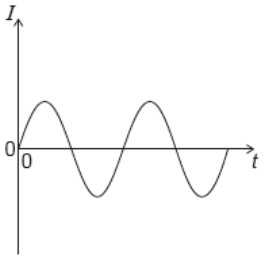
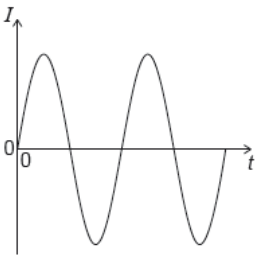
Power transmission *[120 marks]*

1. The graph shows the variation with time *t* of the current *I* in the primary coil of an ideal transformer. *[1 mark]*

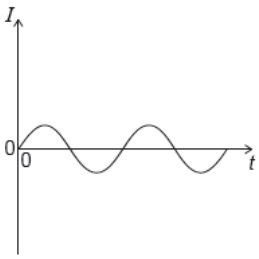


The number of turns in the primary coil is 100 and the number of turns in the secondary coil is 200. Which graph shows the variation with time of the current in the secondary coil?

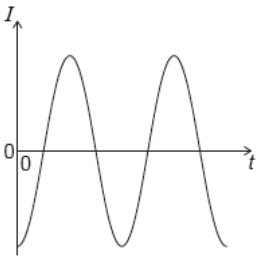
A.



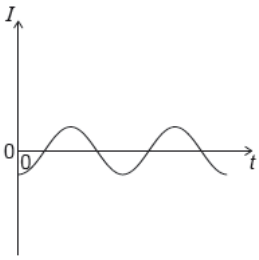
B.



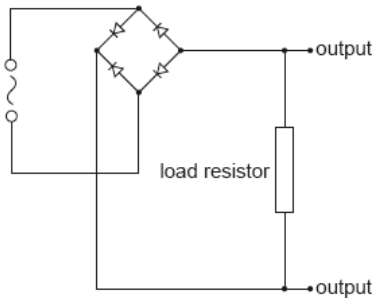
C.



D.

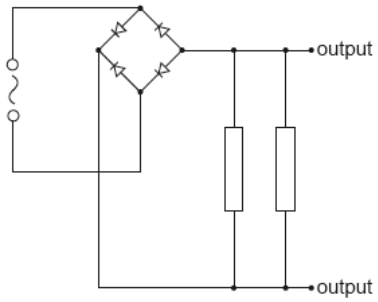


2. The diagram shows a diode bridge rectification circuit and a load resistor. *[1 mark]*

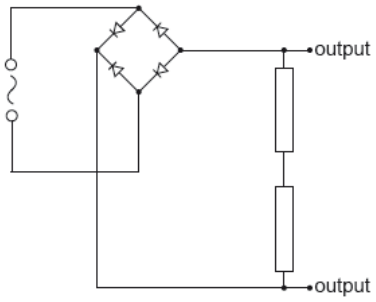


The input is a sinusoidal signal. Which of the following circuits will produce the most smoothed output signal?

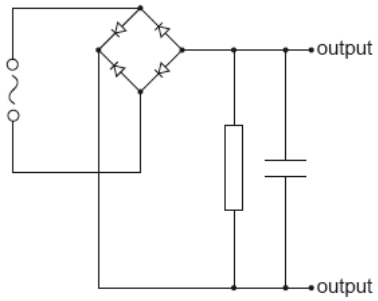
A.



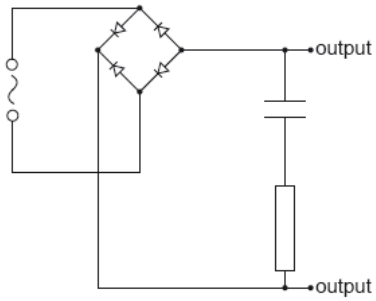
B.



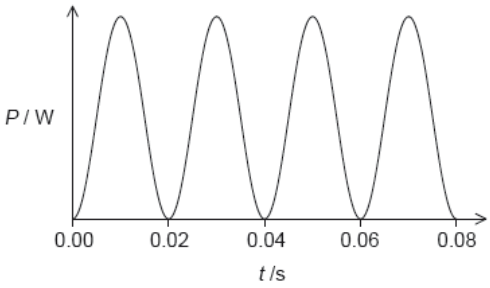
C.



D.



3. The graph shows the power dissipated in a resistor of 100 Ω when connected to an alternating current (ac) power supply of root mean square voltage (V_{rms}) 60 V. *[1 mark]*



What are the frequency of the ac power supply and the average power dissipated in the resistor?

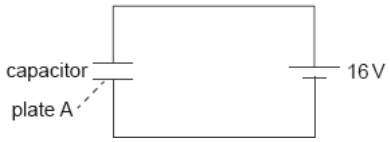
	Frequency of the ac power supply / Hz	Average power dissipated in the resistor / W
A.	25	36
B.	50	36
C.	25	18
D.	50	18

A capacitor consists of two parallel square plates separated by a vacuum. The plates are 2.5 cm × 2.5 cm squares. The capacitance of the capacitor is 4.3 pF.

4a. Calculate the distance between the plates. *[1 mark]*

4b. The capacitor is connected to a 16 V cell as shown. *[2 marks]*

diagram not to scale

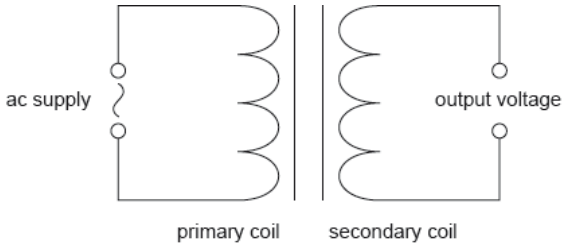


Calculate the magnitude and the sign of the charge on plate A when the capacitor is fully charged.

4c. The capacitor is fully charged and the space between the plates is then filled with a dielectric of permittivity $\varepsilon = 3.0\varepsilon_0$. *[2 marks]*

Explain whether the magnitude of the charge on plate A increases, decreases or stays constant.

4d. In a different circuit, a transformer is connected to an alternating current (ac) supply. *[3 marks]*



The transformer has 100 turns in the primary coil and 1200 turns in the secondary coil. The peak value of the voltage of the ac supply is 220 V. Determine the root mean square (rms) value of the output voltage.

4e. Describe the use of transformers in electrical power distribution. *[3 marks]*

5. The ratio $\frac{\text{number of primary turns}}{\text{number of secondary turns}}$ for a transformer is 2.5. *[1 mark]*

The primary coil of the transformer draws a current of 0.25 A from a 200 V alternating current (ac) supply. The current in the secondary coil is 0.5 A. What is the efficiency of the transformer?

A. 20 %

B. 50 %

C. 80 %

D. 100 %

6. An alternating current (ac) generator produces a peak emf E_0 and periodic time T. What are the peak emf and periodic time when the frequency of rotation is doubled? *[1 mark]*

	Peak emf	Periodic time
A.	$2E_0$	$2T$
B.	$2E_0$	$\frac{T}{2}$
C.	E_0	$2T$
D.	E_0	$\frac{T}{2}$

7. A direct current (dc) of 5A dissipates a power P in a resistor. Which peak value of the alternating current (ac) will dissipate an average power P in the same resistor? *[1 mark]*

A. 5A

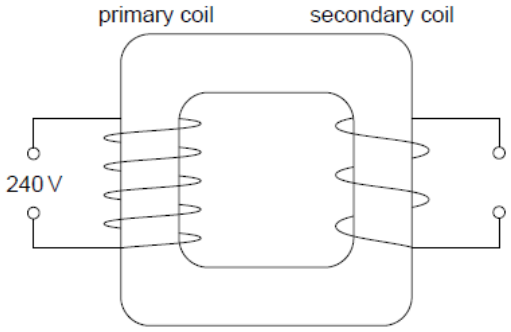
B. $\frac{5}{2}\text{A}$

C. $\frac{5}{\sqrt{2}}\text{A}$

D. $5\sqrt{2}\,\text{A}$

8a. State Faraday's law of induction. *[2 marks]*

The diagram shows a sketch of an ideal step-down transformer.



The number of turns in the primary coil is 1800 and that in the secondary coil is 90.

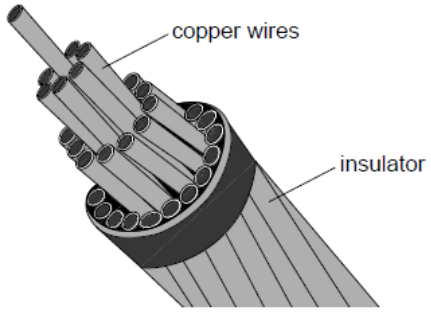
8b. Explain, using Faraday's law of induction, how the transformer steps down the voltage. *[4 marks]*

8c. The input voltage is 240 V. Calculate the output voltage. *[2 marks]*

8d. Outline how energy losses are reduced in the core of a practical transformer. *[2 marks]*

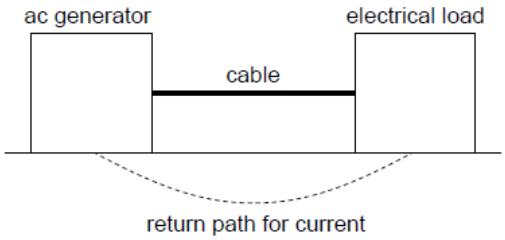
8e. Step-up transformers are used in power stations to increase the voltage at which the electricity is transmitted. Explain why this is done. *[2 marks]*

A cable consisting of many copper wires is used to transfer electrical energy from an alternating current (ac) generator to an electrical load. The copper wires are protected by an insulator.



The cable consists of 32 copper wires each of length 35 km. Each wire has a resistance of 64 Ω. The cable is connected to the ac generator which has an output power of 110 MW when the peak potential difference is 150 kV. The resistivity of copper is 1.7×10^{-8} Ω m.

output power = 110 MW

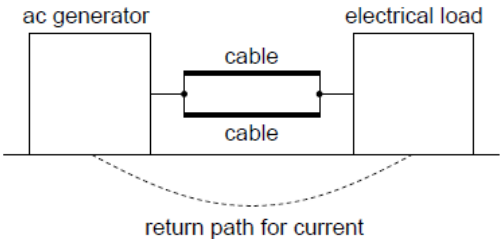


9a. Calculate the radius of each **wire**. *[2 marks]*

9b. Calculate the peak current in the **cable**. *[1 mark]*

9c. Determine the power dissipated in the cable per unit length. *[3 marks]*

To ensure that the power supply cannot be interrupted, two identical cables are connected in parallel.



9d. Calculate the root mean square (rms) current in each cable. *[1 mark]*

9e. The two cables in part (c) are suspended a constant distance apart. Explain how the magnetic forces acting between the cables vary during the course of one cycle of the alternating current (ac). *[2 marks]*

The energy output of the ac generator is at a much lower voltage than the 150 kV used for transmission. A step-up transformer is used between the generator and the cables.

9f. Suggest the advantage of using a step-up transformer in this way. *[2 marks]*

9g. The use of alternating current (ac) in a transformer gives rise to energy losses. State how eddy current loss is minimized in the transformer. *[1 mark]*

10. Which of the following reduces the energy losses in a transformer? *[1 mark]*

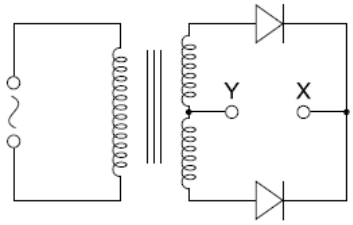
A. Using thinner wires for the windings.

B. Using a solid core instead of a laminated core.

C. Using a core made of steel instead of iron.

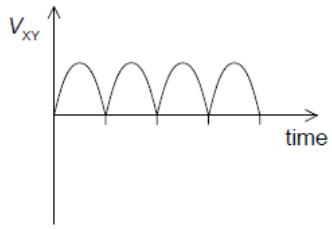
D. Linking more flux from the primary to the secondary core.

11. The secondary coil of an alternating current (ac) transformer is connected to two diodes as shown. *[1 mark]*

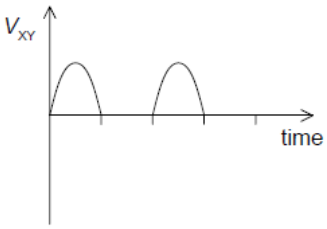


Which graph shows the variation with time of the potential difference V_{XY} between X and Y?

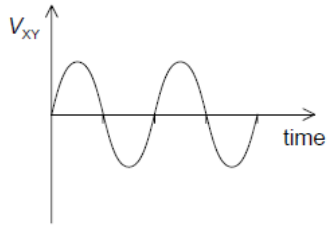
A.



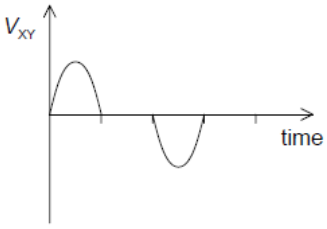
B.



C.



D.



The following data are available for a natural gas power station that has a high efficiency.

Rate of consumption of natural gas	= 14.6 kg s^{-1}
Specific energy of natural gas	= 55.5 MJ kg^{-1}
Efficiency of electrical power generation	= 59.0 %
Mass of CO_2 generated per kg of natural gas	= 2.75 kg
One year	= 3.16×10^7 s

12a. Electrical power output is produced by several alternating current (ac) generators which use transformers to deliver energy to the national electricity grid. *[4 marks]*

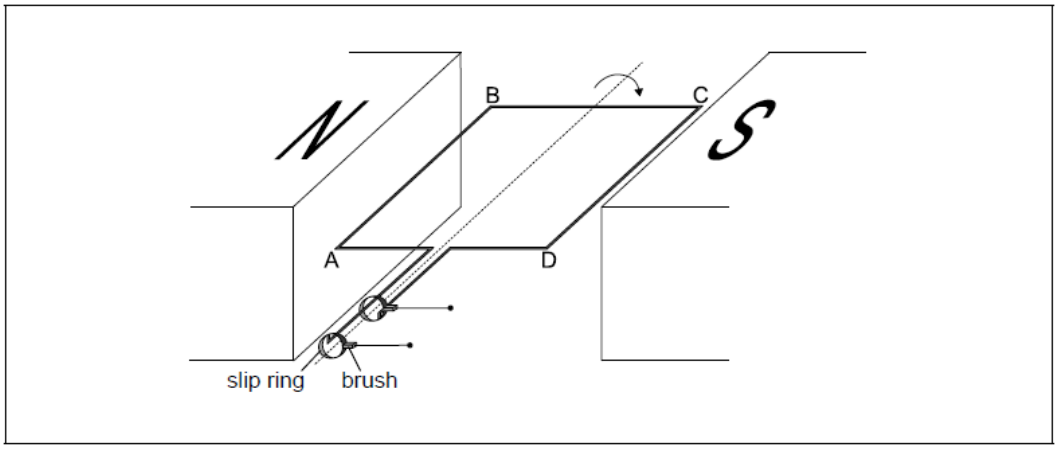
The following data are available. Root mean square (rms) values are given.

ac generator output voltage to a transformer = 25 kV ac generator output current to a transformer = 3.9 kA Transformer output voltage to the grid = 330 kV Transformer efficiency = 96%

(i) Calculate the current output by the transformer to the grid. Give your answer to an appropriate number of significant figures.

(ii) Electrical energy is often delivered across large distances at 330 kV. Identify the main advantage of using this very high potential difference.

12b. In an alternating current (ac) generator, a square coil ABCD rotates in a magnetic field. *[5 marks]*



The ends of the coil are connected to slip rings and brushes. The plane of the coil is shown at the instant when it is parallel to the magnetic field. Only one coil is shown for clarity.

The following data are available.

Dimensions of the coil = 8.5 cm×8.5 cm Number of turns on the coil = 80 Speed of edge AB = 2.0 ms^{-1} Uniform magnetic field strength = 0.34 T

(i) Explain, with reference to the diagram, how the rotation of the generator produces an electromotive force (emf) between the brushes.

(ii) Calculate, for the position in the diagram, the magnitude of the instantaneous emf generated by a **single** wire between A and B of the coil.

(iii) Hence, calculate the total instantaneous peak emf between the brushes.

13. An alternating current (ac) power supply generates an emf with peak amplitude V_0 and delivers an average power P. What is the root mean square (rms) current delivered by the supply? *[1 mark]*

A. $\frac{P}{2V_0}$

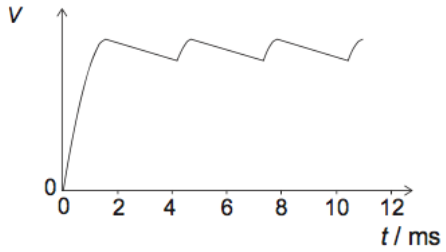
B. $\frac{P}{\sqrt{2}V_0}$

C. $\frac{\sqrt{2}P}{V_0}$

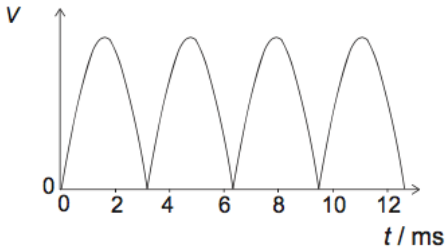
D. $\frac{2P}{V_0}$

14. A full-wave diode rectification circuit is modified with the addition of a capacitor in parallel with the load resistor. The circuit is used to rectify a sinusoidal signal of period 6.3ms. Which graph shows how the potential difference *V* across the load varies with time? *[1 mark]*

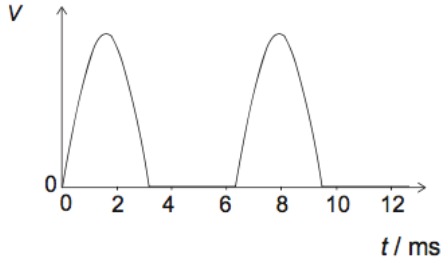
A.



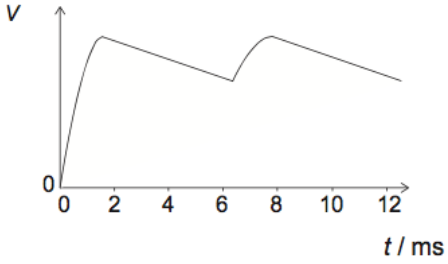
B.



C.



D.



15. Which of the following experiments provides evidence for the existence of matter waves? *[1 mark]*

A. Scattering of alpha particles

B. Electron diffraction

C. Gamma decay

D. Photoelectric effect

16. An alternating current is sinusoidal and has a maximum value of 1.5 A. What is the approximate value of the root mean squared (rms) current? *[1 mark]*

A. 2.3 A

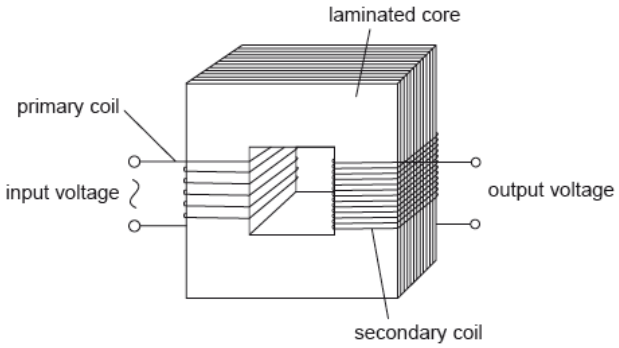
B. 1.5 A

C. 1.0 A

D. 0.75 A

Part 2 Power transmissions

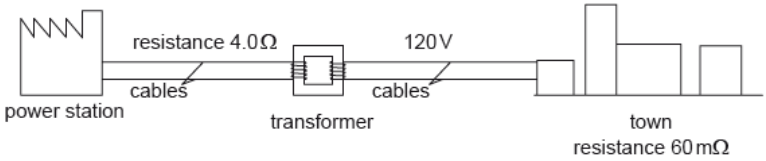
The diagram shows the main features of an ideal transformer whose primary coil is connected to a source of alternating current (ac) voltage.



17a. Outline, with reference to electromagnetic induction, how a voltage is induced across the secondary coil. *[3 marks]*

17b. The primary coil has 25 turns and is connected to an alternating supply with an input voltage of root mean squared (rms) value 12 V. The secondary coil has 80 turns and is not connected to an external circuit. Determine the peak voltage induced across the secondary coil. *[2 marks]*

A different transformer is used to transmit power to a small town.



The transmission cables from the power station to the transformer have a total resistance of 4.0 Ω. The transformer is 90% efficient and steps down the voltage to 120 V. At the time of maximum power demand the effective resistance of the town and of the cables from the transformer to the town is 60 mΩ.

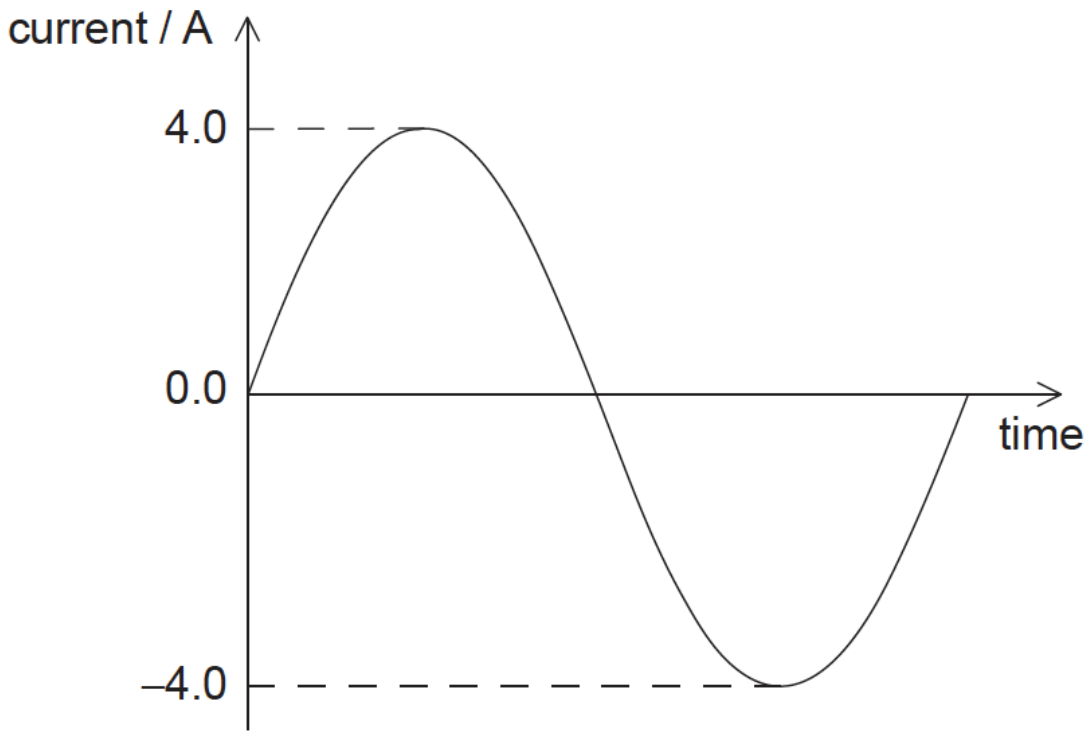
17c. Calculate the current in the cables connected to the town *[1 mark]*

17d. Calculate the power supplied to the transformer. *[2 marks]*

17e. Determine the input voltage to the transformer if the power loss in the cables from the power station is 2.0 kW. *[2 marks]*

17f. Outline why laminating the core improves the efficiency of a transformer. *[2 marks]*

18. The graph below shows the variation with time of an alternating current in a resistor of resistance 2.0 Ω. *[1 mark]*



What is the average power dissipated in the resistor?

A. 0.25 W

B. 8.0 W

C. 16 W

D. 32 W

This question is in **two** parts. **Part 1** is about energy resources. **Part 2** is about transformers.

Part 2 Transformers

Modern televisions (TVs) can be left in "standby" mode so that they are available for immediate use. The internal circuits are powered at low voltage using a step-down transformer connected to the mains power supply. To prevent the TV from using any energy, the transformer must be disconnected from the mains supply.

19a. Outline the features of an ideal step-down transformer. *[2 marks]*

19b. Real transformers are subject to energy loss. State and explain how **two** causes of these energy losses may be reduced by suitable features in these transformers. *[4 marks]*

1.

2.

When in "standby" mode, a TV transformer supplies a current of 0.45 A at 9.0 V to the internal circuits.

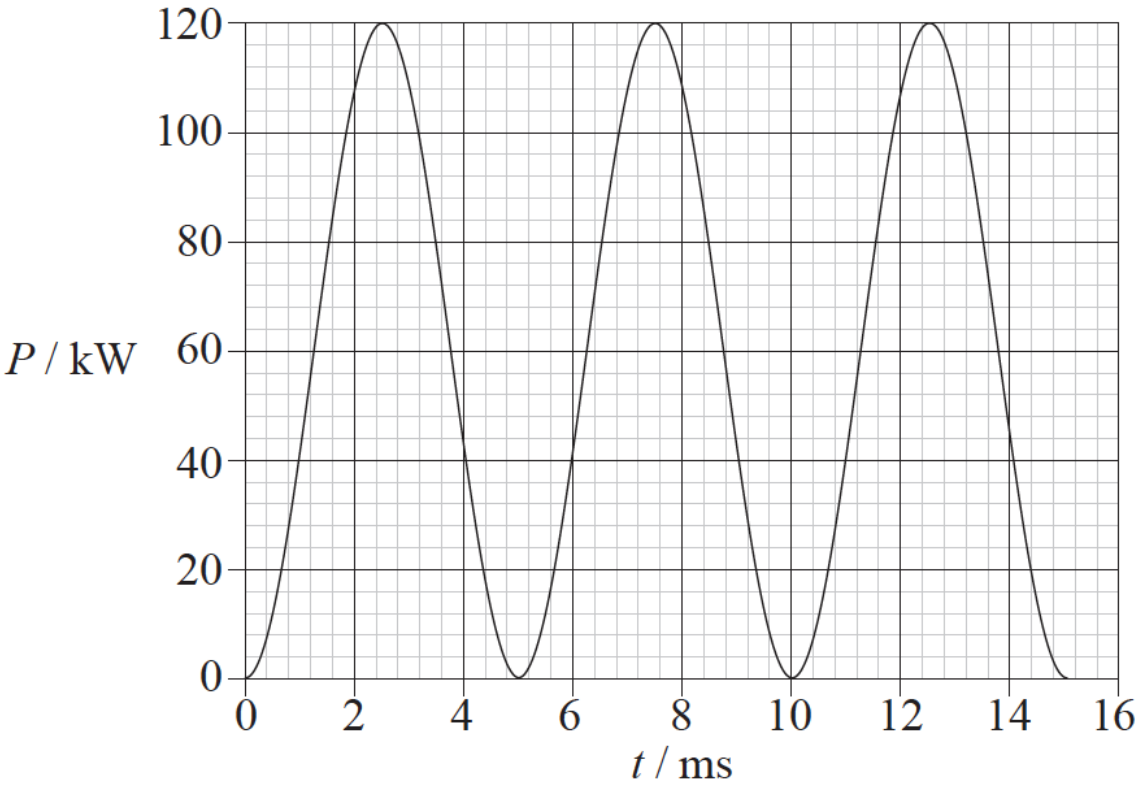
19c. Calculate the power consumed by the internal circuits when the TV is in "standby" mode. *[1 mark]*

19d. The efficiency of the transformer is 0.95. Determine the current supplied by the 230 V mains supply. *[2 marks]*

19e. The TV is on “standby” for 75% of the time. Calculate the energy wasted in one year by not switching off the TV. *[1 mark]*

$$1 \text{ year} = 3.2 \times 10^7 \text{ s}$$

20. The graph shows the variation with time *t* of the power *P* produced in a coil that is rotating in a region of uniform magnetic field. *[1 mark]*



Which of the following describes the average power produced and the period of rotation of the coil?

	Average power	Period
A.	60 kW	5.0 ms
B.	60 kW	10 ms
C.	$\frac{120}{\sqrt{2}}$ kW	5.0 ms
D.	$\frac{120}{\sqrt{2}}$ kW	10 ms

21. The voltage output of a particular power station is stepped up by a factor of 10^3. As a result the power loss in the transmission cables is reduced by a factor of *[1 mark]*

A. 10^3.

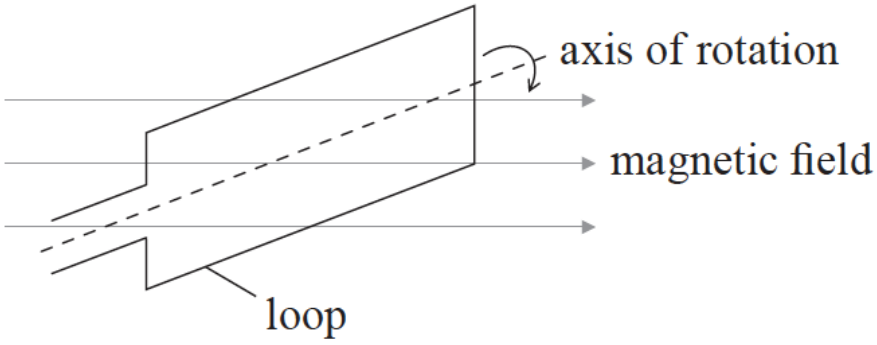
B. 10^6.

C. 10^9.

D. 10^{12}.

This question is about induced electromotive force (emf).

22a. A loop of copper wire in a region of uniform magnetic field is rotated about a horizontal axis. *[4 marks]*



The magnitude of the magnetic field strength is *B* and the area of the loop is *A*.

(i) State the minimum value and the maximum value of the magnetic flux linking the loop.

(ii) Outline with reference to Faraday's law why, if the speed of rotation of the loop is increased, the maximum emf induced in the loop is increased.

22b. The loop in (a) is connected in series with a resistor of resistance 15 Ω. The root mean squared (rms) value of the sinusoidal current in the resistor is 2.3 mA. *[4 marks]*

(i) Explain what is meant by the rms value of a sinusoidal current.

(ii) Determine the maximum power dissipated in the resistor.

23. An ideal transformer has 200 turns of wire on the primary coil and 600 turns on the secondary coil. There is an alternating potential difference of frequency f and of peak value V across the primary coil. Which of the following best describes the emf across the secondary coil? *[1 mark]*

	Peak emf	Frequency
A.	less than V	less than f
B.	less than V	equal to f
C.	greater than V	greater than f
D.	greater than V	equal to f

24. An ideal transformer has a primary coil with N_p turns and a secondary coil with N_s turns. The electrical power input to the primary is P. Which of the following is the power output from the secondary? *[1 mark]*

A. $\left(\frac{N_p}{N_s}\right) P$

B. P

C. $\left(\frac{N_s}{N_p}\right) P$

D. $\frac{1}{P}$

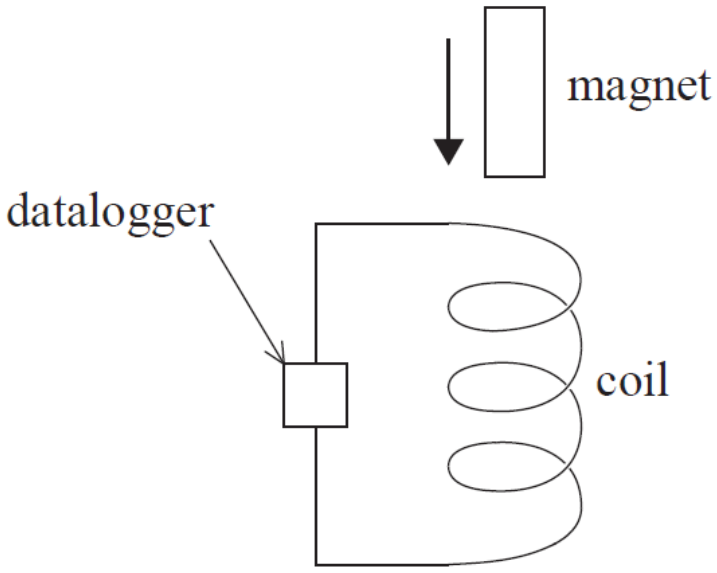
25. An alternating current generator produces a root mean squared (rms) emf of ε at a frequency f. The rotational speed of the coil in the generator is doubled. Which of the following correctly identifies the new output rms emf and the new frequency? *[1 mark]*

	emf	Frequency
A.	2ε	$2f$
B.	$\sqrt{2}\varepsilon$	$2f$
C.	2ε	$\frac{f}{2}$
D.	$\sqrt{2}\varepsilon$	$\frac{f}{2}$

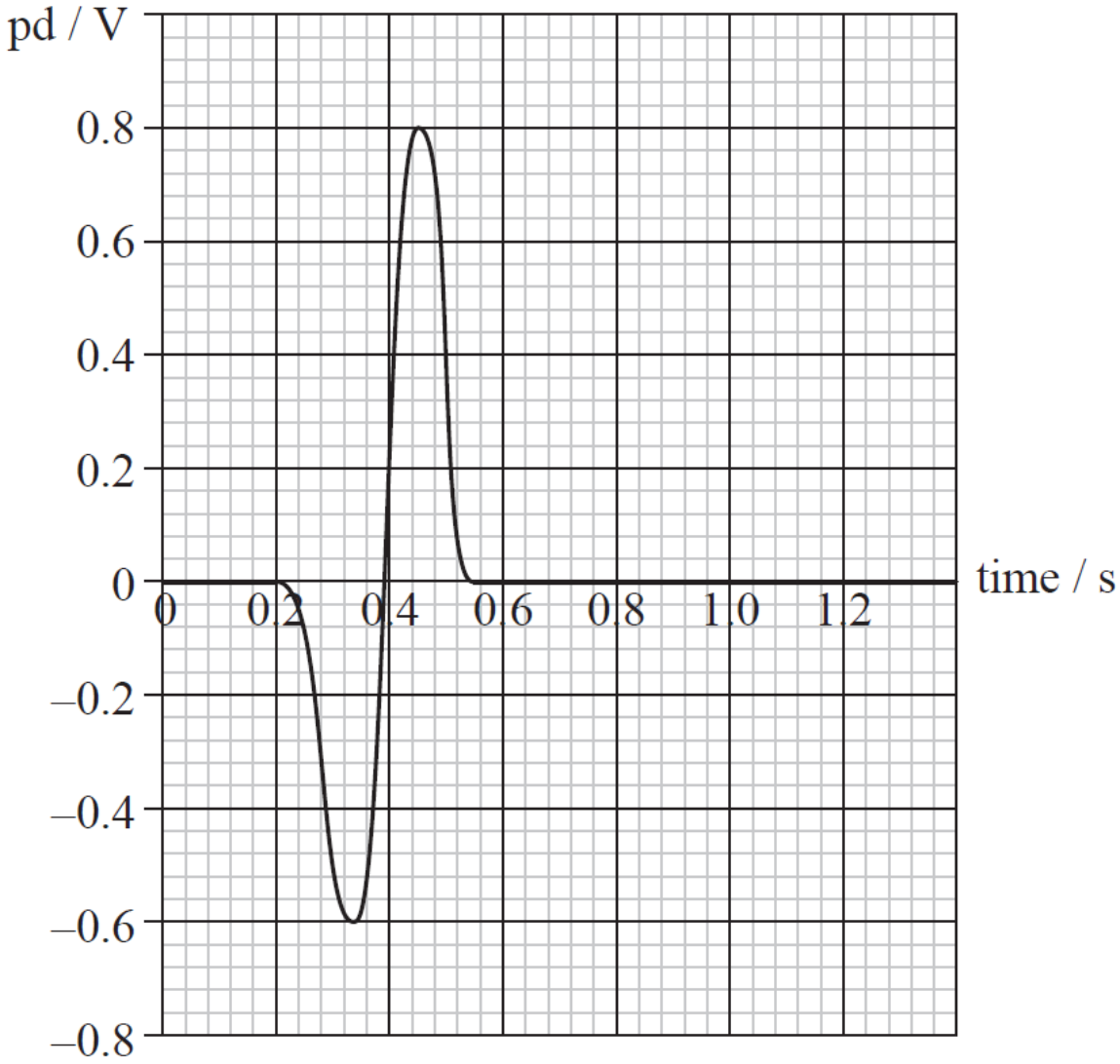
This question is in **two** parts. **Part 1** is about electromagnetic induction. **Part 2** is about nuclear fusion.

Part 1 Electromagnetic induction

26a. A bar magnet falls vertically from rest through a coil of wire. The potential difference (pd) across the coil is recorded by a datalogger. *[6 marks]*



The graph shows the variation with time of the pd across the coil.



(i) Explain, with reference to Faraday's and Lenz's laws, the shape of the graph.

(ii) The coil has 1500 turns. Calculate the magnitude of the maximum rate of change of magnetic flux.

26b. The magnet is now suspended from a spring. The magnet is displaced vertically and starts to oscillate in and out of the coil. A sinusoidal alternating current of rms value 280 nA is induced in the coil. *[5 marks]*

(i) State in words how the rms value of the alternating current relates to a direct current of 280nA.

(ii) The coil has a resistance of 1.5MΩ. Calculate the peak voltage across the coil.

(iii) Explain what effect the generation of the current has on the oscillation of the magnet.

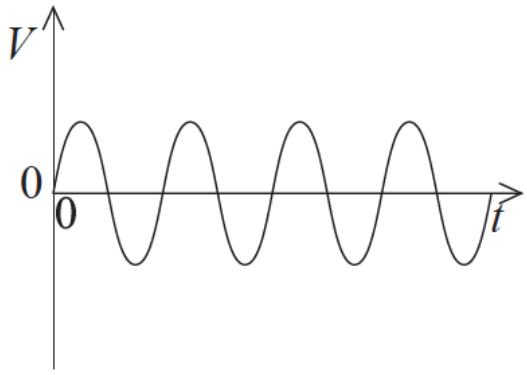
27. In an ideal transformer *[1 mark]*

I. the power output exceeds the power input
II. the magnetic flux produced by the primary coil entirely links the secondary coil
III. there are more turns on the secondary coil than on the primary coil.

Which of the above statements **must** be true?

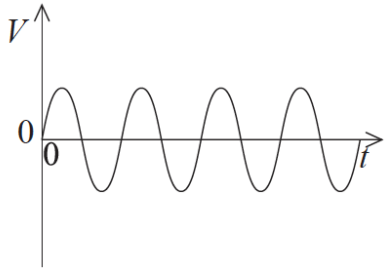
A. I and II only
B. I and III only
C. II only
D. III only

28. The graph shows the variation with time *t* of the output voltage *V* of a generator. *[1 mark]*

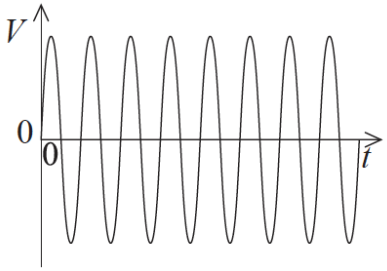


Assuming all graph scales are identical, which graph shows the output when the speed of rotation is doubled?

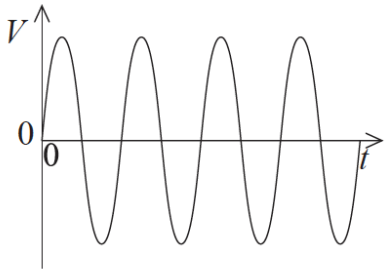
A.



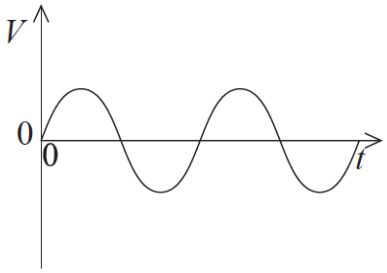
B.



C.



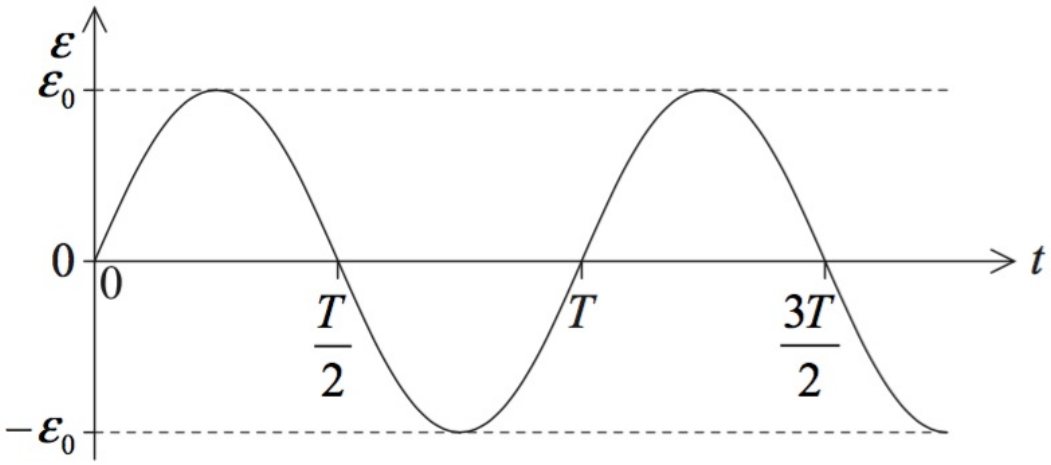
D.



29. The rms voltage of a sinusoidal electricity supply is 110V. The maximum potential difference during one cycle is *[1 mark]*

A. 220 V.
B. 156 V.
C. 110 V.
D. 55 V.

30. A coil rotates in a magnetic field. The emf ε produced in the coil varies sinusoidally with time t as shown. *[1 mark]*



Which of the following correctly gives the rms value of the emf and the frequency of rotation of the coil?

	rms value of emf	Frequency of rotation
A.	$\varepsilon_0\sqrt{2}$	$\frac{1}{T}$
B.	$\frac{\varepsilon_0}{\sqrt{2}}$	$\frac{2}{T}$
C.	$\varepsilon_0\sqrt{2}$	$\frac{2}{T}$
D.	$\frac{\varepsilon_0}{\sqrt{2}}$	$\frac{1}{T}$

31. The peak value of an alternating sinusoidal potential difference is 100V. The approximate rms value of the potential difference will be *[1 mark]*

A. 50V.
B. 70V.
C. 140V.
D. 200V.

32. A sinusoidal ac power supply has rms voltage V and supplies rms current I. What is the maximum instantaneous power delivered? *[1 mark]*

A. $2VI$
B. $\sqrt{2}VI$
C. VI
D. $\frac{VI}{2}$

33. The rms current rating of an electric heater is 4A. What direct current would produce the same power dissipation in the electric heater? *[1 mark]*

A. $\frac{4}{\sqrt{2}}\text{A}$

B. 4A

C. $4\sqrt{2}\text{A}$

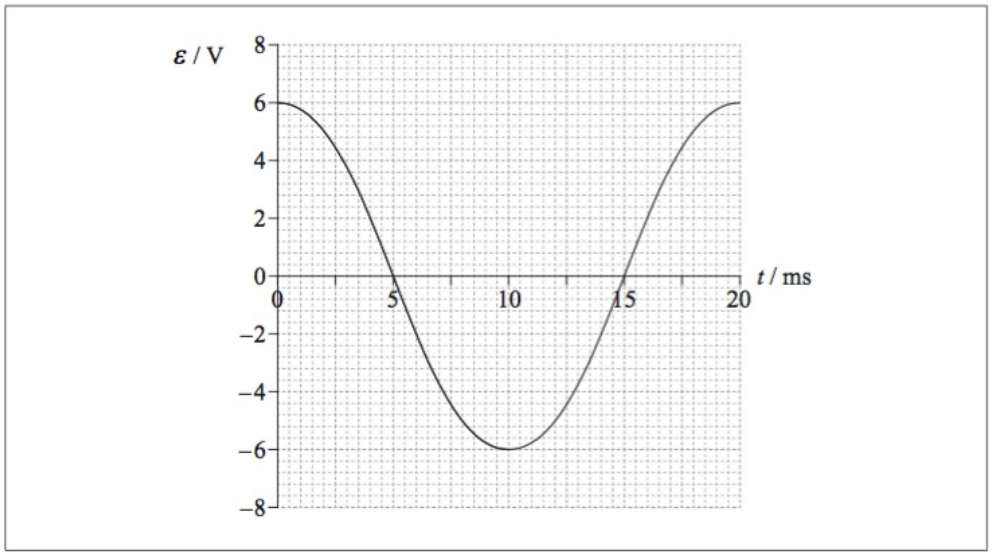
D. 8A

This question is about the emf induced in a coil.

34a. Define *magnetic flux*. *[2 marks]*

34b. A coil is rotated at constant speed in a region of uniform magnetic field. *[3 marks]*

The graph shows the variation with time t of the emf ε induced in the coil for one cycle of rotation.

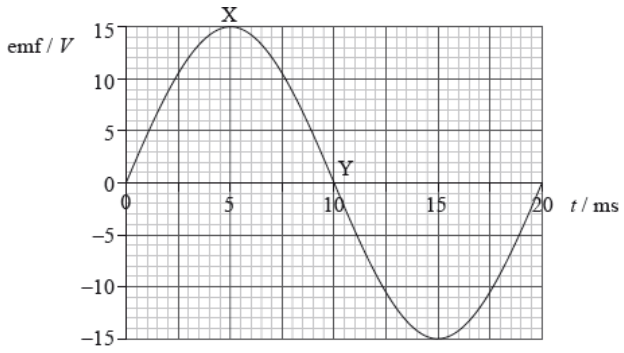


(i) On the graph label, with the letter T, a time at which the flux linkage in the coil is a maximum.

(ii) Use the graph to determine the rate of change of flux at t=4.0ms. Explain your answer.

(iii) Calculate the root mean square value of the induced emf.

A rectangular loop of conducting wire rotates in a region of magnetic field. The graph shows the variation with time t of the induced emf in the loop during one cycle.



35. Which of the following gives the correct times at which the magnitude of the magnetic flux linkage and the magnitude of the current in the loop are maximum? *[1 mark]*

	Flux linkage	Current
A.	Y	Y
B.	Y	X
C.	X	Y
D.	X	X

36. The resistance of the coil is $5.0\ \Omega$. Which of the following is the average power dissipated in the loop? *[1 mark]*

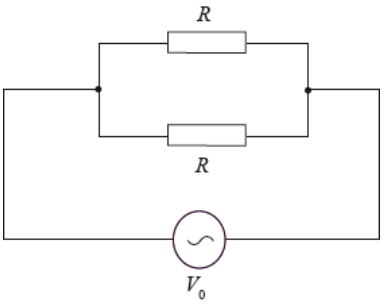
A. $\frac{45}{2}$ W

B. $\frac{45}{\sqrt{2}}$ W

C. 45 W

D. $45\sqrt{2}$ W

37. An alternating current supply of negligible internal resistance is connected to two resistors that are in parallel. *[1 mark]*



The resistance of each resistor is R and the peak voltage of the ac supply is V_0. Which of the following is the average power dissipated in the circuit?

A. $\frac{2V_0^2}{R}$

B. $\frac{V_0^2}{R}$

C. $\frac{V_0^2}{\sqrt{2}R}$

D. $\frac{V_0^2}{2R}$

38. Raoul suggests that power losses in a transformer may be reduced by the following. *[1 mark]*

I. Constructing the core from a solid block of steel.

II. Using large diameter wire in the coils.

III. Using wire of low resistivity.

Which of the above suggestions would reduce power loss?

A. I only

B. II only

C. II and III only

D. I, II and III

39. In order to reduce power losses in the transmission lines between a power station and a factory, two transformers are used. One is located at the power station and the other at the factory. Which of the following gives the correct types of transformer used? *[1 mark]*

	Power station	Factory
A.	step-up	step-up
B.	step-up	step-down
C.	step-down	step-up
D.	step-down	step-down