2. Kinematics

2.1 Equations of motion

Paper 2

Marking Scheme

Q1.

(a)	change in displacement / time (taken)	**B1**
(b)(i)	horizontal velocity = $22 \times \cos 40°$	**C1**
	time taken = $36 / (22 \times \cos 40°)$ = 2.1 s	**A1**
(b)(iii)	$s = ut + ½ at^2$ $= (14 \times 2.1) + (½ \times -9.81 \times 2.1^2)$	**C1**
	= 7.8 (m)	**C1**
	(therefore) height of wall = 7.8 + 1.2 = 9.0 m	**A1**
(b)(iii)	**or**	
	other methods possible e.g. time to maximum height = (0 – 14) / –9.81 (= 1.43 s) time from maximum height to wall = 2.1 – 1.43 (= 0.67 s) maximum height above release = $(14 \times 1.43) + (½ \times -9.81 \times 1.43^2)$ = 9.99 (m)	**(C1)**
	height from maximum to wall = $0.5 \times 9.81 \times 0.67^2$ (= 2.2 m) height above release = 9.99 – 2.2 = 7.8 (m)	**(C1)**
	height of wall = 1.2 + 7.8 = 9.0 m	**(A1)**

Q2.

(a)(ii)	tangent line to curve drawn on Fig. 2.1	**C1**
	a = gradient of tangent line = $\Delta v / \Delta t$ e.g. = (44 – 26) / (18 – 0) $0.9 \leqslant a \leqslant 1.1$ m s^{-2}	**A1**

Q3.

(b)(iv)	distance = $½ \times 40 \times (8 + 4)$ **or** distance = $½ \times 72\,000 \times (8 + 4) / 1800$ **or** distance = $[40^2 / (2 \times 5)] + [40^2 / (2 \times 10)]$ **or** distance = $½ \times 5 \times 8^2 + (40 \times 4 - ½ \times 10 \times 4^2)$	**C1**
	distance = 240 m	**A1**

Q4.

(c)	$x = ut + \frac{1}{2}at^2$ $x = 0.60 \times 3.7 + \frac{1}{2} \times 0.85 \times 3.7^2$	**C1**
	or	
	$v = 0.60 + 0.85 \times 3.7$ (= 3.75 m s^{-1}) $x = 3.75 \times 3.7 - 0.5 \times 0.85 \times 3.7^2$ **or** $x = \frac{1}{2} \times (0.60 + 3.75) \times 3.7$ **or** $x = (3.75^2 - 0.60^2) / (2 \times 0.85)$	**(C1)**
	$x = 8.0$ m	**A1**

Q5.

(c)(iii)	(gravitational / resultant) force / weight is vertical	**B1**
(c)(iv)	straight line with positive gradient starting from non-zero value of v_Y at time t_A to a time t_B	**B1**

Q6.

(c)(iii)	no variation **or** acceleration is (always) vertically downwards	**B1**
(c)(iv)	horizontal straight line at a non-zero value of velocity	**B1**

Q7.

(a)	displacement	**A1**
(b)(i)	a = gradient **or** $a = \Delta v / (\Delta)t$ **or** $a = (v - u) / t$	**C1**
	e.g. $a = (0.30 - 0.12) / (0.35 - 0.15)$ $a = 0.90$ m s^{-2}	**A1**

Q8.

(b)	initial speed / velocity is zero	**B1**
	(non-zero magnitude of) acceleration is constant / uniform (and in a straight line)	**B1**
(c)(i)	• magnitude of acceleration at $t = 8.0$ s is less than that at $t = 14.0$ s	**B1**
	• direction of acceleration at $t = 8.0$ s is opposite to that at $t = 14.0$ s	**B1**
(c)(ii)	a = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / (\Delta)t$	**C1**
	a = e.g. $(20 + 10) / 12$ **or** $(0 + 10) / 4$ **or** $(20 - 0) / (12 - 4)$ $a = 2.5$ m s^{-2}	**A1**
(c)(iii)	displacement $= [\frac{1}{2} \times (12 - 4) \times 20] - [\frac{1}{2} \times 4 \times 10]$ **or** displacement $= (-10 \times 12) + (\frac{1}{2} \times 2.5 \times 12^2)$ **or** displacement $= (20 \times 12) - (\frac{1}{2} \times 2.5 \times 12^2)$ **or** displacement $= \frac{1}{2} \times (20 - 10) \times 12$	**C1**
	displacement = 60 m	**A1**

Q9.

(a)	change in displacement / time (taken)	**B1**
(b)(i)	(displacement =) area under graph	**C1**
	(at t = 4.0 s) v = (–) 2.4	**C1**
	height = ½ × 2.5 × 4.0 – ½ × 1.5 × 2.4 = 3.2 m	**A1**

Q10.

(a)	$v^2 = u^2 + 2as$ $s = 5.6^2 / (2 \times 9.81)$	**C1**
	(max height =) 3.1 + $5.6^2 / (2 \times 9.81)$ = 4.7 (m)	**A1**
(b)	$s = ut + \frac{1}{2}at^2$ $4.7 = \frac{1}{2} \times 9.81 \times t^2$	**C1**
	t = 0.98 s	**A1**
(c)	line drawn from a non-zero speed at t = 0 to a greater speed at $t = T$	**B1**
	a single sloping straight line drawn from t = 0 to $t = T$	**B1**
	line starts with a positive non-zero value of v and ends with a negative non-zero value of v	**B1**
(d)	acceleration (of the ball)	**B1**
(e)(ii)	(speeds are) equal / same	**B1**

Q11.

(a)(i)	t = 1.8 / 4.9 = 0.37 s	**A1**
(a)(ii)	$v = u + at$ = 9.81 × 0.37	**C1**
	= 3.6 m s^{-1}	**A1**

Q12.

(c)(i)	$v^2 = u^2 + 2as$ $3.6^2 = (-1.4)^2 + 2 \times 9.81 \times s$ **or** $3.6^2 = 1.4^2 + 2 \times 9.81 \times s$	**C1**
	s = 0.56 m	**A1**
(c)(ii)	single straight line from any positive non-zero value of v at t = 0 to any negative non-zero value of v at $t = T$	**B1**
	line starting at (0, 1.4) and ending at (T, –3.6)	**B1**

Q13.

(a)	$v^2 = u^2 + 2as$ $u^2 = 8.7^2 - (2 \times 9.81 \times 1.5)$	**C1**
	u = 6.8 m s^{-1}	**A1**
(d)	straight line with a positive gradient and starting from a non-zero value of speed at t = 0 and ending when $t = T$	**B1**

Q14.

(c)(ii)	speed = horizontal component of velocity $= 5.7 \times \cos 41°$	**C1**
	$= 4.3\ \text{m s}^{-1}$	**A1**

Q15.

(b)(iv)	$s = ut + \frac{1}{2}at^2$ $(1.4 \times 10^{-2} / 2) = \frac{1}{2} \times 20 \times t^2$	**C1**
	$t = 2.6 \times 10^{-2}\ \text{s}$	**A1**
(c)	line from $(0, 0.7 \times 10^{-2})$ to a non-zero point on the t-axis	**M1**
	magnitude of gradient of line increases	**A1**

Q16.

(c)	distance $= (\frac{1}{2} \times 2 \times 12) + (2 \times 12)$ $(= 36\ \text{m})$	**C1**
	time taken $= 36 / 338$ $= 0.11\ \text{s}$	**A1**

Q17.

(b)(i)	arrow drawn vertically downwards from point X	**B1**
(b)(ii)	$s = ut + \frac{1}{2}at^2$ $h = \frac{1}{2} \times 9.81 \times 0.81^2$	**C1**
	$= 3.2\ \text{m}$	**A1**
(b)(iii)	$d = 5.4 \times 0.81$ $= 4.4\ \text{m}$	**A1**

Q18.

(a)	(velocity =) change in displacement / time (taken)	**B1**

Q19.

(a)(i)	area $= ut + \frac{1}{2}(v - u)t$ **or** area $= vt - \frac{1}{2}(v - u)t$ **or** area $= \frac{1}{2}(u + v)t$	**A1**
(a)(ii)	displacement	**A1**
(b)(i)	$u = 15 \sin 60°\ (= 13\ \text{m s}^{-1})$	**C1**
	$t = 15 \sin 60° / 9.81$	**C1**
	$= 1.3\ \text{s}$	**A1**
(b)(ii)	the force in the horizontal direction is zero	**B1**

Q20.

(a)	constant gradient	**B1**
(b)	(displacement until 0.20 s =) ½ × 1.96 × 0.20 (= 0.196 m) **or** (displacement after 0.20 s =) ½ × 6.86 × 0.70 (= 2.401 m)	**C1**
	height = 2.401 – 0.196	**C1**
	= 2.2 m (*alternative methods are possible using equations of uniformly accelerated motion*)	**A1**
(d)	curved line from the origin	**M1**
	gradient of curved line decreases and is zero at t = 0.20 s only	**A1**
(e)	acceleration (of free fall) is unchanged/is not dependent on mass and (so) no effect	**B1**

Q21.

(b)(i)	decelerates **or** speed/velocity decreases	**B1**
(b)(ii)	speed = (Δ)d / (Δ)t **or** gradient	**C1**
	= e.g. (0.56 – 0.20) / 1.5 = 0.24 m s^{-1}	**A1**

Q22.

(b)(i)	a = (v – u) / t **or** (Δ)v / (Δ)t **or** gradient	**C1**
	= e.g. 8.0 × 10^{-2} / 2.0 = 4.0 × 10^{-2} m s^{-2}	**A1**
(b)(ii)	distance = (½ × 2.5 × 0.10) + (½ × 1.5 × 0.10) **or** (½ × 4.0 × 0.10) (= 0.20 (m))	**C1**
	depth = 0.32 – 0.20 = 0.12 m	**A1**

Q23.

(a)	(velocity =) change in displacement / time (taken)	**B1**

Q24.

(b)(i)	distance = area under graph **or** s = ½ (u + v) t = ½ × (9 + 13) × 10 **or** s = ut + ½at^2 = (9 × 10) + (½ × 0.40 × 10^2) **or** s = vt – ½at^2 = (13 × 10) – (½ × 0.40 × 10^2) **or** v^2 = u^2 + 2as 13^2 = 9^2 + (2 × 0.40 × s)	**C1**
	distance = 110 m	**A1**

Q25.

(c)	$(\Delta)E = mg(\Delta)h$	**C1**
	$E = ½mv^2$	**C1**
	ratio $= (m \times 9.81 \times 4.8) / (½ \times m \times 9.2^2)$ **or** $(9.81 \times 4.8) / (½ \times 9.2^2)$	**C1**
	$= 1.1$	**A1**

Q26.

(e)(ii)	$v^2 = u^2 + 2as$ $v^2 = 2 \times 13 \times 0.58$	**C1**
	$v = 3.9\ \text{m s}^{-1}$	**A1**

Q27.

(a)	change in velocity / time (taken)	**A1**
(b)(ii)	$s = ut + ½at^2$ $0.280 = ½ \times 9.81 \times t^2$	**C1**
	$t = 0.24$ s	**A1**
(b)(iii)	total distance fallen = 0.280 + 0.080 = 0.360 $0.360 = ½ \times 9.81 \times t^2$ $t = 0.27$ s	**C1**
	time taken = 0.27 – 0.24 = 0.03 s	**A1**
	or	
	$v = 9.81 \times 0.239$ **or** $(2 \times 9.81 \times 0.280)^{0.5}$ **or** $(2 \times 0.280) / 0.239$ $= 2.34\ (\text{m s}^{-1})$	**(C1)**
	$0.080 = 2.34t + ½ \times 9.81 \times t^2$ solving quadratic equation gives $t = 0.03$ s *allow any correct method using equations of uniform accelerated motion*	**(A1)**

Q28.

(b)(i)1.	from 0–2 s, distance = ½ × 2 × 6.8 (= 6.8 m) **and** from 2–3 s, distance = ½ × 1 × 3.4 (= 1.7 m)	**C1**
	magnitude of displacement = 5.1 m	**A1**
	direction of displacement is down(wards)	**B1**
(b)(i)2.	$(\Delta E) = mg\Delta h$ **or** $(E) = mgh$ **or** $(E) = Wh$	**C1**
	$(\Delta)E = 15 \times 5.1$ $= (–)\ 77$ J	**A1**
(b)(ii)	$a = (v – u) / t$ **or** a = gradient **or** $a = \text{d}v/\text{d}t$	**C1**
	$a = 3.4\ \text{m s}^{-2}$	**A1**

Q29.

(a)	time = 12 s	**A1**
(b)	distance (up slope) = ½ × 12 × 18 (= 108)	**C1**
	distance (down slope) = ½ × 12 × 6 (= 36)	**C1**
	displacement from A = 108 – 36 = 72 m	**A1**
(c)	$v = u + at$ **or** a = gradient **or** $a = \Delta v / (\Delta)t$	**C1**
	a = 6 / 12 = 0.50 ($m s^{-2}$) *(other points from the line may be used)*	**A1**
	or	
	$v^2 = u^2 + 2as$ **and** $u = 0$ **or** $v^2 = 2as$	**(C1)**
	$a = 6.0^2 / (2 \times 36) = 0.50$ ($m s^{-2}$)	**(A1)**
	or	
	$s = ut + ½at^2$ **and** $u = 0$ **or** $s = ½at^2$	**(C1)**
	$a = 2 \times 36 / 12^2 = 0.50$ ($m s^{-2}$)	**(A1)**
	or	
	$s = vt – ½at^2$	**(C1)**
	$a = 2 \times (6 \times 12 – 36) / 12^2 = 0.50$ ($m s^{-2}$)	**(A1)**

Q30.

(a)(i)	distance in a specified direction (from a point)	**B1**
(a)(ii)	change in velocity / time (taken)	**B1**
(b)(ii)	$s = ut + ½at^2$ $0 = (3.0 \times t) – (½ \times 9.81 \times t^2)$ **or** $v = u + at$ $–3.0 = 3.0 – 9.81t$	**C1**
	t = 0.61 s	**A1**
(b)(iii)	d = 4.6 × 0.61 = 2.8 m	**A1**
(c)	straight line from positive value of v_y at $t = 0$ to negative value of v_y	**M1**
	straight line ends at $t = T$ and final magnitude of v_y greater than initial magnitude of v_y	**A1**

Q31.

(b)(i)	straight line from (0, 4.8) to (0.49, 0)	**M1**
	straight line continues with same slope to (0.98, –4.8) (labelled Y)	**A1**
(b)(ii)	a horizontal line	**M1**
	from (0, 3.6) to (0.98, 3.6) (labelled X)	**A1**
(c)	$s = ut + ½at^2$ $= (4.8 \times 0.49) + (½ \times –9.81 \times 0.49^2)$ **or** $s = ½(u + v)t$ **or** area under graph $= ½ \times (4.8 + 0) \times 0.49$ **or** $s = vt – ½at^2$ $= ½ \times 9.81 \times 0.49^2$ **or** $v^2 = u^2 + 2as$ $s = 4.8^2 / (2 \times 9.81)$	**C1**
	$s = 1.2$ m	**A1**