1)

Question			Answers	Marks	Guidance
	(a)		The induced e.m.f. is (directly) proportional / equal to the rate of change of (magnetic) flux linkage.	B1	**Allow** $E = \frac{\Delta\Phi}{\Delta t}$ with all terms defined; E = induced e.m.f., Φ = (magnetic) flux linkage and t = time.
	(b)		North / N (pole). There is a repulsive force (between magnet and coil and the work done against this repulsive force is transferred to electrical energy in the coil).	B1	**Allow** - A south (pole) would cause attraction (between the coil and magnet) or there is gain in KE (of magnet which cannot happen hence it must be north pole).
	(c)	(i)	There is no change in (magnetic) flux (linkage) or there is no change in the (magnetic) flux density.	B1	**Allow** 'no change in (magnetic) field strength'.
		(ii)	E = 0 between 0 to 3 cm, 5 – 8 cm and 10 - 12 cm. Two 'pulses' where B is changing. The pulses have opposite signs.	B1 M1 A1	Tolerance: ± ¼ large square **Note**: The pulses must have E = 0 at 3 cm, 5 cm, 8 cm and 10 cm; tolerance ± ¼ large square.
			Total	**6**	

2)

Question			Answer	Marks	Guidance
	(a)		magnetic flux = magnetic flux density × area normal to the field	B1	**Allow**: $\phi = BA$, with terms defined; B = magnetic flux density or magnetic field strength and A = area normal to the field **Note**: If angle is used in the definition then it must be defined correctly
	(b)	(i)	$R = \frac{1.7\times10^{-8}\times130}{\pi\times(4.6\times10^{-4})^2}$ (Any subject) R = 3.3(2) (Ω) current = $\frac{24}{3.32}$ current = 7.2 (A)	C1 C1 A1	**Allow**: Possible ecf if value for R is incorrect after attempted use of the equation $R = \frac{\rho L}{\pi r^2}$.
		(ii)	e.m.f. = rate of change of magnetic flux linkage (initial ϕ =) 0.090 × 1.3 × 10^{-3} or 1.17 × 10^{-4} $150 = \frac{1100\times0.090\times1.3\times10^{-3}}{t}$ (Any subject) time = 8.6 × 10^{-4} (s)	C1 C1 A1	**Allow**: (initial $N\phi$ =) 0.090 × 1.3 × 10^{-3} × 1100 or 0.129 **Allow**: 2 marks for 7.8 × 10^{-7} (s) if 1100 turns omitted
			Total	**7**	

3)

Question			Answer	Marks	Guidance
	(a)	(i)	$f = \frac{1}{T} = \frac{1}{10\times10^{-3}}$ frequency = 100 (Hz)	B1	
		(ii)	$2.0\times10^{-2} = B\times1.6\times10^{-3}\times400$ $B = \frac{2.0\times10^{-2}}{1.6\times10^{-3}\times400}$ $B = 3.1\times10^{-2}$ (T)	C1 C1 A1	**Allow**: 2 mark for 3.1×10^{n}; $n \neq -2$ (POT error) Answer to 3 sf is 3.13×10^{-2} (T) **Special case**: 12.5 scores 1 mark; number of turns omitted
		(iii)	(e.m.f. = -) rate of change of flux linkage Tangent drawn on Fig. 3.1 at 2.5 (ms) or 7.5 (ms) or 12.5 (ms) Values substituted to determine the gradient. The gradient must be 12.5 ± 1.0 (V)	B1 B1 B1	**Allow**: $E = (-)\frac{\Delta(N\phi)}{\Delta t}$ or (e.m.f. =) gradient **Alternative**: maximum e.m.f. = $2\pi f \times$ maximum flux linkage C1 maximum e.m.f. = $2\pi \times 100 \times 2 \times 10^{-2}$ C1 maximum e.m.f. = 12.6 (V) or 4π (V) A1
	(b)		$P = \frac{V^2}{R}$ $P = \frac{12^2}{150}$ power = 0.96 (W)	C1 A1	Possible ecf from **(a)(iii)**
			Total	**9**	

4)

Question			Expected Answers	Marks	Additional Guidance
	a		magnetic flux = magnetic flux density x area (perpendicular to field direction)	**B1**	Allow equation with the symbols identified correctly Do not allow magnetic field or magnetic field strength
	b		Φ = NBA = 500 x 0.035 x 2.5 x 10^{-3} = 0.044 (0.04375) unit: Wb	**C1** **A1** **B1**	 [allow for one mark 8.75 x 10^{-5} (Wb) i.e. B x A] Allow: Wb turns and T m^2 and V s
	c	**(i)**	The component of B perpendicular to the area changes / the idea that the area changes relative to the field direction detail of how it varies / depends on cos θ / maximum when field is perpendicular to B / zero when area is parallel to B	**B1** **B1**	Allow the idea that the direction of the field relative to the area of the coil varies with the orientation of the coil Do not allow reference to cutting of the flux by the coil
		(ii)	Induced / e.m.f is proportional / to the rate of change of (magnetic) flux	**B1**	Allow the emf produced is equal to the rate of change of flux or flux cutting
		(iii)	e.m.f. **max** when ϕ is **zero** or at 0.005 /0.015 /0.025 s e.m.f **zero** when ϕ is a **max** or at 0.0 / 0.01/ 0.02 s e.m.f. and ϕ have the same frequency allow e.m.f and ϕ out of phase by $\pi/2$/ emf follows a sin curve emf is the gradient of the graph **MAX 3**	**(B1)** **(B1)** **(B1)** **(B1)** **(B1)** **B3**	

		(iv)	ε = (change in flux linkage) / time = 0.04375 / 0.005 (8.8 x 10^{-5} x 500) / 0.005 = 8.75 (V)	 C1 A1	 [if N omitted then give one mark (ε = 0.0175)] [if 10^{-5} omitted then minus 1] [reading error from graph is penalised -1 (should be 8.8 and not 8.4)]
		(v)	Max e.m.f. is twice the original value as the rate of flux change is twice the original	B1 B1	Do not allow just larger Allow: the change in magnetic flux occurs in half the time Allow the max gradient will double
			Total	**[14]**	

For additional Induction questions go to theonlinephysicstutor.com and look for question by topic.

Also see question on transformers.