Question	Answer	Marks	AO Element	Notes	Guidance
1	molecules collide with the walls (of the container) (1) momentum of molecules changes (reverses) (1) this causes a force **AND** force spread out (over area of walls) (1)	**3**			
2(a)	(a =) $(v - u) \div t$ **OR** $(62 - 6.0) \div 35$ **OR** $56 \div 35$ (1) 1.6 m/s^2 (1)	**2**			
2(b)	(F =) ma **OR** $\Delta p \div \Delta t$ **OR** $2.5 \times 10^5 \times 1.6$ **OR** $(62 \times 2.5 \times 10^5 - 6.0 \times 2.5 \times 10^5) \div 35$ (1) 4.0×10^5 N (1)	**2**			
2(c)	(p =) mv **OR** $2.5 \times 10^5 \times 6.0$ (1) 1.5×10^6 kg m / s (1)	**2**			

Question	Answer	Marks	AO Element	Notes	Guidance
3(a)	impulse **OR** $\Delta p = m(v - u)$ in any form (1) (impulse =) 750 000 (84 – 42) (1) (impulse =) 3.2×10^7 N s **OR** m kg / s (1)	**3**			
3(b)	Ft = impulse **OR** Δp in any form **OR** (F =) (impulse **OR** Δp) / t (1) (F = 3.2 x 10^7 / 80 =) 3.9×10^5 N; (1)	**2**			
4(a)	(impulse =) <u>change</u> of momentum (1) (impulse =) 71(10 – 4) (1) (impulse =) 430 N s (1)	**3**			
4(b)	(impulse =) force × time	**1**			
4(c)	(average F =) impulse / time (= 430 / 1.2) (1) (average F =) 360 N (1)	**2**			
5(a)	(v =) I /m in any form, words or symbols **OR** 0.019 / 0.00011 (1) 170 m / s (1)	**2**			

Question	Answer	Marks	AO Element	Notes	Guidance
5(b)	*(KE* =) ½*mv*^{2} in any form, words or symbols (1) 0.50 × 0.00011 × 170^2 (1) 1.6 J **OR** 1.7 J (1)	**3**			
6	smaller force (on dock/ship) because increases time of collision **OR** increased distance of collision (on the dock/ship)	**1**			
7	no external forces **OR** isolated system (1) sum of momenta / (total) momentum remains constant (1)	**2**			
8	rocket gains (upward) momentum (1) (ejected) gas gains equal (quantity of) momentum in opposite direction **OR** momentum of gas decreases by equal amount (1)	**2**			
9(a)	(Δ) p=mv in any form **OR** ((Δ)p=) mv **OR** 0.8 × 0.72 (1) (Δp=) 0.58 kg m/s (1)	**2**			

Question	Answer	Marks	AO Element	Notes	Guidance
9(b)	Ft= Δp in any form **OR** (F=) Δp/t **OR** 0.58/6 (1) (F=) 0.096 N (1)	**2**		accept rounding if 0.096 seen	
10	**EITHER** (change in momentum) = *mv* **OR** (change in momentum) = $1.2 \times 10^6 \times 0.04$ (1) (=) 4.8×10^4 (kg m/s) (1) change in momentum = Ft in any form (1) (force = 4.8×10^4 / 0.3 =) 1.6×10^5 N (1) **OR** a = (v-u)/t = 0.04/0.3 (1) = 0.13 (m/s^2) (1) F = ma (1) (force = $1.2 \times 10^6 \times 0.13$ =) 1.6×10^5 N (1)	**4**			
11(a)	(*p* =) *mv* **OR** 0.046 × 65 (1) 3.0 kg m / s **OR** 3.0 N s (1)	**2**			

Question	Answer	Marks	AO Element	Notes	Guidance
11(b)	(*F* =) *m(v–u) /t* **or** 3.0 / 0.00050 **OR** *a* = (v – u) / t **AND** *F* = *ma* **or** 0.046 × 65 / 0.00050 **or** 0.046 × 130 000 (1) 6000 N (1)	**2**			
12(a)	(momentum =) *mv* **OR** 4.0 × 12 (1) 48 kg m / s or N s (1)	**2**			
12(b)	(average force =) momentum change / time **OR** *m(v – u) / t* **OR** *(mv – mu) / t* **OR** *F = ma* **AND** *a = (v – u) / t* **OR** 48 / 0.60 (1) 80 N (1)	**2**			
13	*mv – mu* **OR** *mu – mv* in any form	**1**			
14(a)	(impulse =) *Ft* in any form (1) (impulse =) 2.4 N s (1)	**2**			

Question	Answer	Marks	AO Element	Notes	Guidance
14(b)	$Ft = mv - mu$ in any form **OR** ($v - u =$) Ft / m (1) 43 m / s (1)	**2**			
15	1st box: force (1) 2nd box: impulse (1)	**2**			
16	F = (mv – mu) / t in any form **OR** impulse = mv – mu (1) = 20 × 4.2 / 60 (1) 1.4 N (1)	**3**			
17	C	**1**			
18(a)(i)	($p =$) 3.2 x 4.0 13 kg m / s	**2**			
18(a)(ii)	momentum conserved 12.8 – (3.2 x 1.5) **OR** 12.8 – 4.8 **OR** 8.0 **OR** 8.0 ÷ 1.6 5.0 m / s	**3**			

Question	Answer	Marks	AO Element	Notes	Guidance
18(b)	$(F =) \frac{\Delta p}{\Delta t}$ **OR** 8.0 ÷ 0.050 160 N	**2**			
18(c)	internal energy (of blocks) increase **OR** thermal energy/sound energy (lost/produced at collision)	**1**			
19(a)(i)	(momentum =) mv (momentum = 2.4 × 3 =) 7.2 kg m / s **OR** Ns	**2**			
19(a)(ii)	$(m_A + m_b)v = m_A \times 3$ **OR** momentum conserved (v = 7.2 / 3.6 =) 2.0 m / s	**2**			
19(a)(iii)	(impulse / Ft =) m(v-u) (impulse / Ft = 1.2 × (2-0) =) 2.4 kg m / s **OR** Ns	**2**			
19(b)	thermal/sound energy (produced at collision/lost)	**1**			

Question	Answer	Marks	AO Element	Notes	Guidance
20(a)(i)	*Ft* **OR** 180 × 0.050 9.0 Ns **OR** 9.0 kg m / s	**2**			
20(a)(ii)	*Ft* = *m*(*v* - *u*) **OR** *Ft* = *mv* - *mu* **OR** *Ft* = *mv* **OR** (*m* =) *Ft* / *v* **OR** 9.0 / 20 0.45 kg	**2**			
20(a)(iii)	*mgh* = ½ *mv* ^{2} **OR** (*h* =) *v* ^{2} / 2 *g* (h =) 20^2 / (2 × 10) 20 m **OR** *t* = *v* / *g* = 2 *h* = average speed × time 20 m	**3**			
20(b)	elastic (energy) / strain (energy)	**1**			
21	force × time (for which it acts)	**1**			
22	force and time	**1**			

Question	Answer	Marks	AO Element	Notes	Guidance
23	(momentum =) mass x velocity	**1**			
					[Total: 83]