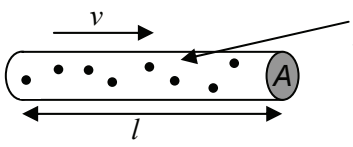
Question			Marking details	Marks Available
1	*(a)*		Rate of change [accept: increase] of velocity [**not** speed]. accept: $\frac{v-u}{t}$ or $\frac{\Delta v}{t}$ or $\frac{\Delta v}{\Delta t}$ (not $\frac{v}{t}$)	1
	(b)	(i)	Both ΣF calculated correctly (20 N and 4 N) (1) Use of $a = \frac{\Sigma F}{m}$ (1) Accelerations = 10 m s^{-2} and 2 m s^{-2} (e.c.f.) (1) [Accept answers based upon calculating resultant acceleration]	3
		(ii)	Diagram with forces shown in opposition (1) and horizontal (1) [B.o.d. on plan-view forces unless clearly incorrect]	2
	(c)		<table><tr><th>Statement</th><th>Must be true</th><th>Could be true</th><th>Cannot be true</th></tr><tr><td>xxxxxxxxxx</td><td></td><td></td><td>✓</td></tr><tr><td>xxxxxxxxx</td><td></td><td>✓</td><td></td></tr><tr><td>xxxxxxxx</td><td></td><td>✓</td><td></td></tr><tr><td>xxxxxxxxx</td><td></td><td></td><td>✓</td></tr></table>	4
				[10]
2.	*(a)*		Same p.d. in both branches (1) 2 × resistance in upper branch (or converse) (1) ½ current in upper branch (or converse) (1) } Correct qualitative answer → 1 mark Currents add up to 0.12 A (1)	4
	(b)	(i)	4.8 V	1
		(ii)	9.6 V	1
	(c)	(i)	Correct use of $R = \frac{V}{I}$ (1) [or by implication] = 120 Ω (1) [e.g. $\frac{4.8}{0.04}$ ✓, $\frac{9.6}{0.08}$ (✓ b.o.d.) or $\frac{9.6}{0.4}$ ✓ **not** $\frac{9.6}{1.2}$ ×]	2
		(ii)	$\frac{1}{R} = \frac{1}{R_A} + \frac{1}{R_B}$ [or equiv.] **and** use of correct values of R_A and R_B. [or by impl.](1) R = 80 Ω (1) **or** $R = \frac{9.6}{0.12}(1) = 80$ Ω (1)	2
				[10]

Question			Marking details	Marks Available
3	*(a)*	(i)	2.4 V	1
		(ii)	$\frac{V}{V_{\text{TOTAL}}} = \frac{R}{R_{\text{TOTAL}}}$ or $V_{\text{OUT}} = \frac{R_1}{R_1 + R_2} V_{\text{IN}}$, selected [or by impl.] Substitution, e.g. $3.6 = \frac{225}{225 + R_2} 6.0$ (1) [or by impl.] Manipulation (1); $R_2 = 150\ \Omega$ (1) **Or** – from 1st principles: $\frac{3.6}{225}(1) = 0.016\text{ A}\ (1)$; $\frac{2.4}{0.016}(1) = 150\,\Omega\,(1)$ [or $\frac{6.0}{0.016} = 375\,\Omega$ then 375 – 225 = 150 Ω]	4
	(b)	(i)	R_2 changed to 1500 Ω	1
		(ii)	Initial current = $\frac{6.0}{375\text{e.c.f.}}$ (1) = 0.016 A (1) Final current = 0.0016 A (1) [**or** accept answer based upon a good qualitative argument] N.B. Calculation of final current → only 2 unless current previously calculated]	3
				[9]
4.	*(a)*		Collisions between electrons and lattice [or atoms of the conductor or [metal] ions] (1) Kinetic energy of electrons transferred to lattice (1) No collisions (and ∴ no energy transfer) in superconductors) (1) [accept: interactions instead of collisions]	3
	(b)	(i)	−190°C	1
		(ii)	A→B [accept −250 - −190, or "temperatures below −190] [full region required]	1
	(c)		liquid nitrogen [accept: liquid helium]	1
				[6]

Question			Marking details	Marks Available
5.	*(a)*		Flow of charge	1
	(b)	(i)	 *n* [free] electrons per unit volume [or electron density] [or in written answer]	
			Diagram (1) Volume of conductor = Al Number of free electrons = nAl } (1) Total charge flowing within $l = nAle$ [Accept without [ ] **if** diagram is clear]	
			$I = \frac{nAle}{t}$ (1) and $v = \frac{l}{t}$ (1)	4
		(ii)	$v = \frac{I}{nAe}$ $= \frac{3.0}{5.0\times10^{28}\times2\times10^{-6}(1)\times1.6\times10^{-19}} = 1.9 \times 10^{-4}$ m s^{-1} ((**unit**))(1)	2
		(iii)	I. ……the same as	1
			II. …….half…..	1
				[9]
6	*(a)*		Units of LHS = N = kg m s^{-2} Units of RHS = (kg m^{-3} . m^2) (+ manip.)(1) × (m^2 s^{-2}) (1)	3
			$v^2 = \frac{2.8\times10^4}{1.2\times15\times4.2}$ (1) [or by impl.] v = 19.2 m s^{-1} (1)	2
	(b)	(i)	Centre of gravity	1
		(ii)	Bottom of near-side wheel labelled as ‘pivot’	1
			F_{wind} × 2.1 (1) = 1.0 × 10^5 × 1.4 (1) [or by impl.] ∴ F_{wind} = 67 kN (1) [accept 66 kN ✓b.o.d.]	3
				[10]

Question			Marking details	Marks Available
7.	*(a)*	(i)	Ball is seen to stay directly in front of the passenger [**or** clearly implied by 2nd statement]. (1) No [horizontal] forces on ball [so horizontal speed is constant, with the same value as the train] (1)	2
		(ii)	Observer sees the ball moving in the same direction as the train [with the same speed]. [Accept: "moving with the train."]	1
	(b)		Passenger sees the ball accelerating [or moving] 'backwards' [or towards the rear of the train]. Observer sees the ball moving in the same direction as the train with decreasing speed. (1) Net [horizontal] force on ball [due to air resistance] towards the back of the train. (1)	3
		(i)	The graph is symmetrical / up time = down time.	1
		(ii)	$x = 11$ m ; $t = 1.5$ s (1) $x = \frac{u+v}{2}t$, **or** $11 = \frac{u}{2} \times 1.5$ (1) **or** $v^2 = u^2 + 2ax$ **or** $0 = u^2 + 2 \times 9.81 \times 11$ (1) **or** $x = ut + \frac{1}{2}at^2$, **or** $11 = 1.5u + \frac{1}{2} 9.81 \times 1.5^2$ (1) $\therefore u = 14.7$ m s^{-1} (1) [accept $v = u + at$ with $v = 0$ and $t = 1.5$ s]	3
		(iii)	**Graph**: v axis – 20 to + 20 e.c.f. (1) Intercept on v axis 14.7 m s^{-1} e.c.f. (1) Straight line graph (1) to intercept time axis of 1.5 s (1) Graph continued straight beyond 1.5 s to negative values of v (1)	5 **[15]**

Question			Marking details	Marks Available
8	*(a)*		Energy cannot be created or destroyed (1) …[only] changed from one form into another (1) [Accept: total energy [in the Universe] is constant for 1st mark]	2
	(b)	(i)	Area under graph = energy stored (1) [or by impl.] x = 70 m chosen (1) [or by impl.] Elastic potential energy [= ½ ×1600 × 70] = 56 kJ (1)	3
			Alternative: calculation of k [22.9 N m^{-1}] or left as, e.g. $\frac{1600}{70}$ ✓ Use of x = 70 m to calculate energy ✓; Energy stored = 56 kJ ✓	3
		(ii)	70 kJ – 56 kJ (e.c.f.) (1) = mgh (1) [**Or** E_p(grav) lost = 60×9.81×96 (1) [= 56 kJ]. ∴ 14 kJ = mgh (1)] ∴ h = 23.8 m (1)	
			Alternative: 7.0 × 10^4 J = mgh ✓→ h = 118.92 m ✓ Then subtract 96 m → 22.92 m ✓	3 **[11]**
		(iii)	Tension in 'bungee' = weight of Jumper = 60 × 9.81 [= 589 N] (1) From graph x = 26 [± 1] m (1) [or from k → 25.8 m] ∴ d = 52 m. (1)	