11.2 Power Generation & Transmission

Question Paper

Course	DP IB Physics
Section	11. Electromagnetic Induction (HL only)
Topic	11.2 Power Generation & Transmission
Difficulty	Hard

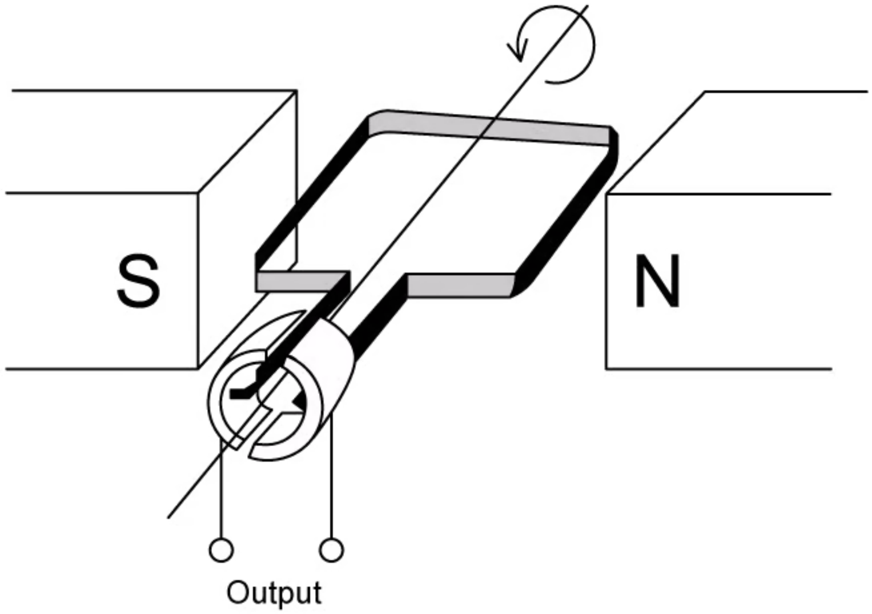
Time allowed: 80

Score: /60

Percentage: /100

Question 1a

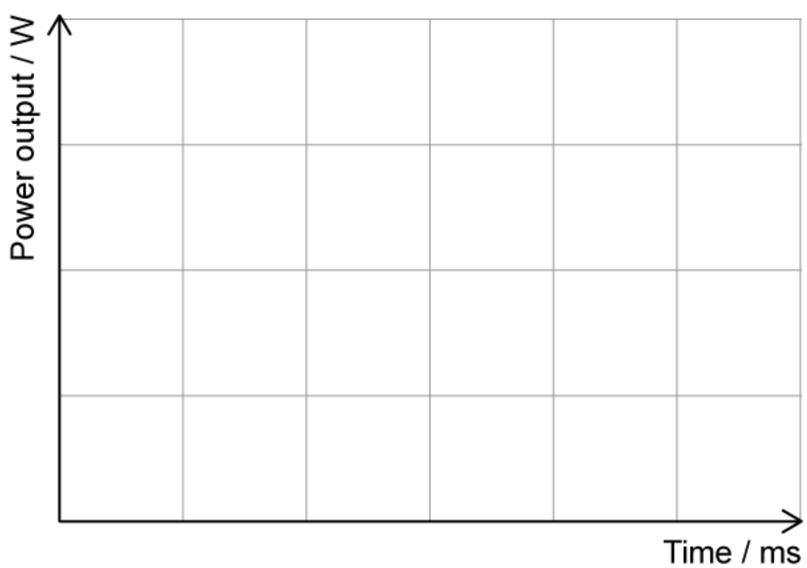
A generator in a hydroelectric plant features a coil rotating in a magnetic field with a constant angular velocity.



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

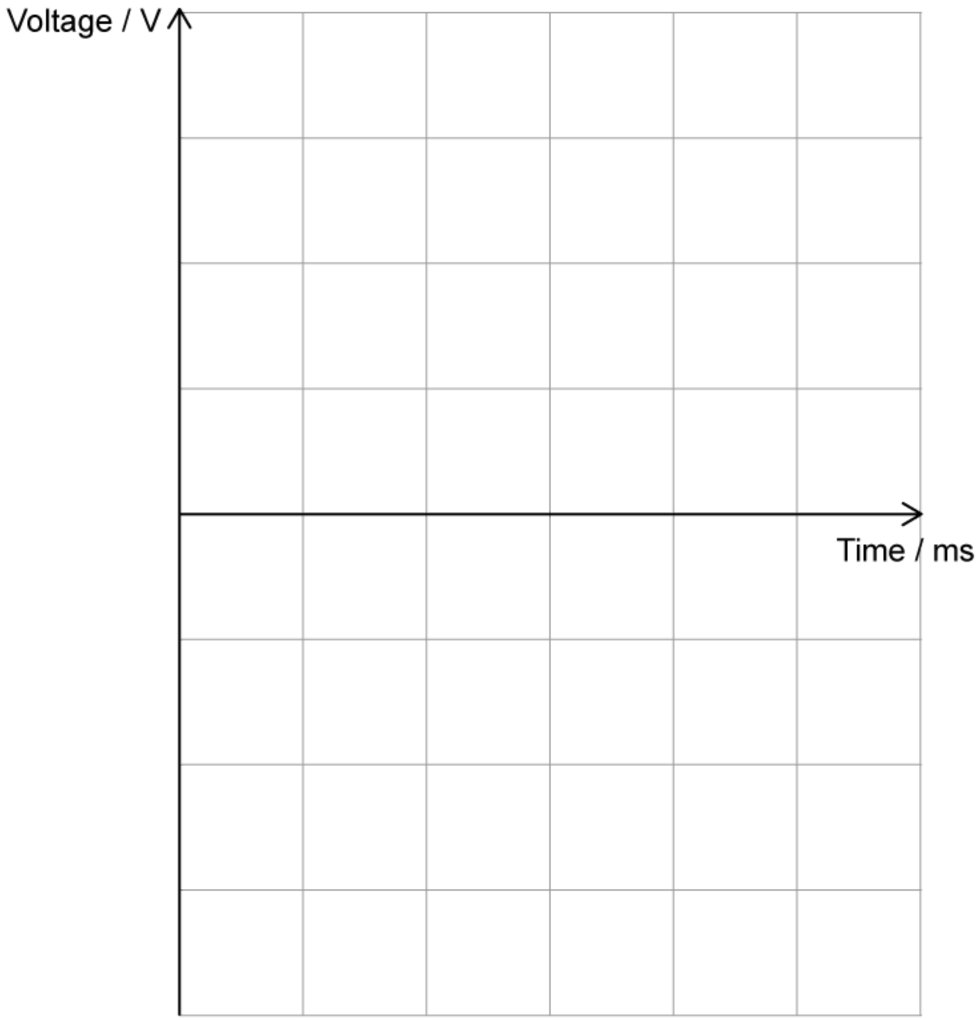
(a)

(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]

Question 1b

(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.

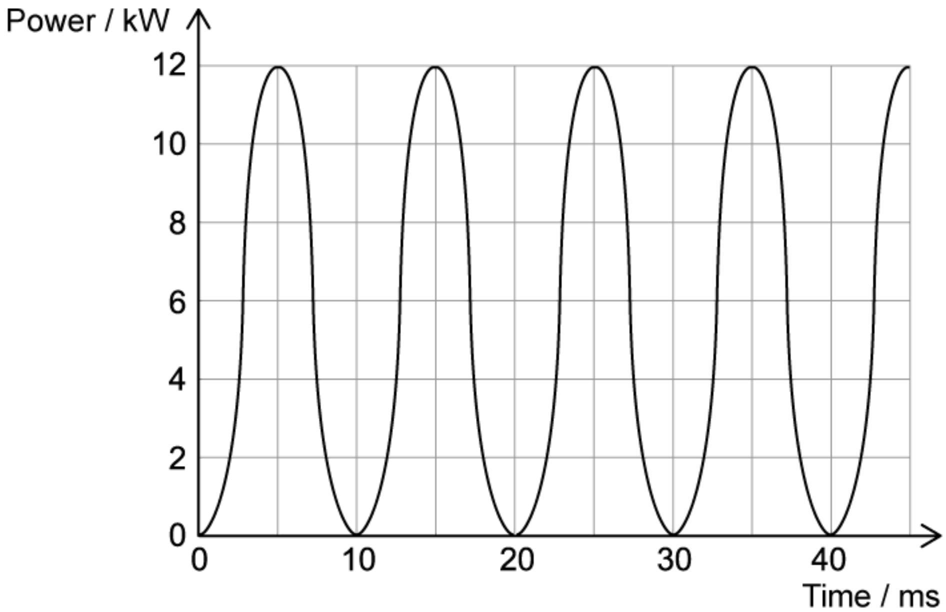
You may use the following equation $\frac{d\phi}{dt} = -\omega BA \sin \omega t$

[4]

[4 marks]

Question 1c

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.

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

[2]

[2 marks]

Question 2a

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.

(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]

Question 2b

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

(b)
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]

[3 marks]

Question 2c

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

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

[4]

[4 marks]

Question 3a

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.

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

[3]

[3 marks]

Question 3b

(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]

Question 3c

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.

(c)
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]

[4 marks]

Question 4a

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.

(a)
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]

[2 marks]

Question 4b

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

(b)

(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]

Question 4c

(c)

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

[3]

[4 marks]

Question 4d

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.

(d)
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]

Question 5a

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.

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

[4]

[4 marks]

Question 5b

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.

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

[3]

[3 marks]

Question 5c

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

(c)

(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]