IB · DP · Physics

3 hours 15 questions

Structured Questions

11.2 Power Generation & Transmission

11.2.1 AC Generators / 11.2.2 Root-Mean-Square Current & Voltage / 11.2.3 Step-Up & Step-Down Transformers / 11.2.4 Transformer Calculations / 11.2.5 AC Electrical Power Distribution / 11.2.6 Diode Bridges / 11.2.7 Investigating Diode Bridges / 11.2.8 Rectification / 11.2.9 Capacitors & Diode Bridges

Easy (5 questions)	/49
Medium (5 questions)	/47
Hard (5 questions)	/63
Total Marks	**/159**

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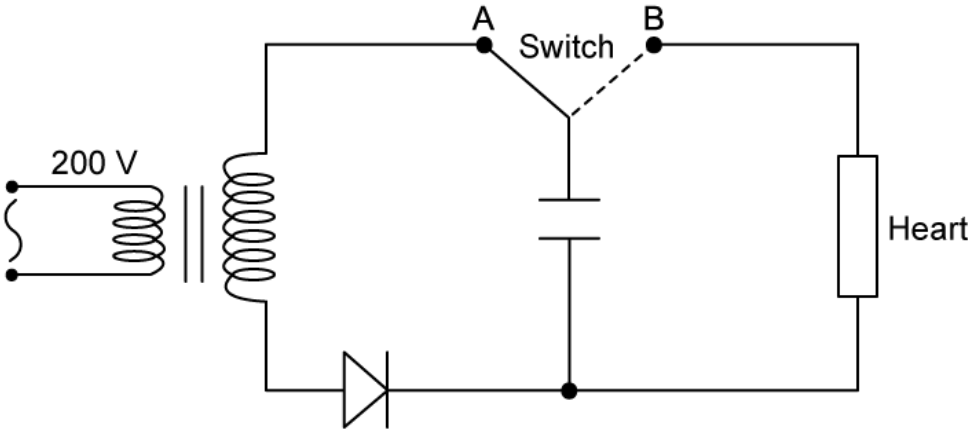
Easy Questions

1 (a) A defibrillator device sends an impulse of electrical energy to maintain a regular heartbeat in a person. The device is powered by an alternating current (ac) supply connected to a step-up transformer that charges a capacitor.



State two reasons for placing the diode in the circuit.

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(2 marks)

(b) The e.m.f. across the primary coil of the transformer is 200 V. The number of turns on the primary coil is 5 and the number of turns on the secondary coil is 50.

Calculate the e.m.f across the secondary coil.

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(3 marks)

(c) Calculate the fraction $\frac{I_s}{I_p}$ between the primary and secondary coils of the transformer.

.....

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(2 marks)

(d) In rectification to produce a steady direct current from an alternating current a smoothing capacitor is necessary.

Define smoothing.

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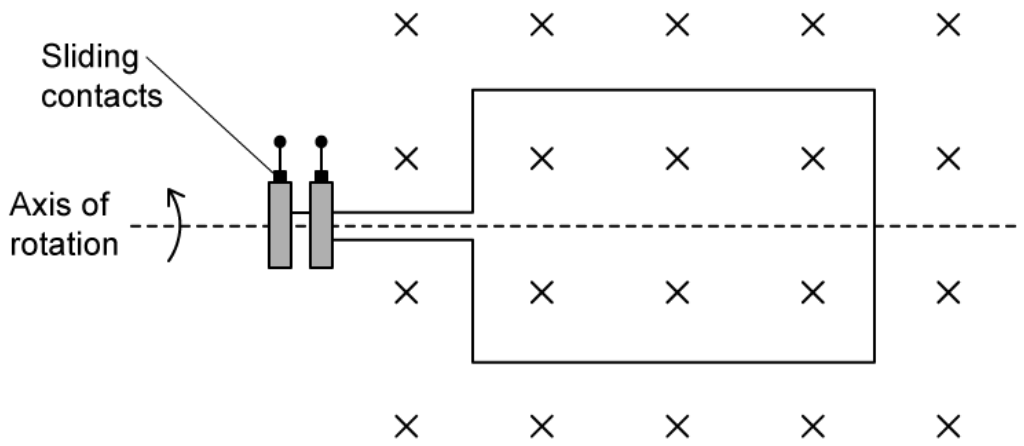
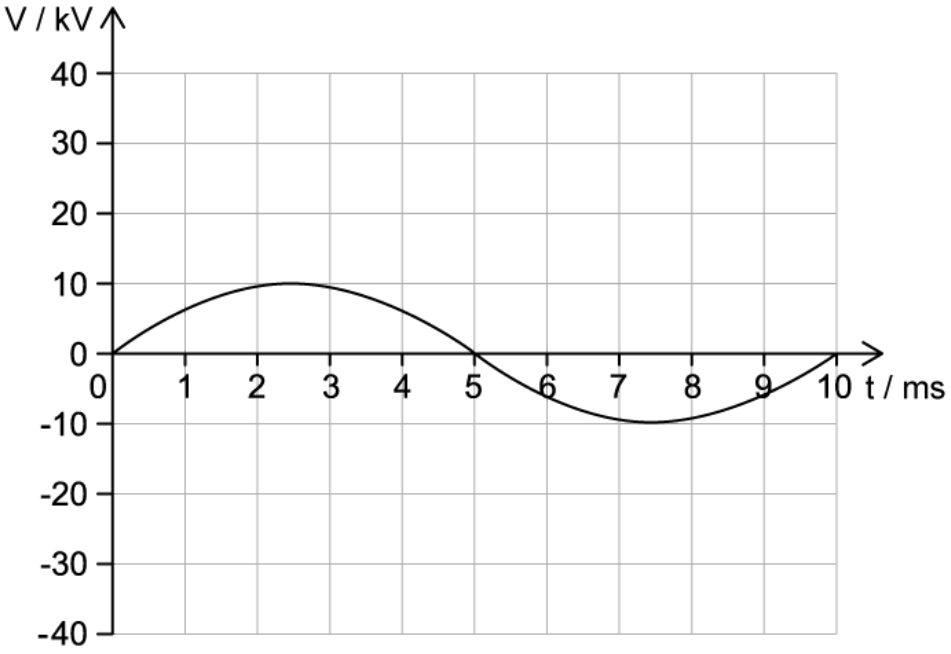
(1 mark)

2 (a) The diagram shows an alternating current generator with a rectangular coil rotating at a constant frequency in a uniform magnetic field.



The graph shows how the output voltage *V* from the generator varies with time *t*.



Use the graph to determine the maximum output voltage.

.....

.....

(2 marks)

(b) Calculate the root mean squared voltage, V_{rms}.

(3 marks)

(c) The average power output of the generator is 4.8×10^5 W.

Calculate the root mean squared current, I_{rms}.

(4 marks)

(d) Sketch a line on the graph to show the V_{rms}.

(2 marks)

3 (a) A transformer inside the charger of a household appliance has a primary coil at 230 V and a secondary coil at 80 V. The number of turns in the primary coil is 1650.

Calculate the number of turns in the secondary coil.

(3 marks)

(b) Hence, state whether this is a step-up or step-down transformer. Explain your answer.

(2 marks)

(c) The appliance has an output power of 30 W.

Calculate the output current for the appliance.

(3 marks)

(d) Outline how eddy currents are reduced in the core of a transformer.

(2 marks)

4 (a) State the meaning of rectification.

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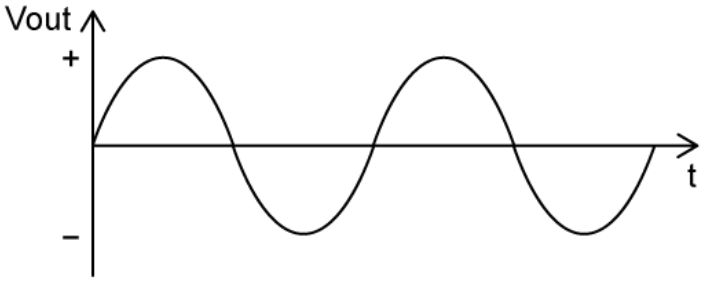
(1 mark)

(b) The graph shows the voltage output from an alternating current supply.



Sketch how the graph changes during:

(i) Half-wave rectification

[1]

(ii) Full-wave rectification

[1]

.....

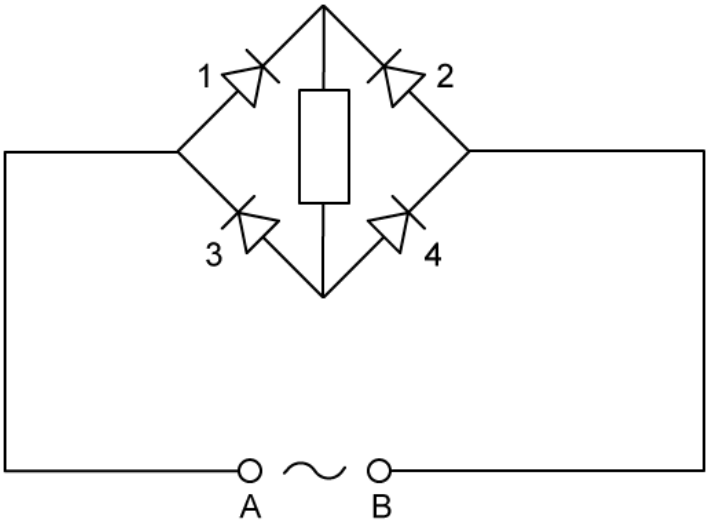
(2 marks)

(c) In rectification, a smoothing capacitor is often necessary. The resulting graph of the output current against time gives a 'ripple' shape.

State how the 'ripples' in the graph can be reduced.

(2 marks)

(d) The circuit shows a diode bridge circuit.



State the diodes that will conduct when

(i) A is positive.

(ii) B is positive.

[1]

[1]

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.....

(2 marks)

5 (a) The following paragraph explains the operation of a basic a.c. generator.

An a.c. generator consists of a coil rotating in a _____ field. The ends of the coil are attached to _____ rings that rotate along with the coil. These touch _____ that transfer the current into an external circuit. The magnetic _____ changes as the coil rotates and an _____ is induced. An ac generator converts _____ energy into _____ energy.

Complete the sentences using keywords from below.

You may use any keyword once, more than once, or not at all.

e.m.f. flux electrical field magnetic

brushes mechanical slip electric

(5 marks)

(b) A generator produces an rms voltage of 35 V.

Show that the peak voltage for the generator is around 50 V.

(3 marks)

(c) The average power output of the generator is 0.25 kW.

Calculate the peak current produced by the generator.

(4 marks)

(d) Outline the effect of the output if the frequency of an ac generator is increased.

(1 mark)

Medium Questions

A permanent magnet is attached to a vertical spring so that it undergoes simple harmonic motion. A coil of conducting wire is arranged so that when the magnet is displaced vertically it oscillates in and out of the coil, inducing a sinusoidal alternating current (ac) of rms value 1.65 mA.

(i) Explain in words how the rms value of the alternating current relates to a direct current of 1.65 mA.

[1]

(ii) Sketch the graph shape which would be expected from this direct current.

[1]

(iii) Sketch the graph shape which would be expected from this ac current.

[2]

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1 (a) **(4 marks)**

(b) The coil which the magnet is oscillating inside has a resistance of 120 kΩ.

Calculate the peak voltage induced across the coil.

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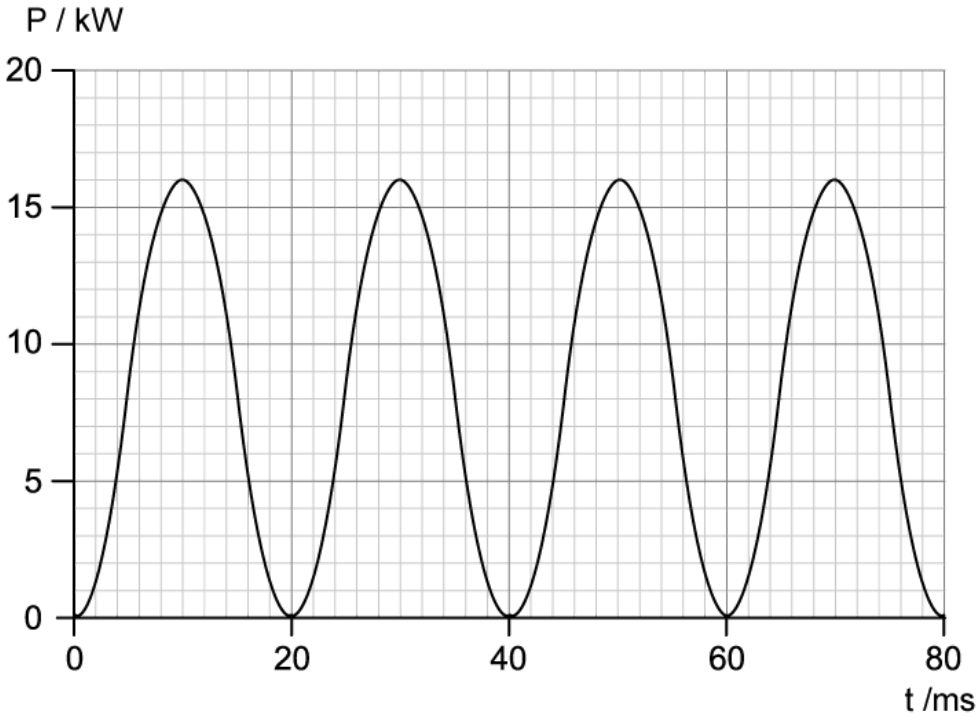
(2 marks)

(c) The graph shows the variation with time of the power delivered by an ac generator.



Determine the frequency of rotation of the generator.

(2 marks)

(d) Sketch a graph to show the power delivered when the frequency is halved.

(2 marks)

2 (a) A transformer is connected to an alternating power supply.

The transformer has 250 turns in the primary coil and 3500 turns in the secondary coil. The peak value of the voltage of the ac supply is 220 V.

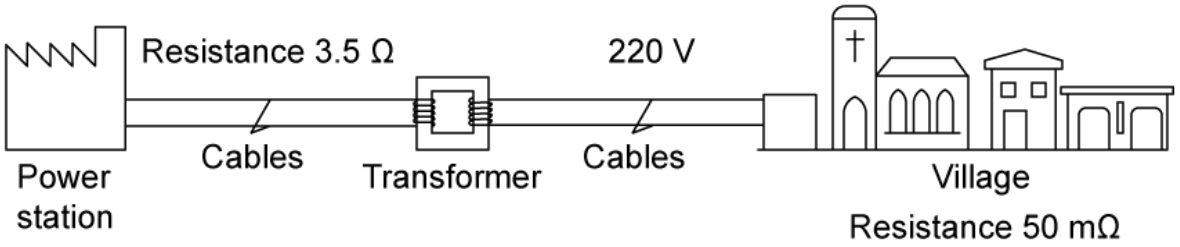
Determine the root mean square (rms) value of the output voltage.

(3 marks)

(b) Describe the use of transformers in electrical power distribution.

(3 marks)

(c) A different transformer is used to transmit power to a village.



The transmission cables connecting the power station to the transformer have a total resistance of 3.5 Ω. The transformer is 92% efficient and steps down the voltage to 220 V. At the time of maximum power demand the effective combined resistance of the cables to the village and the village is 50 mΩ.

Calculate the current in the cables connected to the village.

(2 marks)

(d) Calculate the power supplied to the transformer.

(2 marks)

3 (a) Electrical power is produced for the national electricity grid using a series of alternating current (ac) generators connected to identical transformers.

The following data are available for one transformer. All values are root mean squares (rms).

ac generator output voltage to a transformer	= 35 kV
ac generator output current to a transformer	= 2.8 kA
Transformer output voltage to the grid	= 330 kV
Transformer efficiency	= 96%

Calculate the current output by this transformer to the grid.

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(2 marks)

(b) Transformers are often used to step up voltage to 330 kV so that energy can be delivered across long distances.

State and explain the main advantage of using this very high potential difference.

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(2 marks)

(c) The rms of the transmitted voltage is stepped down from 330 kV to 230 V to be used in the home.

(i) Determine the ratio of the number of turns on the primary coil compared to the number of turns on the secondary coil of the step-down transformer.

[1]

(ii) Calculate the peak output voltage delivered to the home.

[2]

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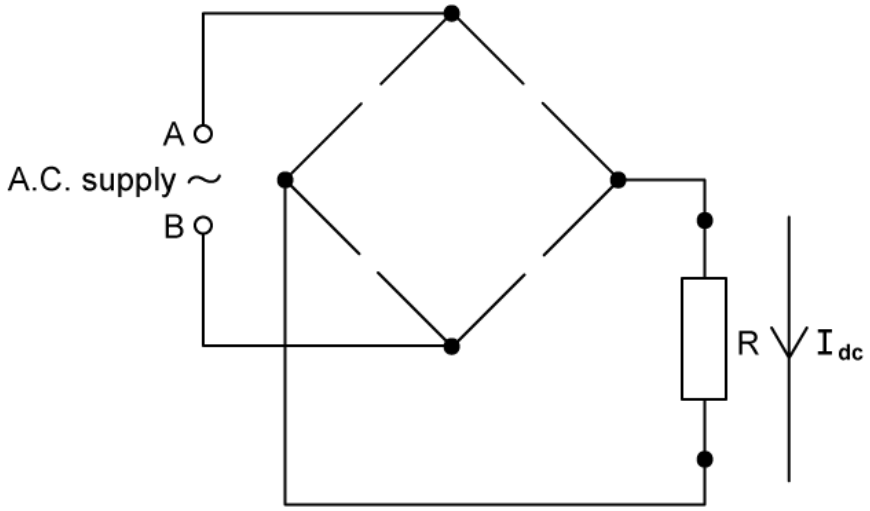
(3 marks)

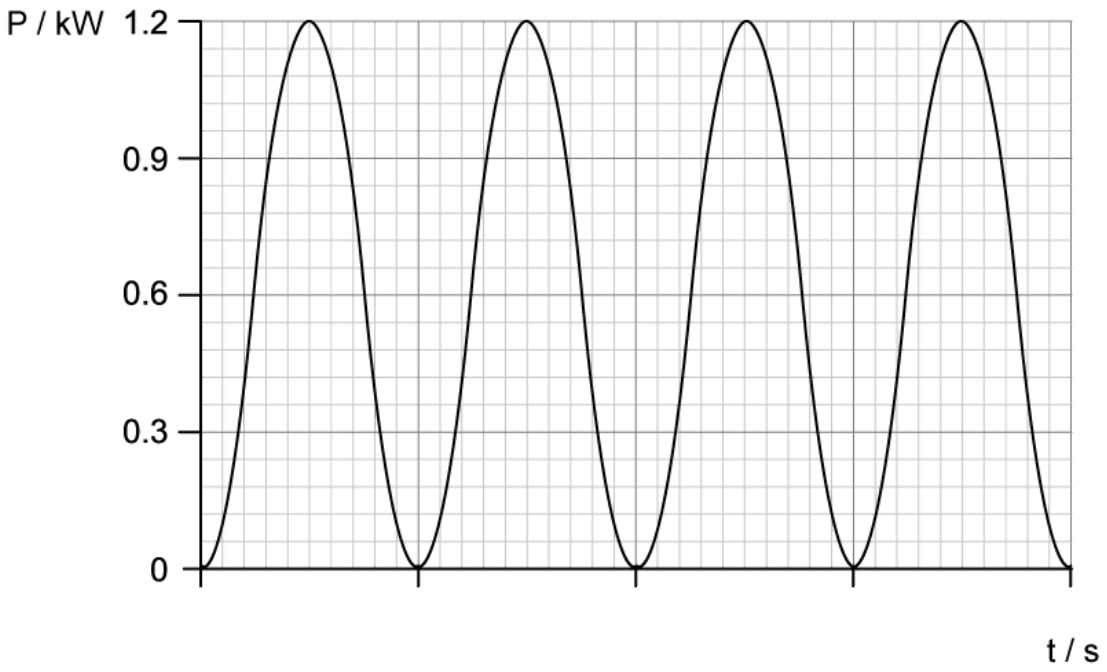
(d) Current from ac generators must be converted to dc current for some uses.



Complete the sketch to show an arrangement of diodes which would achieve full rectification with dc current in the load in the direction shown.

(2 marks)

4 (a) An ac voltage is established at the ends of a 75 Ω resistor. The graph shows the variation with time of the power dissipated in the resistor.



Find the rms value of the current.

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(2 marks)

(b) Calculate the rms value of the voltage.

.....

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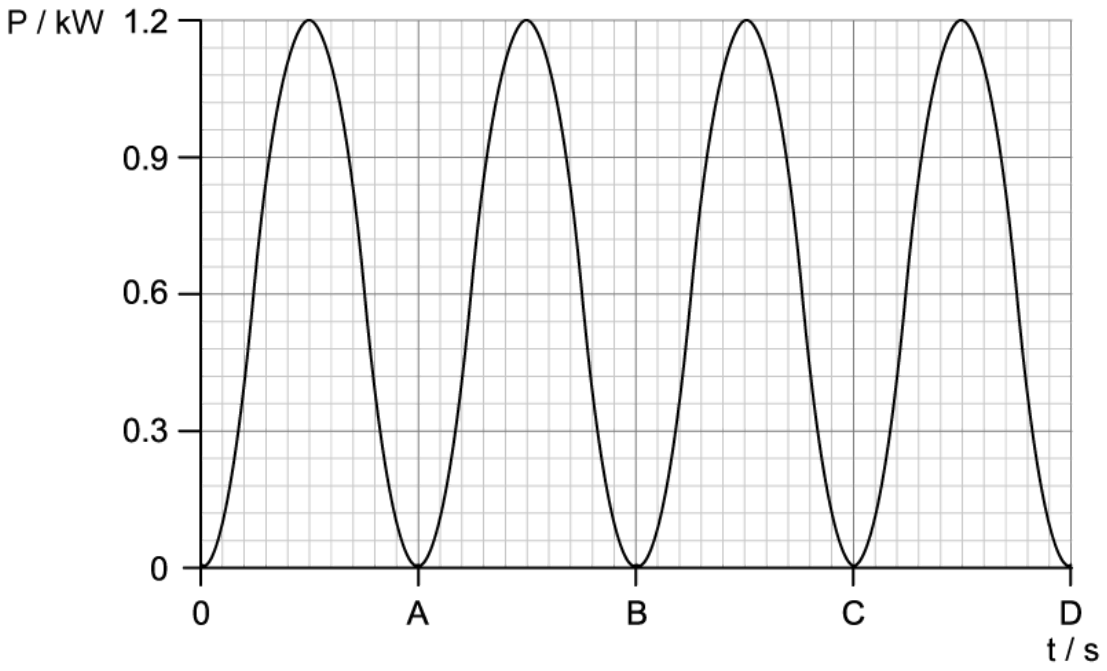
(2 marks)

(c) The coil is rotating with a frequency of 50 Hz.



Determine the times on the graph at points A, B, C and D.

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.....

(2 marks)

(d) A transformer has 700 turns in its primary coil and 300 in the secondary coil. An ac voltage of 220 V and frequency 50 Hz is established in the primary coil.

For the secondary coil calculate the induced

(i) Frequency.

[1]

(ii) Voltage.

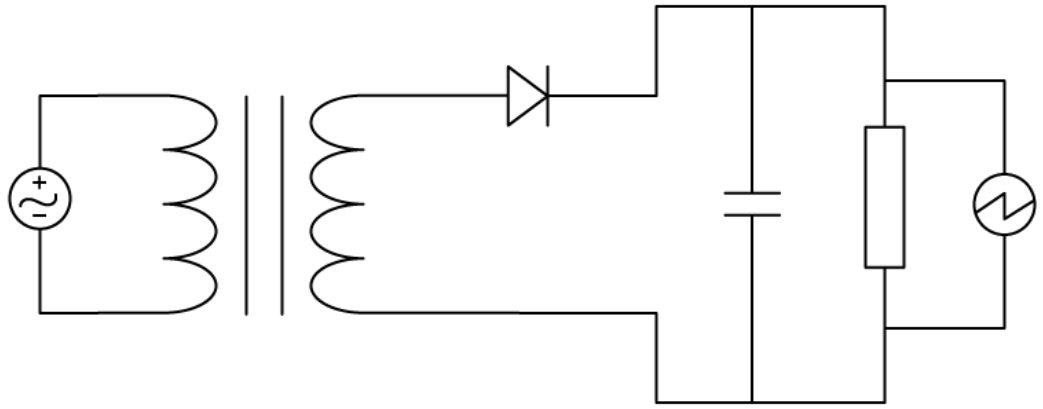
[1]

.....

.....

(2 marks)

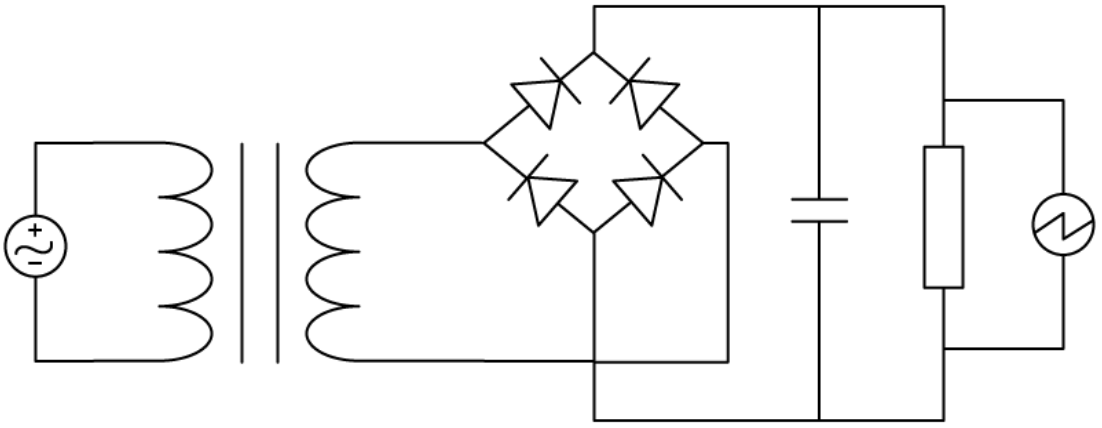
5 (a) An investigation into rectification used the circuit shown.



For this investigation, sketch the resulting graph.

(2 marks)

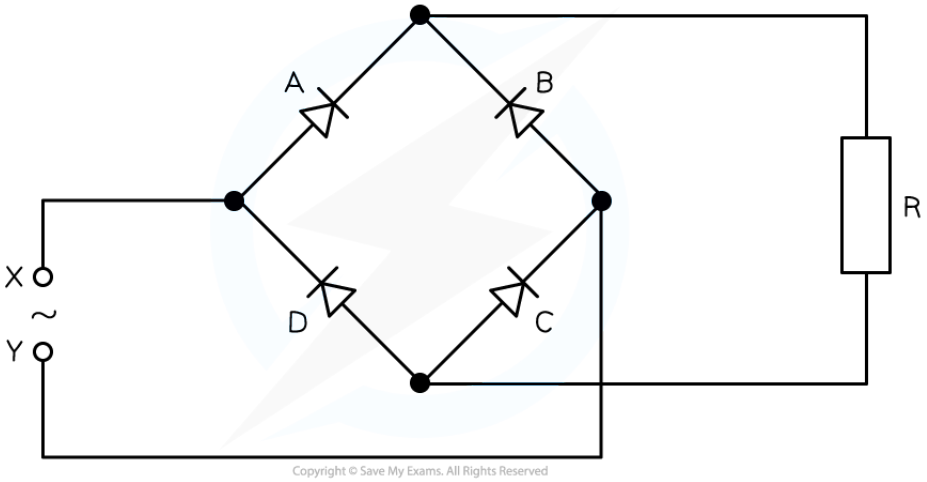
(b) The investigation continues, using a second circuit.



Sketch the expected graph of the output voltage for this circuit.

(3 marks)

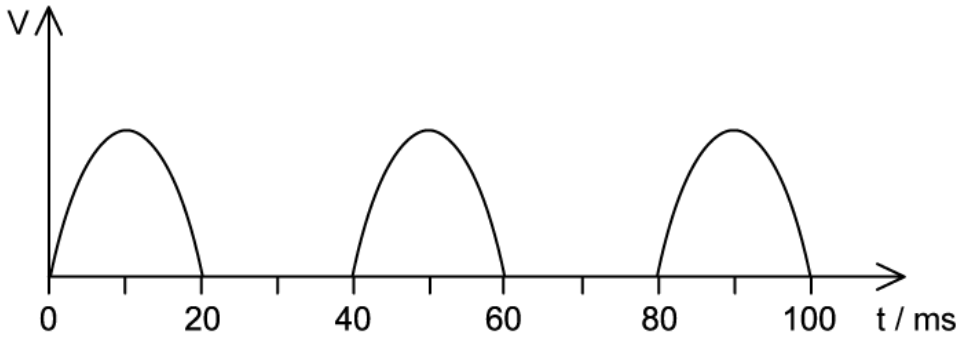
(c) A bridge rectifier consisting of four ideal diodes is connected to an ac generator with terminals X and Y.



Identify which diodes are conducting when terminal X of the ac generator is negative.

(2 marks)

(d) The graph shows the output from an ac generator after undergoing half-wave rectification.



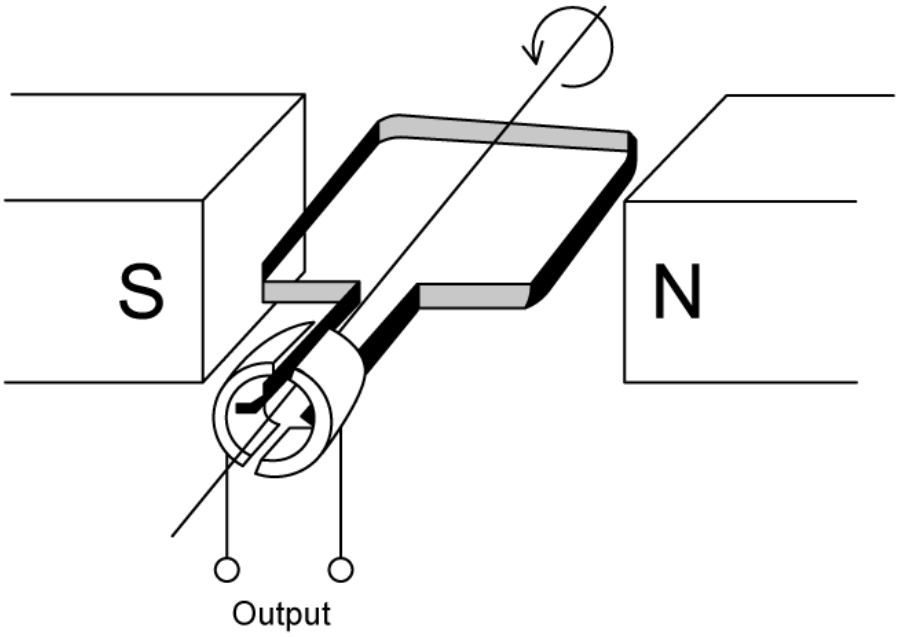
The load resistor has a resistance of 3.6 kΩ. Capacitors of 360 nF and 60 μF are available.

Select the appropriate capacitor to smooth this output.

(3 marks)

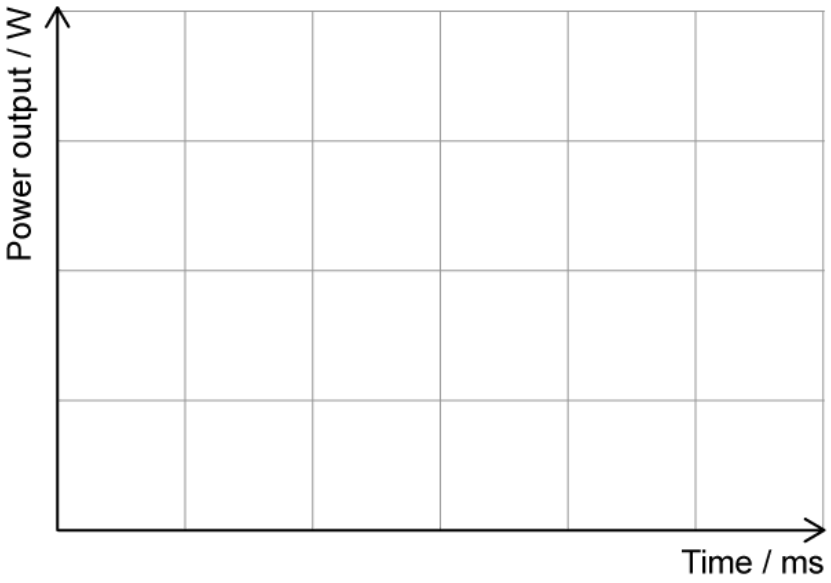
Hard Questions

1 (a) A generator in a hydroelectric plant features a coil rotating in a magnetic field with a constant angular velocity.



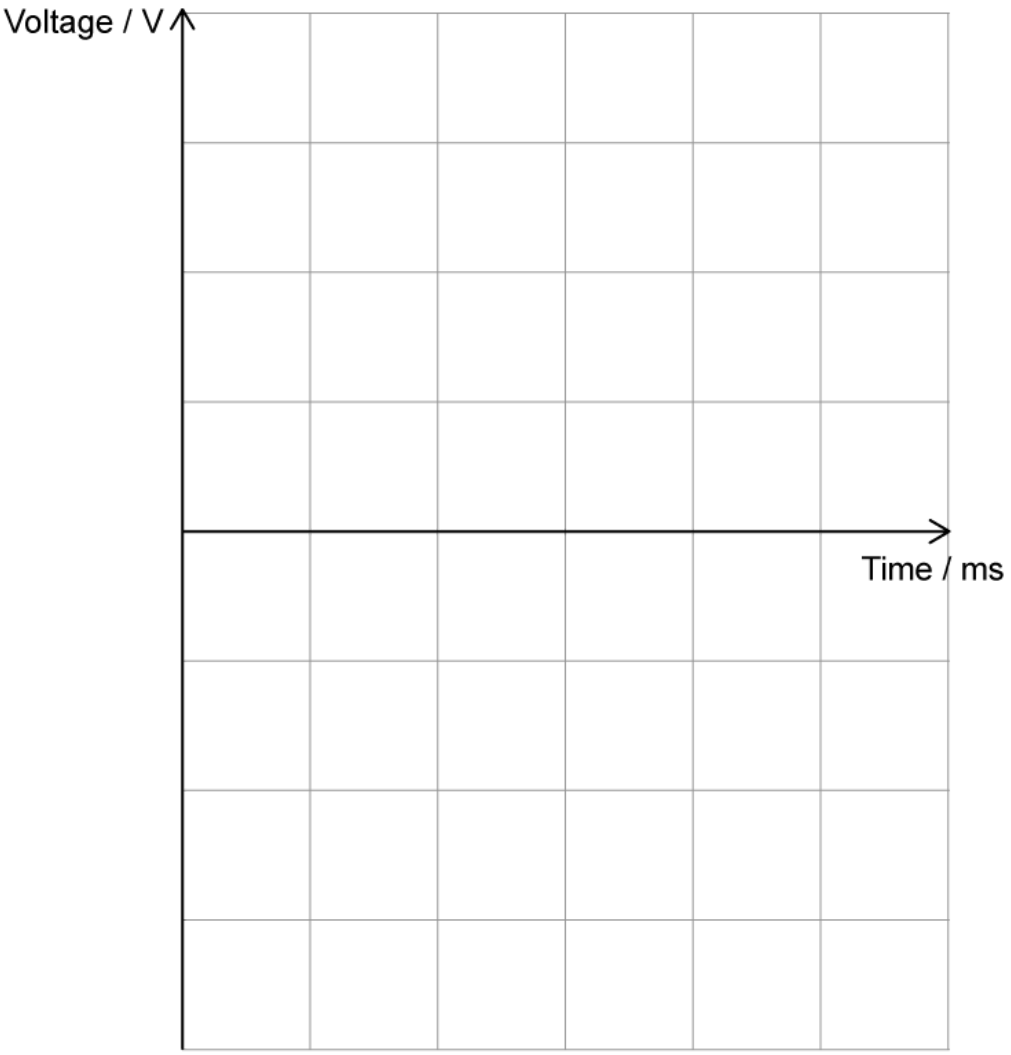
The power output varies over time for a generator rotating with a maximum power output of P_0 and a frequency of 20 Hz.

(i) Sketch the variation of power output with time for a single complete revolution of the coil. Indicate any key values on your axes.



[2]

(ii) Sketch the variation of voltage with time for a single complete revolution of the coil. Indicate any key values on your axes.



[2]

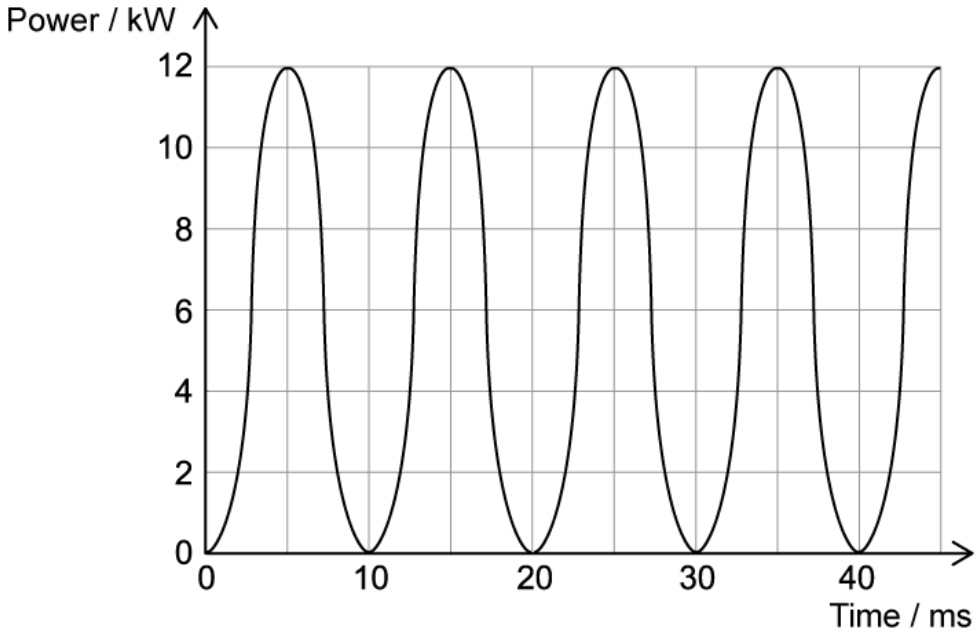
(4 marks)

(b) Using Faraday's Law, show that the new power output is $16P_0$ if the frequency of the rotation of the coil increases to 80 Hz.

You may use the following equation $\frac{d\phi}{dt} = -\omega BA \sin \omega t$

(4 marks)

(c) A graph showing the variation in power over time for a different hydroelectric generator is shown below.



In this generator, when the rate of flow of water from the dam doubles, the frequency of revolution of the coil also doubles.

On the diagram above, sketch a curve showing the new variation in power over time when the flow rate halves.

(2 marks)

2 (a) Bicycles can be fitted with a type of light powered by a dynamo in which a coil of wires is rotated by the motion of the pedals. A dynamo outputs direct current by using a split-ring commutator.

Before the split-ring commutator is fitted to the generator, it is tested by the manufacturer at a particular frequency. The variation in the current of the AC generator at a particular frequency is given by

$$I = I_0 \sin\left(\frac{200\pi}{3}t\right)$$

The rms value of the alternating current is 2.12 A.

Sketch a graph to show the variation of current against time

(i) For the manufacturer's test.

[2]

(ii) When the split-ring commutator is fitted to the generator.

[2]

For each graph, label the peak current, I_0, with a numerical value.

(4 marks)

(b) For another bike light which only operates on direct potential difference, it is not possible to fit a split-ring commutator to the generator.

Suggest an alternative configuration for supplying the light with direct potential difference from an AC generator, such that the light shines continuously. Explain your reasoning.

(3 marks)

(c) Some bicycle lights rapidly flash off and on at a constant rate to make the cyclist more visible on the road.

Describe and explain the configuration which would lead to this discontinuous flashing effect. You may sketch a graph to aid your explanation.

(4 marks)

3 (a) Root mean square (rms) values are used throughout this question.

A step down transformer connects an AC supply to a 18V system of 8 light up garden gnomes connected in parallel. The AC supply has a potential difference of 230V. Each gnome is rated at 35 W at average brightness.

Calculate the current in the primary coil of the transformer. Assume that the transformer is ideal.

(3 marks)

(b) Flux leakage is one reason why a transformer may not be ideal.

(i) Explain the effect of flux leakage on the transformer.

[2]

(ii) Discuss a potential change to the transformer that could reduce flux leakage.

[2]

(4 marks)

(c) Transformers are also used to supply electricity to homes with minimal power loss. A power company are evaluating a step-up transformer between a generator in a power plant and power cables leading to homes.

The primary coil has 300 turns and the secondary coil has 6000 turns and the cables in the primary and secondary coils have the same resistance.

Assuming the transformer is ideal, calculate the power loss in the secondary coil as a percentage of the power loss in the primary coil.

(4 marks)

4 (a) In a nuclear plant, steam heated by fission chain reactions rotates a turbine. This turbine then spins a generator, which is specified as "240 V_{rms}, 50 Hz AC". The generator produces an rms current of 6.00 A.

An ideal transformer steps up the voltage to 2700 V_{rms}, in preparation for long-distance transfer through an aluminium power line with a resistivity of 2.65×10^{-8} Ω m.

Sketch two waveforms of the supply voltage on the same axes, one before and one after the transformer. Include numerical values on the axes where appropriate.

(2 marks)

(b) In reality, transformers are not ideal and some power is lost.

(i) Explain the mechanism behind the power loss during the transformer's operation.

[3]

(ii) Assuming 10% of the power is lost, sketch a graph of the variation in power over time in the secondary coil. Include numerical values on the axes where appropriate.

[3]

(6 marks)

(c) Calculate the power lost over 5 km of the power cable which has a radius of 4 cm.

(4 marks)

(d) This cable connects to a step-down generator. The secondary coil supplies power to a flood lamp lighting an important game of ultimate frisbee. It is crucial that the lights do not flicker, but they have been fitted with a single diode.

The lamps have been fitted with a single diode as they only operate with direct current:

(i) Explain why the lights would flicker with a single diode in the circuit.

[2]

(ii) Describe a configuration that could be added between the diode and the lamp that would ensure the lights produce a steady beam.

[1]

(iii) Explain how this configuration produces this effect.

[2]

(5 marks)

5 (a) A step-up transformer has a peak current of 1.70 A and 500 turns in its primary coil and 1200 turns on the secondary coil.

Calculate the value of the rms current output by the secondary coil for an 80% efficient transformer.

(4 marks)

(b) A step-down generator on the other side of the cable brings the rms value of the alternating voltage to 230 V. This is supplied to the main electricity plugs inside a local library. A student charges their laptop.

Outline how, and explain why, the alternating current from the mains source must be altered before it can charge a device.

(3 marks)

(c) The expression $V = 565\,000 \sin(100\pi t)$ represents the sinusoidal alternating voltage for an overhead cable on an electrical distribution system

(i) Determine the value of the rms voltage.

[1]

(ii) Explain why such a high voltage is advantageous for the transmission of electrical energy.

[3]

(4 marks)

(d) Describe how such high voltages are obtained in practice.

(3 marks)