3. Dynamics

3.1 Momentum and Newton's laws of motion

Paper 2

Marking Scheme

Q1.

(c)	$E_K = ½ \times m \times v^2$ $(= ½ \times 4.2 \times 6.0^2)$ (= 76 J)	**C1**
	force = work done / distance	**C1**
	force = 76 / 0.050 = 1500 N	**A1**
(c)	**or**	
	$a = (–)u^2 / 2s$ $= (–)6.0^2 / (2 \times 0.050)$ $(= (–)360\ m\ s^{–2})$	**(C1)**
	$F = ma$	**(C1)**
	$F = 4.2 \times 360$ = 1500 N	**(A1)**
	or	
	$a = (–)u^2 / 2s$ $= (–)6.0^2 / (2 \times 0.050)$ $(= (–)360\ m\ s^{–2})$	**(C1)**
	$t = –u / a$ $= –6.0 / –360$ (= 0.017 s) $F = \Delta p / t$	**(C1)**
	$F = (0 – 4.2 \times 6) / 0.017$ = 1500 N	**(A1)**

Q2.

(b)	$(\Sigma)F = 68 \times 9.81 – 1800$ $(= –1133\ N)$	**C1**
	$a = (\Sigma)F / m = – 1133 / 68$ $= (–)17\ m\ s^{–2}$	**A1**
	upwards	**B1**
(c)(ii)	$(\Delta)p = m\Delta v$ **or** $(\Delta)p = m(v – u)$	**C1**
	$= 68 \times (5.7 – 39)$ $= (–)2300$ N s	**A1**

Q3.

(a)	product of mass and velocity	**B1**
(b)(i)	maximum speed $= 7.2 \times 10^4 / 1800$ $= 40 \text{ m s}^{-1}$	**A1**
(b)(iii)	a = gradient of line / mass **or** $a = (v - u) / t$ **or** $a = \Delta v / t$	**C1**
	a = e.g. $(3.6 \times 10^4) / (4.0 \times 1800) = 5.0 \text{ m s}^{-2}$ **or** a = e.g. $20 (- 0) / 4 = 5.0 \text{ m s}^{-2}$ **or** F = e.g. $3.6 \times 10^4 / 4.0 = 9.0 \times 10^3$ **and** $a = 9.0 \times 10^3 / 1800 = 5.0 \text{ m s}^{-2}$	**A1**
(c)	stepped shape, showing one constant value up to 8.0 s then stepping to a different constant value from 8.0 s with no time delay	**B1**
	horizontal straight line from (0, 5.0) to (8.0, 5.0)	**B1**
	horizontal straight line from (8.0, –10.0) to (12.0, –10.0)	**B1**

Q4.

(a)	product of mass and velocity	**B1**
(b)	$F = m\Delta v / \Delta t$ $= 16 \times 0.60 / 1.1$	**C1**
	$= 8.7$ N	**A1**

Q5.

(a)	(resultant) force (on an object) is proportional to / equal to the rate of change of momentum	**B1**
(b)(i)	resultant force = e.g. 6.0 / 4.0 = 1.5 N	**A1**
(b)(ii)	force X = 1.5 + 2.0 = 3.5 N	**A1**
(c)	from $t = 0$ to $t = 4.0$ s: horizontal line at any non-zero value of X	**B1**
	from $t = 0$ to $t = 4.0$ s: horizontal line at $X = 3.5$ N	**B1**
	from $t = 4.0$ s to $t = 6.0$ s: horizontal line at $X = 2.0$ N	**B1**

Q6.

(a)(i)	rate of change of momentum	**B1**
(a)(ii)	change in momentum = $(1.4 - 0.80) \times 3.0$	**C1**
	$= 1.8 \text{ kg m s}^{-1}$	**A1**
(b)(i)	resultant force (on block) is zero	**B1**
	(so) velocity is constant	**B1**
(c)	0 to 3.0 s: upward sloping straight line from the origin.	**B1**
	3.0 to 6.0 s: horizontal line at non-zero value of momentum with no 'step change' in momentum at 3.0 s	**B1**

Q7.

(a)(iii)	$m = W / g$ **or** $a = F / m$	**C1**
	$a = (4.00 \times 10^2) / [(3.39 \times 10^4) / 9.81)]$	**C1**
	$a = 0.12$ m s^{-2}	**A1**

Q8.

(b)(i)	acceleration = 9.8 m s^{-2}	**A1**
(c)	$F = ma$ $= 4.0 \times 1.9$ (= 7.6 N)	**C1**
	resistive force = $(4.0 \times 9.81) - (4.0 \times 1.9)$ = 32 N	**A1**

Q9.

(a)(iii)	magnitudes: equal	**B1**
	directions: opposite	**B1**

Q10.

(b)(ii)	change in momentum = 7.5 (–4.0 – 2.4)	**C1**
	= (–) 48 N s	**A1**
(b)(iii)	$W = \Delta p / (\Delta)t$ **or** $\Delta mv / (\Delta)t$	**C1**
	= 48 / 4.0 = 12 N	**A1**
	or	
	$W = ma$ **or** mg **or** $m(v - u) / t$	**(C1)**
	= 7.5 × 1.6 **or** 7.5 × (4 + 2.4) / 4.0 = 12 N	**(A1)**

Q11.

(e)(i)	(magnitudes of accelerations are) equal / same	**B1**

Q12.

(b)	$m = 0.053 / 9.81$ (= 5.4 × 10^{-3} kg)	**C1**
	$F = 0.071 - 0.053$ (= 0.018 N)	**C1**
	$a = (0.071 - 0.053) / (0.053 / 9.81)$ = 3.3 m s^{-2}	**A1**

Q13.

(c)(i)	(p =) 0.25×2.3 **or** 0.25×1.5	**C1**
	change in momentum = 0.25 (2.3 + 1.5) = 0.95 N s	**A1**
(c)(ii)	resultant force = 0.95 / 0.086 or $0.25 \times (2.3 + 1.5) / 0.086$ = 11 N	**A1**

Q14.

(a)(ii)	$a = F / m$	**C1**
	a = 18 / 72 = 0.25 ($m s^{-2}$) t = 1.4 / 0.25	**C1**
	= 5.6 s	**A1**
(b)(i)	a = (54 – 18) / 72 **or** 36 / 72 (= 0.50 $m s^{-2}$)	**C1**
	$v^2 = 2 \times 0.50 \times 9.5$	**C1**
	v = 3.1 $m s^{-1}$	**A1**

Q15.

(b)	(magnitude of) force on ball (by ground) equal to force on ground (by ball)	**B1**
	(direction of) force on ball (by ground) opposite to force on ground (by ball)	**B1**
(c)(i)	(p =) 0.059×8.7 **or** 0.059×5.4	**C1**
	change in momentum = 0.059 (8.7 + 5.4) = 0.83 N s	**A1**
(c)(ii)	resultant force = 0.83 / 0.091 **or** 0.059 [(8.7 + 5.4) / 0.091] = 9.1 N	**A1**
(c)(iii)	(W =) 0.059×9.81	**C1**
	(W =) 0.58 (N) force = 9.1 + 0.58 = 9.7 N	**A1**

Q16.

(a)	mass × velocity	**B1**
(b)(ii)	change in momentum = ½ × 240 × 5.0 × 10^{-3}	**C1**
	= 0.60 N s	**A1**
(b)(iii)	(change in velocity of Y) = 0.60 / 0.12 (= 5.0 m s^{-1})	**C1**
	final velocity of Y = 5.0 – 2.3 = 2.7 m s^{-1}	**A1**
	or	
	(final momentum of Y) = 0.60 – 0.12 × 2.3 (= 0.324 N s)	**(C1)**
	final velocity of Y = 0.324 / 0.12 = 2.7 m s^{-1}	**(A1)**
(c)	sloping straight line from (0, 0) to *t* = 3.0 ms **and** another straight line continuous with the first from *t* = 3.0 ms to (5.0, 0)	**B1**
	lines showing maximum force of magnitude 240 N	**B1**
	lines wholly in the negative *F* region of the graph	**B1**

Q17.

(b)(iii)	(*a* =) *F* / *m* **or** 2*W* / *m* **or** 2*g*	**B1**
	a = 9.2 × 10^{-14} / (4.6 × 10^{-14} / 9.81) = 20 (m s^{-2}) **or** *a* = 2 × 9.81 = 20 (m s^{-2})	**A1**

Q18.

(a)	(resultant) force proportional to rate of change of momentum	**B1**

Q19.

(c)(i)	*p* = *mv* **or** 0.40 × 7.5 **or** 0.40 × 4.3	**C1**
	Δ*p* = 0.40 (7.5 + 4.3) = 4.7 kg m s^{-1}	**A1**
(c)(ii)	force = 4.7 / 0.12 **or** 0.40 × [(7.5 + 4.3) / 0.12] = 39 N	**A1**

Q20.

(a)	(force =) rate of change of momentum	**B1**
(b)(ii)	*p* = *mv* **or** 0.062 × 3.8 **or** 0.062 × 1.7	**C1**
	change in momentum = 0.062 × (1.7 + 3.8) = 0.34 N s	**A1**
(b)(iii)	(average resultant force =) 0.34 / 0.081 = 4.2 (N) **or** (average resultant force =) 0.062 × (1.7 + 3.8) / 0.081 = 4.2 (N)	**A1**
(b)(iv)	**1.** average force = 4.2 + (0.062 × 9.81) = 4.8 N	**A1**
	2. average force = 4.8 N	**A1**

Q21.

(b)(ii)	$E = \frac{1}{2}mv^2$	**C1**
	$p = mv$	**C1**
	$0.72 = \frac{1}{2} \times 0.020 \times v^2$ and $p = 0.020 \times v$ $p = 0.17$ N s	**A1**

Q22.

(a)	(momentum =) mass × velocity	**B1**
(b)(i)	time = 40 ms	**A1**
(b)(ii)	**1.** (the magnitude of the acceleration is) constant	**B1**
	2. (the magnitude of the acceleration is) zero	**B1**
(c)	$F = \Delta p / (\Delta)t$ **or** F = gradient	**C1**
	e.g. $F = 0.50 / 40 \times 10^{-3}$ $= 13$ N	**A1**

Q23.

(a)	(resultant) force proportional/equal to/is rate of change of momentum	**B1**
(b)(ii)	**1.** a = gradient **or** $a = (v - u) / t$ **or** $a = \Delta v / (\Delta)t$ e.g. $a = (14 - 9) / 12.5$ **or** $(13 - 9) / 10$	**C1**
	$a = 0.40$ m s^{-2}	**A1**
	2. resultant force $= 850 \times 0.40$ $= 340$ N	**A1**
	3. (F =) 510 + 440 + 340 = 1300 (N)	**A1**
	4. $P = Fv$	**C1**
	$= 1300 \times 13$ $= 1.7 \times 10^4$ W	**A1**

Q24.

(e)(i)	$m = 5.4 \times 10^{-5} / 9.81$ ($= 5.5 \times 10^{-6}$)	**C1**
	$a = 7.2 \times 10^{-5} / (5.5 \times 10^{-6})$ $= 13$ m s^{-2}	**A1**

Q25.

(b)(i)	$\Delta p = 0.55 \times 7.6$ $= 4.2$ N s	**A1**
(b)(ii)	$F = 4.2 / 3.0$ **or** $0.55 \times 7.6 / 3.0$ $= 1.4$ N	**A1**
(c)(i)	$F = 1.4$ N	**A1**
(c)(ii)	Newton's third law (of motion)	**B1**
(d)	$2 \times 1.4 = m \times 9.81$ $m = 0.29$ kg	**A1**

Q26.

(a)	force on body A (by body B) is equal (in magnitude) to force on body B (by body A)	**B1**
	force on body A (by body B) is opposite (in direction) to force on body B (by body A)	**B1**
(c)(i)	**1.** (magnitude of resultant force is) zero	**B1**
	2. (magnitude of resultant force is) constant	**B1**
	(direction of resultant force is) opposite to the momentum	**B1**

Q27.

(a)	a body continues at (rest or) constant velocity unless acted upon by a resultant force	**B1**
(b)(iii)	$T - W = ma$ **or** $T - mg = ma$	**C1**
	$T = 15 + (15/9.81) \times 3.4 = 20\,\text{N}$ or $20.2\,\text{N}$	**A1**
(b)(v)	block is in equilibrium/has no resultant force	**B1**
	block could be stationary (**or** have constant velocity/speed) (so no, not possible to deduce)	**B1**

Q28.

(a)	mass is the property (of a body/object) resisting changes in motion **or** mass is the quantity of matter (in a body)	**B1**
(b)(i)	force on A (by B) equal and opposite to force on B (by A) **or** both A and B exert equal and opposite forces on each other	**B1**
	force is rate of change of momentum and time (of contact) is same	**B1**

Q29.

(a)	rate of change of momentum	**B1**

Q30.

(d)(i)	$F = 70 \times 0.50$ (= 35)	**C1**
	frictional force $= 80 - 35$ $= 45\,\text{N}$	**A1**
(d)(ii)	$\sin\theta = 80/(70 \times 9.81)$	**C1**
	$\theta = 6.7°$	**A1**

Q31.

(c)	force is equal to rate of change of momentum	**B1**
	force on ball (by block) equal and opposite to force on block (by ball) so rates of change of momentum are equal and opposite	**B1**
	or	
	force on ball (by block) equal and opposite to force on block (by ball)	**(B1)**
	force is equal to rate of change of momentum so rates of change of momentum are equal and opposite	**(B1)**

Q32.

(b)(ii)	**1.** $(\Delta)p = (\Delta)mv$	**C1**
	$= 0.030 \times 1.8$ $= 0.054\,\text{N s}$	**A1**
	2. $F = 0.054/2.0$ **or** $0.030 \times 1.8/2.0$ $= 0.027\,\text{N}$	**A1**
(b)(iii)	force on air (by propeller) equal to force on propeller (by air)	**M1**
	and opposite (in direction)	**A1**
(b)(iv)	resultant force $= 0.20 \times 0.075$ (= 0.015 N) frictional force $= 0.027 - 0.015$	**C1**
	$= 0.012\,\text{N}$	**A1**