 2 \times 9.8 \times 0.98$ *or* $v = 6.2 / \sqrt{2}$ C1
speed = 4.4 m s^{-1} .... A1 [2]
(*allow calculation of t = 0.447 s, then v = 4.4 m* s^{-1})

(ii) **1** momentum = *mv* C1
change in momentum = 0.034 (6.2 + 4.4) C1
= 0.36 kg m s^{-1} .... A1 [3]
(*use of 0.034 (6.2 - 4.4) loses last two marks*)
2 force = $\Delta p / \Delta t$ ....(however expressed) C1
$= \dfrac{0.36}{0.12}$
= 3.0 N ......(*allow 1 s.f.*) .... A1 [2]

[Total: 12]

Q23.

2 (a) (i)	horizontal speed constant at 8.2 m s^{-1}	C1	
	vertical component of speed = 8.2 tan 60°	M1	
	= 14.2 m s^{-1}	A0	[2]
(ii)	$14.2^2 = 2 \times 9.8 \times h$ (using g = 10 then –1)	C1	
	vertical distance = 10.3 m	A1	[2]
(iii)	time of descent = 14.2 / 9.8 = 1.45 s	C1	
	x = 1.45 × 8.2		
	= 11.9 m	A1	[2]
(b) (i)	smooth path curved and above given path	M1	
	hits ground at more acute angle	A1	[2]
(ii)	smooth path curved and below given path	M1	
	hits ground at steeper angle	A1	[2]

Q24.

2 (a) (i)	V_H = 12.4 cos 36° (= 10.0 m s^{-1})	C1	
	distance = 10.0 × 0.17		
	= 1.7 m	A1	[2]
(ii)	V_V = 12.4 sin 36° (= 7.29 m s^{-1})	C1	
	$h = 7.29 \times 0.17 - ½ \times 9.81 \times 0.17^2$	C1	
	= 1.1 m	A1	[3]
(b)	smooth curve with ball hitting wall below original	B1	
	smooth curve showing rebound to ground with correct reflection at wall	B1	[2]

Q25.

4 (a)	acceptable straight line drawn (touching every point)	B1	[1]
(b)	the distance fallen is not d	C1	
	d is the distance fallen plus the diameter of the ball	A1	[2]
	('d is not measured to the bottom of the ball' scores 2/2)		
(c) (i)	diameter: allow 1.5 ± 0.5 cm (accept one SF)	A1	[1]
	no ecf from **(a)**		
(ii)	gradient = 4.76, ± 0.1 with evidence that origin has not been used	C1	
	gradient = g / 2	C1	
	g = 9.5 m s^{-2}	A1	[3]

Q26.

3	(a)	(i)	horizontal velocity = 15 cos 60° = 7.5 m s^{-1}	A1	[1]
		(ii)	vertical velocity = 15 sin 60° = 13 m s^{-1}	A1	[1]
	(b)	(i)	$v^2 = u^2 + 2as$ $s = (13)^2 / (2 \times 9.81) = 8.6(1)$ m using g = 10 then max. 1	A1	[1]
		(ii)	t = 13 / 9.81 = 1.326 s or t = 9.95 / 7.5 = 1.327 s	A1	[1]
		(iii)	velocity = 6.15 / 1.33 = 4.6 m s^{-1}	M1 A0	[1]
	(c)	(i)	change in momentum = 60 × 10^{-3} [–4.6 – 7.5] = (–)0.73 N s	C1 A1	[2]
		(ii)	final velocity / kinetic energy is less after the collision or relative speed of separation < relative speed of approach hence inelastic	M1 A0	[1]

Q27.

1	(a)	average velocity = 540 / 30 = 18 m s^{-1}	C1 A1	[2]
	(b)	velocity zero at time t = 0 positive value and horizontal line for time t = 5 s to 35 s line / curve through v = 0 at t = 45 s to negative velocity negative horizontal line from 53 s with magnitude less than positive value and horizontal line to time = 100 s	B1 B1 B1 B1	[4]

Q28.

2 (a) 1. constant velocity / speed — B1 [1]

2. *either* constant / uniform decrease (in velocity/speed)
or constant rate of decrease (in velocity/speed) — B1 [1]

(b) (i) distance is area under graph for both stages — C1
stage 1: distance $(18 \times 0.65) = 11.7$ (m)
stage 2: distance $= (9 \times [3.5 - 0.65]) = 25.7$ (m)
total distance = 37.(4) m — A1 [2]
(–1 for misreading graph)
{for stage 2, allow calculation of acceleration ($6.32\,\text{m s}^{-2}$)
and then $s = (18 \times 2.85) + \frac{1}{2} \times 6.32\,(2.85)^2 = 25.7\,\text{m}$}

(ii) *either* $F = ma$ *or* $E_K = \frac{1}{2}mv^2$ — C1
$a = (18 - 0)/(3.5 - 0.65)$ $E_K = \frac{1}{2} \times 1250 \times (18)^2$ — C1

$F = 1250 \times 6.3 = 7900\,\text{N}$ *or* $F = \frac{1}{2} \times 1250 \times (18)^2 / 25.7 = 7900\,\text{N}$ — A1 [3]
or initial momentum = 1250×18 — (C1)
F = change in momentum / time taken — (C1)
$F = (1250 \times 18) / 2.85 = 7900$ — (A1)

(c) (i) stage 1: *either* half / less distance as speed is half / less
or half distance as the time is the same
or sensible discussion of reaction time — B1 [1]

(ii) stage 2: *either* same acceleration and $s = v^2 / 2a$ *or* v^2 is ¼ — B1
¼ of the distance — B1 [2]

Q29.

1 (a) units for *D* identified as kg m s^{-2} — M1
all other units shown: units for *A*: m^2 units for v^2: $\text{m}^2\,\text{s}^{-2}$ units for ρ: kg m^{-3}

$C - \dfrac{\text{kgms}^{-2}}{\text{kg m}^{-3}\,\text{m}^2\,\text{m}^2\,\text{s}^{-2}}$ with cancelling / simplification to give *C* no units — A1 [2]

(b) (i) straight line from (0,0) to (1,9.8) ± half a square — B1 [1]

(ii) $\frac{1}{2}mv^2 = mgh$ or using $v^2 = 2as$ — C1
$v = (2 \times 9.81 \times 1000)^{1/2} = 140\,\text{m s}^{-1}$ — A1 [2]

(c) (i) weight = drag (*D*) (+ upthrust) — B1 [1]
Allow *mg* or *W* for weight and *D* or expression for *D* for drag

(ii) 1. $mg = 1.4 \times 10^{-5} \times 9.81$ — C1

$1.4 \times 10^{-5} \times 9.81 = 0.5 \times 0.6 \times 1.2 \times 7.1 \times 10^{-6} \times v^2$ — M1

$v = 7.33\,\text{m s}^{-1}$ — A0 [2]

2. line from (0,0) correct curvature to a horizontal line at velocity of $7\,\text{m s}^{-1}$ — M1
line reaches $7\,\text{m s}^{-1}$ between 1.5 s and 3.5 s — A1 [2]

Q30.

3 (a)	power is the rate of doing work or power = work done / time (taken) or power = energy transferred / time (taken)	B1	[1]
(b) (i)	as the speed increases drag / air resistance increases	B1	
	resultant force reduces hence acceleration is less	B1	
	constant speed when resultant force is zero	B1	[3]
	(allow one mark for speed increases and acceleration decreases)		
(ii)	force from cyclist = drag force / resistive force	B1	
	$P = 12 \times 48$	M1	
	$P = 576\,W$	A0	[2]
(iii)	tangent drawn at speed = $8.0\,m\,s^{-1}$	M1	
	gradient values that show acceleration between 0.44 to $0.48\,m\,s^{-2}$	A1	[2]
(iv)	$F - R = ma$	C1	
	$600 / 8 - R = 80 \times 0.5$ [using $P = 576$] $576 / 8 - R = 80 \times 0.5$	C1	
	$R = 75 - 40 = 35\,N$ $R = 72 - 40 = 32\,N$	A1	[3]
(v)	at $12\,m\,s^{-1}$ drag is 48 N, at $8\,m\,s^{-1}$ drag is 35 or 32 N		
	R / v calculated as 4 and 4 or 4.4		
	and consistent response for whether R is proportional to v or not	B1	[1]

Q31.

3 (a) (i)	velocity = rate of change of displacement OR displacement change / time (taken)	A1	[1]
(ii)	acceleration = rate of change of velocity OR change in velocity / time (taken)	A1	[1]
(b) (i)	initial constant velocity as straight line / gradient constant	B1	
	middle section deceleration/ speed / velocity decreases / slowing down as gradient decreases	B1	
	last section lower velocity (than at start) as gradient (constant and) smaller	B1	[3]
	[special case: all three stages correct descriptions but no reasons 1/3]		
(ii)	velocity = 45 / 1.5 = $30\,m\,s^{-1}$	A1	[1]
(iii)	velocity at 4.0 s is (122 – 98) / 2.0 = 12 ($m\,s^{-1}$) (allow 12 to 13)	B1	
	acceleration = (12 – 30) / 2.5 = $-7.2\,m\,s^{-2}$ (if answer not this value then comment needed to explain why, e.g. difficulty in drawing tangent)	A1	[2]
(iv)	$F = ma$	C1	
	= (–)1500 × 7.2 = (–)11000 (10800) N	A1	[2]