1

(a)	**(i)**	mass x velocity / mv with symbols defined	1	
	(ii)	$0 = m_1v_1 - m_2v_2$ / $m_1v_1 = m_2v_2$/ $0 = m_1v_1 + m_2v_2$	1	
		$v_1/v_2 = m_2/m_1$ or $- m_2/m_1$ *consistent with line above*	1	[3
		max 1 mark for final expression without line 1		
(b)	**(i)**	$E = 1/_2mv^2$ (= 1.2×10^{-14})	1	
		$v = \sqrt{(2 \times 1.2 \times 10^{-14}/6.7 \times 10^{-27})}$	1	
		$v = 1.9 \times 10^6$ (m s^{-1})		
	(ii)	(mv =) $6.7 \times 10^{-27} \times 1.9 \times 10^6$		
		$mv = 1.3 \times 10^{-20}$ (kg m s^{-1})	1	
	(iii)	$1.3 \times 10^{-20} = mv = 4.0 \times 10^{-25}$ v ecf	1	
		or 3.9×10^{-25} v if mass of α-particle is subtracted		
		$v = 3.3 \times 10^4$ (m s^{-1})	1	
		or $6.7 \times 10^{-27}/4.0 \times 10^{-25} = v/1.9 \times 10^6$	1	
		$v = 3.2 \times 10^4$ (m s^{-1})	1	[5
(c)	**(i)**	X is about 15 mm from P	1	
	(ii)	XP arrow direction is a straight line through P	1	
	(iii)	N is about 0.3 mm from P; ecf from (b) (iii)	1	[3

2

Question	Expected Answers	Marks	
(a)	Same speed (mandatory) as energy transfer is the same / some further qualification, e.g. (increase in) k.e = (loss in) p.e./car falls through same height	2	[2]
(b)	(i) $h = 1.2 \sin 45 = 0.85$ m	1	
	mgh; = 0.05 x 9.8 x 0.85 = 0.42 (J) accept g=10ms^{-2}	2	
	(ii) $1/2mv^2 = 0.42$ ecf or $v^2 = 2gh$	1	
	v = 4.1 (m s^{-1})	1	[5]
(c)	(i) $m(v + 2v/3)$; = 5m = 0.25; kg m s^{-1}/N s	3	
	(ii) $F = m\, \Delta v/\Delta t$; = 1.25 (N) ecf c(I)	2	[5]
	Total		12

3

(a)	**(i)**	Two vertical arrows of equal length (by eye) and opposite direction in the same vertical line passing through the ball;	1	
		weight/gravity/mg/0.49 N and (normal)reaction/string tension/0.49 N	1	2
	(ii)	gravity; acts on ball and Earth /AW	2	
		contact/reaction forces; between ball and strings/racket	2	4
	(iii)	(resultant force) = ma; = 0.05 x 2 = 0.1 (N)	2	2
(b)	**(i)**	$v^2 = u^2 + 2gh$/ $\frac{1}{2} mv^2 = mgh$ to give $v^2 = 2gh$;	1	
		$v^2 = 2 \times 9.8 \times 0.8$ to give v = 4.0 (m s^{-1}) accept 3.96	1	2
	(ii)	mv = 0.20 (kg m s^{-1}) accept 0.198	1	1
	(iii)	2mv = 0.40 (kg m s^{-1}) accept 0.396	1	1
	(iv)	2mv/t = 8.0 (N) accept 7.92 *ecf b(iii)*	1	1
		[Total		**13]**

4

(a)		Work = force x distance (moved in direction of force);	1	
		Power = work/time /AW	1	
		Power = force x distance/time = force x velocity	1	3
(b)	(i)	$P = Fv = 2 \times 10^5 \times 10$	1	
		$= 2M / 2 \times 10^6$ (W) *give 1 mark for 20(W)*	1	2
	(ii)	Graph shows F is proportional to 1/v **or** minimum of two more calculations of P to show same value	1	1
	(iii)	$F = 2 \times 10^6/5 = 4 \times 10^5$ (N) *ecf from b(i)*	1	1
(c)	(i)	Resultant force = mass x acceleration;	1	
		$2 \times 10^5 - 5 \times 10^4 = 3 \times 10^5 a$;	1	
		$a = 0.5$ ($m\ s^{-2}$) *give max 1 mark for a = 0.67 ($m\ s^{-2}$)*	1	3
	(ii)	max. speed when a = 0 / $F = 5 \times 10^4$ N;	1	
		giving v = 40 ($m\ s^{-1}$) from fig 1.1 or by calculation	1	2
			Total	**12**

5

(a)	(i)	Line in direction NA	1	
	(ii)	Line passing perpendicular to the tangent at the point of closest approach to N *judged by eye*	1	2
(b)	(i)	k.e. = ½ mv^2 (= 8×10^{-13})	1	
		$v^2 = 2 \times 8 \times 10^{-13}/6.7 \times 10^{-27} = 2.39 \times 10^{14}$	1	
		$v = 1.5(45) \times 10^7$ ($m\ s^{-1}$)		2
	(ii)	$mv = 6.7 \times 10^{-27} \times 1.5 \times 10^7 = 1.0(35) \times 10^{-19}$ ($kg\ m\ s^{-1}$)	1	1
(c)	(i)	m/4, v x 2 so p/2 from b(ii) or use k.e = $p^2/2m$;correct substitution with $m = m_p$ to give $p = 5 \times 10^{-20}$ ($kg\ m\ s^{-1}$)	2	2
	(ii)	(average) force smaller/recoil slower/momentum less/interaction time shorter/angle of recoil different/steeper/AW *allow smaller/shorter distance* *any 2*	2	2
(d)		$F = (1/4\pi\varepsilon_0) Q_1Q_2/r^2$; $Q_1 = 1$ (e), $Q_2 = 97$ (e);	2	
		correct substitution of figures	1	
		giving $F = 3.97 \times 10^{-2}$ (N) accept 0.04 N *allow 79e giving 0.032 (N)*	1	4
			Total	**13**

6

stion		**Expected Answers**	**Marks**	
a	**i**	Work = force x distance ;moved in direction of force;		2
	ii	power = work/time;AW	1	
		power = force x distance/time = force x velocity	1	2
b	**i**	k.e. = ½ mv^2 ;	1	
		= 0.5 x 120 x 25 = 1500 (J)	1	2
	ii	P = Fv or 200 = F x 5 ; F = 200/5 = 40 (N)		2
	iii	Fd = 1500 ; so d = 1500/40 = 37.5 (m) ecf from b(i) and (ii)		2
c		Δp.e./second = mgvsin θ = 120 x 9.8 x 5 x 0.033 ; = 194 (W)	2	
		n.b. allow using 1/30 ans: 196 (W)		
		AW, e.g.: force downhill F = mgsin θ; extra power = Fv, etc.		
		P = 200 + 194 = 394 (W)	1	3
			Total	**13**

Question			Expected Answers	Marks	
7	a		Momentum of a particle = mass x velocity,	1	
			linear momentum is constant in the collision; always/ in every collision;	2	
			because there are no external forces	1	
			total energy is constant in every collision;	1	
			k.e. is (only) conserved in elastic collisions;	1	
			otherwise some k.e. is lost/dissipated/randomised/turned to heat,etc	1	
			max 6 marks		6
	b		*Neatest and possibly shortest answer is in terms of constant steady motion of the centre of mass of the system*		
			there are several ways of approaching a satisfactory answer with many marking points; use 1 mark per valid point and 1 mark per valid reason.		
			here is a selection of likely marking points:		
			small particle incident on large one		
			Analogy with ball bouncing off wall;	1	
			energy transfer to massive particle is very small;	1	
			as v of massive particle is so small; because momentum conserved;	2	
			large particle incident on small one		
			massive particle can only transfer a small fraction of its momentum;	1	
			so keeps most of its k.e.; small particle hardly needs any k.e.;	2	
			alternative wording such as:		
			small particle moves off at roughly twice velocity of massive particle;	1	
			massive particle hardly slowed	1	
			common features which can be expressed in many alternative ways		
			(constant/steady) motion of c.of mass of system (towards right)	1	
			incident momentum very small in first case compared to second	1	
			ratio of masses to inverse ratio of velocities/distances moved	1	
			k.e depends on v^2, so v ratio has more effect than mass ratio on energy transfer	1	
			any other valid points *for each*	1	
			mathematical expositions acceptable as long as they reach meaningful conclusions		
			max 6 marks		6
			Quality of written communication		4
			Total		**16**
8	a	i	$\rho = m/V = m/Av$; $m = A\rho v = 7.5 \times 10^{-5} \times 1000 \times v = 0.09$ giving $v = 1.2\ m\ s^{-1}$	2	
		ii	2.4 ($m\ s^{-1}$)	1	
		iii	F = d (mv)/dt /AW; F = 0.09 x (2.4 – 1.2) ;= 0.11 (N) ; *ecf (a)ii*	3	
		iv	towards or into shower head/backwards *ecf (a)iii*	1	7

Question			Expected Answers	Marks	
9	a	i	48 (N) 0.25 (s)	1	
		ii	estimating area under graph or mean F; 6.5 ± 1	2	3
	b	i	a = F/m or = 48/0.5 ; = 96 (m s^{-2}) *ecf a(i)*	2	
		ii	Ft = mv; v = *a(ii)*/0.5 = 2*a(ii)* (m s^{-1}) *ecf a(ii)*	2	
		iii	k.e. = ½ mv^2 or = ½ x 0.5 x *b(ii)*^{2} ; = *a(ii)*^{2} (J) *ecf b(ii)*	2	6
	c		Ft = mv ± mu or = 0.5 (8 ± 14) ;	1	
			F = 11/0.18 ; = 61(.1) (N) *aliter mean a = 12(2) m* s^{-2} *F = ma*	2	3
			Total		12

Question			Expected Answers	Marks	
10	a	i	3.8 ± 0.3 (N s)	1	
		ii	momentum (of the ball) *accept impulse*	1	
		iii	mv = 3.8 or v = 3.8/0.16; = 23 (m s^{-1}) *ecf a*	2	
		iv	use F = ma giving 24 = 0.16a; a = 150 (m s^{-2})	2	6
	b	i	exponential	1	
		ii	e.g. $h_1/h_2 = e^k$ = 2.1(5) ; giving k = 0.74 to 0.76 or substitution from a line of table; gives 0.748, 0.757 or 0.746	2	
		iii	1.5 (m)	1	
		iv	Δk.e. = mgΔh; = 0.16 x 9.8 x 0.38 (= 0.60 J)	2	6
			Total		12

Question			Expected Answers	Marks	
11	a		(mv =) 300 ; kg m s^{-1} **or** N s	2	2
	b	i	(The speed of the bar increases so) it is accelerated forwards/AW; this	1	
			requires a resultant (forward) force/F = ma idea	1	
		ii	Arrow in direction of motion/to right	1	
		iii	(t = s/v = 3.0/0.60 =) 5.0 s	1	
		iv	F = m (v – u)/t ; = 500 x 1.2/5.0 ; = 120 (N) *ecf b (iii)*	3	7

Question			Expected Answers	Marks	
12	a	i	½ mv^2 = 7.6 x 10^{-13} to give v = √(2 x 7.6 x 10^{-13} /6.6 x 10^{-27}	1	
			evidence of calculation v = √2.3 x 10^{14} *or* = 1.52 x 10^7 (m s^{-1})	1	
		ii	(electrostatic) repulsion between charged particles	1	
			slows alpha and accelerates nucleus/AW	1	
			momentum of system is conserved(as no external forces)	1	
			sum of momenta of alpha and nucleus must always equal initial momentum of alpha/be a constant	1	
			so speed of nucleus can be calculated as momentum = mv	1	
			max 3		
		iii	mv = MV or V = 6.6 x 10^{-27} x 1.52 x 10^7 / 3.0 x 10^{-25} ; = 3.3 x 10^5 (m s^{-1})	2	
		iv	Ft = 2mv or 9.0 x t = 2 x 6.6 x 10^{-27} x 1.52 x 10^7 ; t = 2.2 x 10^{-20} (s)	2	9
			give 1 mark for change in momentum = impulse *or* Δmv = F(Δ)t		

Question			Expected Answers	Marks	
13	a	i	Mass x velocity/mv with symbols defined	1	
		ii	$0 = m_A v_A \pm m_B v_B$ or $m_A v_A = m_B v_B$	1	
			$v_A/v_B = \pm m_B/m_A$	1	3
			max 1 mark for final expression without line 1		
	b	i	v_A = (10/5 =) 2.0 (ms^{-1}) and v_B = (10/10 =) 1.0 (m s^{-1})	1	
		ii	t_1 = 3.0/2.0 = 1.5 (s) *ecf b(i)*	1	
		iii	x = 2.1 – 1.0 x 1.5 = 0.6 (m)	1	
		iv	$v = v_B + (5/50)v_A$ = 1.0 + 0.2 (= 1.2 m s^{-1})	1	
		v	$t_2 = t_1$ + 0.6/1.2 = 2.0 (s)	1	
		vi	At collision the container (and fragments) stop	1	
			By conservation of momentum, total momentum is still zero/AW	1	
		vii	straight lines from (0,0) to (1.5,0); (1.5,0) to (2.0,0.1); (x,0.1) for all x >2	3	10
			Total		13

Question			Expected Answers	Marks	
14	a		mgh or 0.014 x 9.8 x h ;	1	
			= 0.22 J so h = 1.6 m	1	2
	b		k.e. increases;	1	
			at a decreasing rate	1	2
	c	i	½ mv^2 = 0.11	1	
			v = √(0.11 / 0.007) = (3.96 m s^{-1})	1	
		ii	F = mg = 0.014 x 9.8 = 0.137 or 0.14 (N)	1	
		iii	Fv = mgv or 0.14 x 4.0	1	
			= 0.54 to 0.56 (W) *ecf c(ii)*	1	5
	d		k.e. after bounce = 0.088 J giving u = √(0.088/0.007) = 3.55 m s^{-1}	1	
				1	
			change in momentum = m (v ± u)	1	
			= 0.014(7.55)= 0.11;	1	4
			kg m s^{-1} /N s		
			Total		**13**

Question			Expected Answers	Marks	
15	a	i	Using F = ma gives P = 3ma hence a = P/3m	1	
		ii	P/3	1	
		iii 1	P/3m	1	
		2	P/3	1	
		iv 1	P/3	1	
		2	2P/3	1	6
	b	i	$mu = mv_1 + mv_2$	1	
			$1/2mu^2 = 1/2mv_1^2 + 1/2mv_2^2$	1	
		ii	some details of algebra/substitution to be shown resulting in e.g. $u = v_2$ and $u^2 = v_2^2$	1	3
	c	i	all momentum is passed to block 2,(block 1 stops); then	1	
			momentum is passed to block 3 (so block 2 does not move)/AW	1	
			or argument in terms of k.e.		
		ii	block 1 bounces back; and blocks 2 & 3 move (to right/together)	2	4
			Total		**13**

Question			Expected Answers	Marks	
16	a	i	area under curve (= momentum gained)	1	
			Ft = (change in) momentum/AW	1	
		ii	taken as two triangles of base 3 ms and height 900 N gives 2.7 (N s) or count squares	1	
		iii	N = kg m s^{-2} so N s = kg m s^{-1} **or** momentum = mv unit kg m s^{-1} (Δ)mv = Ft unit N s	1	
		iv1	area = 2.7 = mv = 0.06v giving v = 45 (m s^{-1})	1	
		2	F(max) = 900 = ma = 0.06a; a = 15000 (m s^{-2})	2	7
	b	i	mu + mv = 0.06 (40 + 38) = 4.68 (kg m s^{-1})	1	
		ii	Δk.e. = 1/2m($v^2 - u^2$) = 0.03 ($40^2 - 38^2$) ; = 4.68 (J)	2	
		iii	F = Δp/Δt = 4.68/0.012 ; = 390 (N) *ecf*	2	5
			Total		12
17	a	i	momentum before= 2mv - 3mv = - mv	1	
			momentum after = 4mv – m5v = - mv	1	2
		Ii	initial k.e. = 2.5 mv^2; final k.e. = 14.5 mv^2 (so Δk.e. = 12 mv^2)	2	2
		iii	k.e. of n is 12.5 mv^2 ; so takes all of the extra k.e./AW	2	2
		iv	12 mv^2 = 12 x 1.67 x 10^{-27} x 1.19^2 x 10^{14} = 2.84 x 10^{-12} (J) *ecf ii*	1	1