1)

Question			Expected Answers	Marks	Additional guidance
	(a)		Electromotive force is the energy transferred (from one form of energy) to electrical per unit charge	B1	**Allow:** 'electrical energy (gained) per unit charge' **Not:** electrical energy per coulomb
	(b)		Magnetic flux is the product of the (magnetic) flux density and the area (normal to the field)	B1	**Allow:** $\phi = BA$, where B = (magnetic) flux density and A = area. If $\phi = BA \cos \theta$ is used, then θ must be defined as the angle (between the normal to the plane of the area and the magnetic field) **Do not allow** 'field strength' for 'flux density'
	(c)	**(i)**	A changing (magnetic) flux is produced (in the primary coil / in the iron core) The iron core links this (magnetic) flux /(magnetic) flux density to the secondary coils The changing (magnetic) flux / (magnetic) flux density through secondary induces e.m.f. (in secondary coils)	B1 B1 B1	**Allow:** A changing (magnetic) flux density is produced (in the primary coil) but **not** '*changing (magnetic) field*' **Allow:** The rate of change of (magnetic) flux (linkage) induces an e.m.f. (in the secondary coil)
		(ii)	Any one from: More coils / turns on secondary Less coils / turns on primary Laminate the core	B1	**Not:** Increase frequency of alternating supply
	(d)	**(i)**	$\frac{n_s}{4200} = \frac{12}{230}$ (Any subject) number of turns = 219 or 220	C1 A1	 **Note:** A bald answer 219 or 220 scores 2 marks
		(ii)	current = $(12.0 - 11.8)/0.35$ current = 0.57 (A) ------------------------------------ $P = VI$ or $P = I^2R$ or $P = V^2/R$ $P = 0.2 \times 0.57$ or $P = 0.57^2 \times 0.35$ or $P = 0.2^2/0.35$ power = 0.114 (W) or 0.11 (W)	C1 A1 C1 A1	 Possible e.c.f. from **(ii)**1
			Total	**12**	

2)

Question			Answers	Marks	Guidance
	(a)		magnetic flux = (magnetic) flux density × (cross-sectional) area Idea of (magnetic) field normal to the plane of the area	M1 A1	Allow full credit for magnetic flux = BA, where B = magnetic flux density normal to area and A = (cross-sectional) area
	(b)	(i)	constant rate of change of (magnetic) flux / flux density	B1	**Not**: 'graph has constant gradient'
		(ii)	e.m.f. = rate of change of flux linkage e.m.f. = $\frac{1.4\times10^{-2}\times\pi\times(3.2\times10^{-2})^2\times180}{2.5}$ e.m.f. = 3.2×10^{-3} (V) or 3.24×10^{-3} (V)	C1 C1 A1	**Allow**: $E = \frac{\Delta N\phi}{\Delta t}$ Deduct 1 mark if B is misread from the graph and then ecf **Allow**: 2 marks for an answer 3.24×10^n (if $n \neq -3$) **Allow**: 2 marks for 1.78×10^{-5} (when 180 has been missed out)
	(c)	(i)	$P = VI$ current in secondary = 15/6 or 2.5 (A) primary voltage = 6.0 × turn ratio = 6.0 × 40 = 240 (V) V_p = 240 (V) or I_s = 2.5 (A) primary current = 2.5/40 or 15/240 input current = 6.3×10^{-2} (A) or 6.25×10^{-2} (A)	 C1 A1	 The C1 mark is for either of these values
		(ii)	There is no change in flux density / (magnetic) flux / (magnetic) flux linkage	B1	**Not**: 'There is no change in the magnetic field'
			Total	**9**	

3)

a	i	current $I \left(= \frac{P}{V}\right) = \frac{500 \times 10^3}{25 \times 10^3}$ = 20 (A) ✓	1
a	ii	wasted power ($I^2 R$) = 20^2 × 30 = 1.20 × 10^4 (W) (12.0 kW) ✓ power output from cables = 500 – 12 = 488 (kW) ✓ **or** voltage drop along cables = IR = 20 × 30 = 600 (V) ∴ output voltage = 25000 – 600 = 24400 (V) ✓ power output = IV = 20 × 24400 = 4.88 × 10^5 (W) ✓	2
a	iii	efficiency $\left(= \frac{P_{out}}{P_{in}}\right) = \frac{488}{500}$ × 100 = 98 (97.6) (%) ✓	1
b	i	primary coil must have more turns than secondary ✓	1
b	ii	to reduce heating (I^2R) loss [**or** energy/power/copper loss] ✓ (because) $I_S > I_P$ ✓ and R is reduced (by use of thicker wire) ✓	max 2
c		**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive and logical description of the main principles of the grid system. They should identify I^2R heating as the main cause of energy loss, and know that this can be reduced by using transformers to raise voltage and therefore decrease current (for the same power), and that transformers require ac. They may not have referred to safety and insulation issues that ultimately require the voltage to be reduced again or to energy losses from transformers.	max 6

	Intermediate Level (Modest to adequate): 3 or 4 marks The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a description of the main features of the grid system which recognises that heating losses can be reduced by use of transformers to decrease the current. They should know that transformers require ac. They may not fully explain the reasoning for the use of a higher voltage and they are unlikely to refer to safety and insulation issues that require the voltage to be reduced again. **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate recognises that the use of higher voltage will reduce transmission losses and that transformers need ac. They give a much weaker account (if any) of the underlying principles. **Incorrect, inappropriate of no response: 0 marks** No answer or answer refers to unrelated, incorrect or inappropriate physics. **The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.** voltages are changed using transformers, which work with ac but not with dc ac generation and transmission is therefore essential current in cables causes joule heating (or I^2R loss) resistance of cables should be as low as possible losses are reduced if current in cables can be reduced current can be reduced (for same power IV) if voltage is increased the higher the voltage, the smaller the proportion of the input power that is wasted high voltage introduces insulation problems and raises safety issues voltage must be reduced as the supply reaches its consumers this is done in stages as the supply is moved from overhead cables to underground wires transformers cause energy losses because they are not perfectly efficient features are incorporated in the design of transformers to reduce losses from them	
	Total	**13**

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