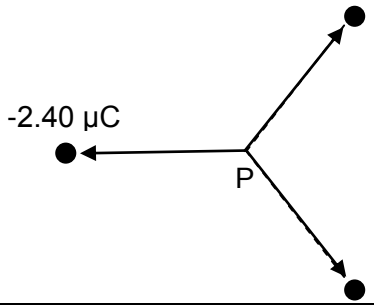
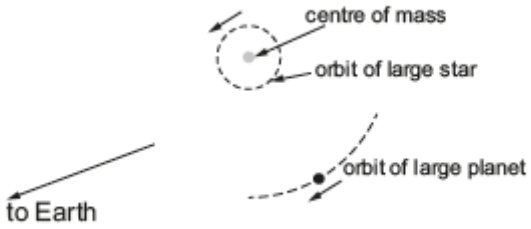
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*	(i)		Values substituted into $C = \frac{\varepsilon_0 A}{d}$ [= 7.32 × 10^{-9} F] (1) $Q = CV$ (or implied) note $C = \frac{Q}{V}$ not good enough (1) Answer = 9.37 × 10^{-7} [C] (1)	1	 1 1		 3	 3	
		(ii)		Answer = 6.0 × 10^{-5} [J]		1		1	1	
		(iii)		Use of $E = \frac{V}{d}$ (1) Answer = 2 170 000 V m^{-1} **unit mark** (1)	1	 1		 2	 2	
	(b)	(i)		Capacitance decreases (independent) (1) Energy stored increases (independent) (1)		2		2		
		(ii)		Work done by separating forces (independent) (1) Equal to increase in stored energy (1)			2	2		
				Question 1 total	**2**	**6**	**2**	**10**	**6**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*			$n = \frac{9560}{1.45}$ (1) Correct answer = 2.65 m[T] (1)	1	 1		 2	 2	
	(b)			$B = \frac{\mu_0 I}{2\pi a}$ used (e.g. 2.82×10^{-6} T or 4.35×10^{-6} T or 10^{x} slips) (1) Subtracting or adding fields (1) 1.53×10^{-6} T **unit mark (no ecf)** (1) Out of paper (1)	1	 1 1 1		 4	 2	
	(c)			Application of $E = \frac{hc}{\lambda}$ **or** $E = hf$ and $c = f\lambda$ ***or*** equivalent (1) Division by e (i.e. conversion) (1) Answer = 5.57×10^{-7} [eV] (1)		3		3	3	
				Question 2 total	**2**	**7**	**0**	**9**	**7**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*			$F = Eq$ (or eE) used **or** implied (1) $E = \frac{V}{d}$ quoted or implied **and** $a = \frac{F}{m}$ used or implied (1) Algebra leading clearly to $a = \frac{Ve}{m_e d}$ (1)	1 1	 1		. 3	3	
	(b)	(i)		No horizontal forces or field has no horizontal component		1		1		
		(ii)		Constant vertical force or uniform electric field		1		1		
	(c)			Correct application of $s = ut + \frac{1}{2}at^2$ or equivalent (1) Time correct = 5.4 n[s] (1) Correct conclusion e.g. agrees with 5.0 ± 0.5 ns (1) Value is inside range of uncertainty or equivalent (1)		1 1	 1 1	 4	 2	
	(d)			Valid method e.g. definition of eV, force x distance, getting resultant velocity and finding change in $\frac{1}{2}mv^2$ (1) Answer = 5.6 eV (which can simply be written for full marks) (1) **or** 8.96×10^{-19} J (answer of 11.2 eV gets 1/2 marks)		 2		 2	 2	
				Question 3 total	**2**	**7**	**2**	**11**	**7**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*			Flux increases **or** flux cutting (1) Because area increases **or** direction of cutting mentioned for top and bottom sides (1) Analysis of evidence in light of Faraday's law so correct conclusion from previous argument (1)		1 1	1	3		
	(b)			Anticlockwise gives field out **or** correct explanation (using FLHR or FRHR) for current left on top **and** right on bottom (1) Using right hand grip rule **or** FLHR **or** FRHR (1)	1	1		2		
	(c)			Area = πr^2 used (1) $V = \frac{BA}{t}$ **or** $\frac{d}{dt}(BAN)$ etc (1) $I = \frac{V}{R}$ used (1) Algebra e.g. $I = \frac{B\pi r^2}{tR}$ (1) Answer = 0.63 [A] (1)	1 1 1	 1 1		5	5	
				Question 4 total	**4**	**5**	**1**	**10**	**5**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*			All arrows correct ✓✓ (1) Directions in line with dotted lines but some (or all) directions inverted (1)  	1 1			2		
	(b)			$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ used (1) The 2 vertical components cancel or no field into or out of page **and** Pythagoras or trig e.g. $\sqrt{5^2 - 4^2} = 3$ **or** recognising 3,4,5 triangle (1) (equivalent is to realise $\cos\theta$ = 3/5 or θ = 53^o etc.) 2 nC charge field ×2 **and** ×3/5 (for horizontal components) (1) Calculations all ok e.g. 8 640 = 7 200 ×2 × 3/5 or equivalent shown (1)	1	 1 1 1		4	4	
	(c)			$V = \frac{Q}{4\pi\varepsilon_0 r}$ used (1) Attempt at adding all 3 potentials (1) - 360 -360 - 432 = - 1 152 [V] (1)	1	 1 1		3	3	
	(d)			Use of PE = $q\Delta V$ must be a change (1) Rearrangement i.e. $v^2 = \frac{2\text{xPE}}{m}$ allow **ecf** on V (1) Answer = 18.3 × 10^6 [m s^{-1}] (**ecf** only if a ΔV used) (1)	1	 1 1		3	3	
				Question 5 total	**5**	**7**	**0**	**12**	**10**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*			 Reasonable orbit of star and companion in mutual orbit shown with Earth shown or direction towards Earth (1) In position shown star moves towards Earth therefore radial velocity is maximum towards Earth, ½ orbit later radial velocity is maximum away from Earth (1)	2			2		
	(b)			170 (± 2) days quoted/obtained/used (1) $r = \frac{1700\text{x}170\text{x}24\text{x}3600}{2\pi}$ [=3.97 × 10^9] (1)			2	2	1	
	(c)			$T = 2\pi\sqrt{\frac{d^3}{G(M+m)}}$ **or** $\sqrt{\frac{d^3}{GM}}$ used (1) Convincing algebra and substitution [= 6.63 × 10^{10}] (1)	1	1		2	2	
	(d)			Correct method e.g. $m_1r_1 = m_2r_2$ used **or** $r_1 = (m_1+m_2) / d$ used (1) Correct answer 4.8, 5.1 or 4.4 × 10^{28} [kg] (depending on approximation and value of radius taken) (1)	1	1		2	2	

	(e)			**Star theory** S0 – Need luminosity (or power output) of star. S1 – Star is a black body. S2 – Total power calculated using Stefan's law (or $P = 4\pi r^2 \sigma T^4$) S3 – Assume star is main sequence. S4 – Data can be obtained from spectrum / magnitude (mass, temperature, power). **Planet theory** P0 – Need star-planet distance. P1 – Inverse square law for intensity at planet. P2 – Stefan's law can (again) be used to obtain planet temperature. P3 – Planet not a black body or albido must be guessed. **Life conditions** L0 – Need moderate temperature (~ 300 K). L1 – Need water. L2 – Needs atmosphere. L3 – Planet needs to be large enough (for atmosphere). L4 - Planet shouldn't be too large / too strong a gravitational field. L5 – Assuming life similar to Earth. **5-6 marks** Expect 2 from S0 – S4 to be present. Expect 2 from P0 – P3 to be present. Expect 2 from L0 – L5 to be present. There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** Expect 1 from S0 – S4 to be present. Expect 1 from P0 – P3 to be present. Expect 1 from L0 – L5 to be present. There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.			6	6		

				1-2 marks Expect any 2 points to be made. There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure. **0 marks** No attempt made or no response worthy of credit.						
				Question 6 total	**4**	**2**	**8**	**14**	**5**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*			$\frac{1}{2}mv^2 = \frac{GMm}{R}$ (1) Mass = $\frac{4}{3}\pi r^3 \times \rho$ (1) Substitution of $v = H_0 d$ (1) Convincing algebra (1)	4			4	4	
	(b)			Answer = 9.5×10^{-27} (1) 5 or 6 H atoms (1)		2		2	1	
	(c)			$v = \frac{2\pi R}{T}$ quoted/used **or** $v = \omega r$ and $T = \frac{2\pi}{\omega}$ (1) 150 km/s and $30 \times 3.1 \times 10^{19}$ used (1) Answer = 3.9×10^{16} s / 1.2 (billion year) (1)			3	3	3	3
	(d)			$v = H_0 d$ = 50 000 [m/s] (1) Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ even if with irrelevant velocity e.g. 50 000 (1) Answers = - 0.22 n[m] (0.22 nm blue shift) and 0.44 n[m] (red shift) (1)			3	3	3	3
	(e)			Hubble's experiment repeated or further experiments carried out (1) Data obtained is improved (more accurate etc) or Hubble's law valid over a wider range (1)			2	2		2
				Question 7 total	**4**	**2**	**8**	**14**	**11**	**8**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*	(i)		Flux linkage is continually varying **or** flux continually being cut (1) Flux dependent on angle between normal [of area] and B-field **or** cutting direction continually changing as coil rotates (1)		2		2		
		(ii)		Increasing area increases emf because of more flux [linkage] (1) Increasing B increases emf because of more flux [linkage] (1) Increasing T decreases emf due to decreasing rate of change (1)			3	3		
	(b)	(i)		$\omega L = \frac{1}{\omega C}$ **or** $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ (1) Answer = 1 239 [Hz] (1)	1	1		2	2	
		(ii)		V_R = 25 [V] (1) I = 0.167 [A] (1) $V_L = I\omega L$ **or** $V_C = I\text{x}\frac{1}{\omega C}$ (1) V_L = 71.5 [V] **and** V_C = 71.5 [V] or implied e.g. V_C = same (1)	1 1	1 1		4	3	
	(c)	(i)		$Z = \sqrt{(X_L - X_C)^2 + R^2}$ used (1) Z = 333 [Ω] (1) Current = $\frac{25}{333}$ = 75 [mA] (1)	1	1 1		3	3	
		(ii)		Equation for Q factor e.g. $Q = \frac{\omega_0 L}{R}$ (1) Decreasing R (1) Decreasing L or increasing C (1)	1		1 1	3		

	(d)			$\frac{R}{X_L} = \frac{1}{2}$ (1) $X_L = 2\pi fL$ **or** $X_L = \omega L$ and $\omega = 2\pi f$ (1) Answer = 955 [Hz] (1)	1	 1 1		3	2	
				Question 8 total	**6**	**9**	**5**	**20**	**10**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
9	*(a)*	(i)		Same shape curve below original with bigger minimum wavelength and line spectra in the same place/missing		1		1		
		(ii)		Line spectrum would change	1			1		
		(iii)		$eV = \frac{hc}{\lambda}$ (1) λ = 1.65 × 10^{-11} [m] (1)		2		2	2	
		(iv)		Power = IV = 9 375 [W] (1) 99.5% heat = 0.995 × 9 375 = 9 328 [W] (1)		2		2	2	
	(b)	(i)		Time = $\frac{17x2x10^{-6}}{34x10^{-6}}$ [s](1) Distance = 0.0493 [m] **(ecf)** for time (1) Thickness = $\frac{0.0493}{2}$ or 0.0259 **(ecf)** for distance (1)		3		3	3	
		(ii)		Z_{air} = 442 and Z_{skin} = 1 720 000 (1) R = 0.99[8] (1)	1	1		2	2	
		(iii)		No (no mark for merely quoting No) Due to large impedance difference (1) All ultrasound reflected off first air pocket (1)			2	2		
	(c)	(i)		Nuclei precess / wobble around field lines / radio waves cause resonance (1) Relaxation time explained (1)	2			2		
		(ii)		Uses very powerful magnets / no metal inside MRI (1) CT scan most suitable (1) Distinguishes soft tissue well (1)			3	3		
	(d)			Effective dose = Equivalent dose × W_T where W_T = tissue weighting factor (1) Units Sieverts / Sv (1)	2			2	1	
				Question 9 total	**6**	**9**	**5**	**20**	**10**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10	*(a)*	(i)		The relative speed (of the ball) <u>after</u> hitting the bat (1) is equal to <u>0.73</u> x relative speed <u>before</u> collision (1)		2		2		
		(ii)		Equation $e = \sqrt{\frac{h}{H}}$ applied correctly (1) Height after second bounce = 2.2 [m] (1)	1	1		2	2	
		(iii)		**Any 2 × (1) from:** • Forces clearly labelled as lift, drag and weight • Spin provides more lift **or** gives friction on contact with the floor **or** gives stability when moving through air • Air pressure reduced behind the ball **or** to the side (can produce 'swing') **Third mark:** Description e.g. the ball deviates from normal trajectory depending on spin; can be implied from diagram (1)	2		1	3		
	(b)	(i)		Using appropriate equation of motion to determine t = 1.42 [s] (1) Recall and using angular velocity $\omega = \frac{\theta}{t}$ (1) Mean angular velocity = 11 [rad s^{-1}] (1)	1	1 1		3	3	
		(ii)		Conservation of angular momentum applied correctly i.e. ω = 6.7 [rad s^{-1}] (1) Use of rotational KE ($= \frac{1}{2} I\omega^2$) (1) Correct final answer 22 [J] (1)		3		3	3	
		(iii)		Definition of moment of inertia (implied) (1) Reduce radius of rotation (1) Valid comment e.g. diver adopts a tuck position, draws in arms and legs (1)	1 1		1	3		

	(c)			Clockwise moment of wind = 1 180 × 5.2 = 6 136 [N m] (1) Anticlockwise moment of crew & height of boat = [(2 060 × 1.8) + (1 400 × 0.9)] (1) = 4 968 [N m] (1) Therefore boat topples in a clockwise direction (1)		1	1 1 1	4	2	
				Question 10 total	**6**	**9**	**5**	**20**	**10**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
11	*(a)*	(i)		Any three reasonable and appropriate statements e.g. • Significant (or equivalent or > × 5) increase in generation by renewable sources between 2000 and 2013 (1) • Biggest increase due to offshore and/or onshore wind sources (or numerical analysis) (1) • Little/no contribution from solar PV pre 2010 (or converse) (1)			3	3		
		(ii)		10 TWh produced in 2000 - from chart (1) $10 \times 10^{12} \times (60)^2$ (1) = [3.6×10^{16} J]		2		2	1	
		(iii)		Contribution from offshore wind ≈ 10 TWh from graph (**or use of** 3.6×10^{16} J) (1) $\frac{3.6\times10^{16}}{1.9\times10^{17}}\times100\%$ = 18.9% (1)		2		2	1	
		(iv)	(I)	$\rho = ½ A\rho v^3$	1			1		
			(II)	Energy per second from each turbine = $½ A\rho v^3$ $= ½ \times \pi \times 50^2 \times 1.2 \times 9^3$ [substitution (1)] $= 3.44 \times 10^6$ [J s^{-1}] **(x 0.45 used appropriately)** (1) $1.55 \times 10^6 \times 3\,600 \times 24 \times 365.25$ $= 4.88 \times 10^{13}$ [J] (1) $n = \frac{3.6\text{x}10^{16}}{4.88\text{x}10^{13}} \approx 740$ (1)		1 1	1 1	4	4	

	(b)	(i)		$\frac{\Delta Q}{\Delta t}$ Energy flowing through material per second **and** $\Delta\theta$ Temperature difference across the material	1			1		
		(ii)		Correct substitution into $\frac{\Delta Q}{\Delta t} = \frac{KA\Delta\theta}{l}$ (1) Conversion of units from mm into m (16 mm $\rightarrow$0.016 m) **and** calculation of A (18 m $\times$ 15 m) (1) $\frac{\Delta Q}{\Delta t}$ = 40.5 kW (1)	1	1 1		3	2	
		(iii)		U = rate of energy transfer/$A\Delta\theta$ (1) U = 10 (1) W m^{-2} K^{-1} (1)	1 1	1		3	2	
		(iv)		**Either:** Reduce temperature difference between interior and loft space by reducing interior temperature **or** use material with lower U value as insulation in loft space	1			1		
				Question 11 total	**6**	**9**	**5**	**20**	**10**	**0**