Question number	Answer	Notes	Marks
3 (a)	momentum = mass × velocity;	allow standard symbols and rearrangements e.g. $p = m \times v$ reject M, m for momentum	1
(b)	substitution; evaluation; unit; e.g. $p = 1.67 \times 10^{-27} \times 2200$ (p =) 3.7×10^{-24} kg m/s	 allow $3.6(74) \times 10^{-24}$ allow 3.7×10^{-21} g m/s for 3 marks	3
(c)	(total) momentum before (collision) = (total) momentum after (collision);		1
(d)	evaluation of momentum of U-235 before collision; addition of neutron momentum; rearrangement to give velocity of U-236; correct evaluation; e.g. $p_{U-235} = (3.99 \times 10^{-25} \times 10 =) \ 3.99 \times 10^{-24}$ $p_{U-236} = 3.99 \times 10^{-24} + 3.7 \times 10^{-24}$ v_{U-236} = momentum / mass = $7.664 \times 10^{-24} / 4.01 \times 10^{-25}$ (v_{U-236} =) 19 (m/s)	 allow ecf from (b) seen or implied by working not adding neutron momentum gives 9.95 m/s = 2 marks allow 19.1… (m/s)	4

Total for Question 3 = 9 marks

Question number	Answer	Notes	Marks
4 (a) (i)	substitution; evaluation; e.g. (GPE =) 1.8 × 10 × 0.95 (GPE =) 17 (J)	allow g = 9.8, 9.81 allow 16.8, 16.7…, 17.1… (J)	2
(a) (ii)	idea that KE (gained) is greater than GPE (lost); idea KE gained = GPE lost + work done; e.g. 17 + 4 = 21 OR 21 – 17 = 4		2
(b) (i)	use of KE = ½ × mass × speed^2; substitution; rearrangement; evaluation; e.g. KE = ½ × m × v^2 21 = 0.5 × 1.8 × v^2 v = √(21/0.9) (v =) 4.8 (m/s)	allow standard symbols can be implied from working allow 4.83, 4.83… (m/s)	4
(ii)	substitution into F = mv-mu / t; evaluation; e.g. F = (1.8 × 4.8) / 0.12 (F =) 72 (N)	allow ecf from (b)(i) allow alternative method using a = (v-u)/t and F = ma allow 72.5, 72.45… (N)	2

Total for Question 4 = 10 marks

Question number	Answer	Notes	Marks
8 (a) (i)	buzzer B travels **twice** the distance; in the same time (period) OR (average) speed = distance/time taken;	ignore quoting distances since given in question	2
(ii)	any three from: MP1. frequency decreases; MP2. due to Doppler effect; MP3. idea of increased wavelength; MP4. idea that **decrease** in frequency of buzzer B is twice that of buzzer A;	 allow for either / both buzzer(s) reject if one frequency said to be increased allow idea of waves behind buzzers being more spread out reject if one wavelength said to be decreased allow frequency of buzzer B being lower than frequency of buzzer A / ORA	3
(b)	determination of number of squares for one period; correct use of oscilloscope settings; evaluation in standard form; e.g. period = 4 squares (period = 4) × 0.002 (period =) 8×10^{-3} (s)	 seen anywhere in working award 2 marks for answers of 4×10^{-3}, 16×10^{-3} (s)	3
(c) (i)	10 (nm);		1
(ii)	idea the speed of Q is double the speed of P;	allow greater speed	1
(iii)	20 (nm);	allow ecf from (c)(i)	1
(iv)	any four from: MP1. further / faster galaxy (Q) shows greater red shift; MP2. further galaxy (Q) is travelling faster; MP3. (which suggests) universe is expanding; MP4. idea that at an earlier point in time; MP5. the universe was a single point;	 allow use of phrases such as “originated” / eq.	4

Total for Question 8 = 15 marks