Question			Marking details	Marks Available
1	*(a)*		Reasonable attempt at conservation of momentum (1) e.g. 330 000m = ±10 000m + 6.6 × 10^{-27} × v_1 conservation of momentum applied correctly and values substituted (1) e.g. 330 000 × 3.4 × 10^{-25} = -10 000 × 3.3 × 10^{-25} + 6.6 × 10^{-27}× v_1 correct answer = 1.75 × 10^7 [m s^{-1}] (**no ecf**) (1)	3
	(b)	(i)	Any valid answer e.g. impulse (**or** force **or** acceleration **or** change in momentum) is vertical, gamma has no momentum in horizontal direction, perpendicular directions are independent etc. Accept: no horizontal force	1
		(ii)	Attempt at using $p = \frac{h}{\lambda}$ (1) $E = hf$ **and** $c = f\lambda$ quoted (**or** equivalent $E = \frac{hc}{\lambda}$) (1) N.B. $p = \frac{E}{c}$ gains 2 marks Correct momentum = 6.33 × 10^{-22} (1) Answer = = $\frac{6.33\times10^{-22}}{3.3\times10^{-25}}$ [1 920 m s^{-1}] (1)	4
		(iii)	Method i.e. $\sqrt{10000^2 + 2000^2}$ (1) Answer = $10\,200$ [m s^{-1}] **ecf** on v from *(b)*(ii) (1) Method and correct **indication of angle** e.g. $\tan^{-1}\left(\frac{2000}{10000}\right)$ (1) Answer = $11.5°$ **or** 0.2 [rad] (or 90-11.5 for other angle if indicated etc.) (1)	4
			Question 1 Total	**[12]**

© WJEC CBAC Ltd.

Question			Marking details	Marks Available
2	*(a)*	(i)	(Number of moles) $n = 4.73$ (1)	3
			Mass = 4 × 4.73 **or** 0.004 × 4.73 (**or** implied) (1)	
			Density = 0.004 × 4.73 / 0.113 [= 0.167] (1)	
		(ii)	Either $p = {}^1/_3\,\rho\overline{c^2}$ used **or** equivalent e.g. ${}^3/_2\,nRT = {}^1/_2\,M\overline{c^2}$ (1)	2
			1 350 [m s^{-1}] (1)	
	(b)		Density = 0.004 × 4.73 / 0.212 **or** $T = \frac{45000\times0.212}{4.73\times8.31}$ **ecf** (1)	3
			$p = {}^1/_3\,\rho\overline{c^2}$ used **or** ${}^3/_2\,nRT = {}^1/_2\,M\overline{c^2}$ used **or** equivalent (1)	
			Answer = 1 230 [m s^{-1}] (1)	
			Question 2 Total	**[8]**
3	*(a)*		Substitution into $v = \sqrt{\frac{GM}{r}}$ (1)	2
			Answer = 158 000 [m s^{-1}] (1)	
	(b)		Measured velocity is greater (1)	3
			Which implies that the mass is greater (1)	
			Suggests the existence of dark matter (1)	
			Question 3 Total	**[5]**

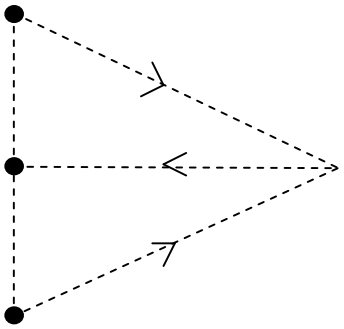
© WJEC CBAC Ltd.

Question			Marking details	Marks Available
4	*(a)*		Mass substituted into $T = 2\pi\sqrt{\frac{m}{k}}$ (1) $T = \frac{1}{f}$ used **or** implied (1) Answer = 152 N m^{-1} **UNIT mark** (1)	3
	(b)		3.47 × 2π [= 21.803]	1
	(c)	(i)	$v = \omega A$ [= 1.853] **or** max PE = max KE (1) KE = $\frac{1}{2}mv^2$ used **or** = ½ kx^2 (1) Answer = 0.55 [J] (1)	3
		(ii)	Acceleration = $\omega^2 A$ **or** $F = kA$ Accept $F = kA - mg$ (1) Answer = 12.9 [N] (1)	2
	(d)		Substitution of values e.g. $-1.4 = 8.5\sin(21.8 \times 0.1 + \varepsilon)$ (1) $\sin^{-1}\left(\frac{-1.4}{8.5}\right) = -0.165$ (1) $\varepsilon = -2.35$ **or** equivalent in degree (-135^o) **or** other quadrant (-5.16) **ecf** on minus sign (1)	3
			Question 4 total	**[12]**

© WJEC CBAC Ltd.

Question			Marking details	Marks Available
5	*(a)*	(i)	Force per unit mass (this minimalist answer is acceptable unless some contradiction)	1
		(ii)	Work done per unit mass from infinity (this minimalist answer is acceptable unless some contradiction)	1
	(b)	(i)	$F = \frac{GMm}{r^2}$ used (1) Answer = 22.8 [N] (1)	2
		(ii)	$PE = [-]\frac{GMm}{r}$ used **or** equivalent (1) Answer = - 13.7 M[J] (1)	2
	(c)		$PE = [-]\frac{GMm}{r}$ used **or** equivalent (1) Answer = - 61.8 M[J] (**ecf** on – sign) (1)	2
	(d)		Difference in PE attempted (1) Correct answer = 48.1 M[J] (*(b)*(ii) – *(c)*) **ecf** (1) Answer must be consistent with their signs	2
			Question 5 Total	**[10]**

© WJEC CBAC Ltd.

Question			Marking details	Marks Available
6	*(a)*		All arrows correct ✓✓ Directions in line with dotted lines but some (or all) directions inverted ✓ 	2
	(b)		$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ used (1) Answer = 1 500 V m^{-1} **or** N C^{-1} **or** equivalent **UNIT mark** (1)	2
	(c)		Field of 13 μC ×2 **and** ×12/13 (1) Answer = 222 [V m^{-1}] (1) To the left **or** implied clearly in the calculation (1)	3
	(d)		$V = \frac{Q}{4\pi\varepsilon_0 r}$ used for 3 charges with r = 12 or 13 (1) $V = \frac{1}{4\pi\varepsilon_0}\left(2\frac{13}{13} - \frac{24}{12}\right)$ as shown **or** equivalent (cm perfectly valid) (1)	2
	(e)		**Any 3 (×1) from:** • initial **total** energy is zero / initial and final PE is zero • final **total** energy is zero / initial and final KE is zero • initial force is to the right (has to be linked to the field and the negative charge) • later the force is to the left (but not a resistive force)	3
			Question 6 Total	**[12]**

© WJEC CBAC Ltd.

Question			Marking details	Marks Available
7	*(a)*		$T = 2\pi\sqrt{\dfrac{(3\times10^{10})^3}{6.67\times10^{-11}\times(7\times10^{29}+4\times10^{28})}}$ (1) Answer = 4.65×10^6 [s] (1) (4.78×10^6 s scores 1/2 marks)	2
	(b)		$r_1 = \frac{M_1}{M_1+M_2}d$ used **or** $M_1r_1 = M_2r_2$ used (1) Star orbit radius = 0.162×10^{10} [m] (1) (0.171×10^{10} scores 1/2 marks)	2
	(c)		$v = \frac{2\pi r}{T}$ **or** $v = \omega r$ and $\omega = 2\pi f$ **ecf** on T and r (1) $v = \frac{2\pi\times0.162\times10^{10}}{4.65\times10^6}$ [= 2 191] (1) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ attempted **or** rearranged **ecf** on v (1) Answer = 4.8×10^{-12} [m] (1)	4
	(d)		Hotter **or** the Earth is cooler **or** equivalent (1) Due to higher intensity [of e-m radiation] (1) Accept because $5^2 > 20$ **or** similar	2
			Question 7 Total	**[10]**

© WJEC CBAC Ltd.

Question			Marking details	Marks Available
8	*(a)*	(i)	$T = \frac{pV}{nR}$ seen **or** equivalent **or** implied (1) $T = \frac{95000 \times 0.79}{28.9 \times 8.31}$ $(= 312.5\ \text{K})$ (1)	2
		(ii)	$U = \frac{3}{2}nRT$ used **or** 3/2 pV (1) AB = -36 400[J] (1)	2
	(b)	(i)	0	1
		(ii)	Valid method either stated **or** clearly implied (1) Accept area under the graph Answer = - 47 250 [J] (1)	2
	(c)		AB: W 0; ΔU -36.4 kJ; Q -36.4 kJ; ✓ **ecf** on ΔU BC: W 37.6 kJ; ΔU 33.5 kJ; Q 71.1 kJ; ✓ **no ecf** CA: W -47.3 kJ; ΔU 2.9 kJ; Q -44.4 kJ; ✓ **ecf** on W ABCA: W -9.7 kJ; ΔU 0; Q -9.7 kJ; ✓ **ecf** on all if $\Delta U \approx 0$ but must make sense	4
			Question 8 Total	**[11]**

© WJEC CBAC Ltd.