OCR
GCSE Twenty First Century Science
Additional Science A
Unit 4: Ideas in Context (Higher Tier) – Physics

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The National Grid

The National Grid is the high-voltage electric power transmission grid in the UK. It ensures that electricity generated anywhere in the UK can be used anywhere else in the country.

Generators used in power stations produce electricity at about 23 kV. Transformers increase this voltage for transmission through the Grid. The National Grid delivers electricity to major substations. Transformers then reduce the voltage for the electricity supply to factories and homes.

History

This table shows the history of the National Grid.

End of 19th century	Nikola Tesla establishes the principles of alternating current high-voltage electrical power distribution while working for Westinghouse in the United States.
1901	Charles Merz opens the first major UK power station (the Neptune Bank power station near Newcastle upon Tyne).
1912	The integrated power system developed by Merz in the north east of England is the largest in Europe. It uses an alternating current system. The rest of the UK, however, continues to use a patchwork of small supply networks.
1925	The UK government asks William Douglas Weir, a Glasgow industrialist, to solve the problem of Britain's inefficient electricity supply industry. Weir consults Merz, and the result is the formation of the Central Electricity Board.
1933	The Central Electricity Board sets up the UK's first nationwide a.c. grid, running at 132 kV, 50 Hz.
1949	The Grid is upgraded when links at 275 kV are added.
1965	The Grid is further upgraded by adding some 400 kV links.

Facts from the 2005/6 National Grid Report

- Maximum demand: 63 Gigawatts
- Annual electrical energy used in the UK : 360 TWh (1.3 EJ)
- Capacity: 80 GW
- Number of large power stations: 181

Power Losses in the Grid

- Generator transformer heating losses: 0.157 GW
- In cables: 0.858 GW
- Substation transformer heating losses: 0.142 GW
- Other losses: 0.266 GW

Planning for the future

On average, approximately 11 GW produced in the north of the UK (particularly Scotland and northern England) is transferred through the National Grid to be used in the south of the UK. This is expected to grow to approximately 12 GW by 2014. It has been suggested that any new power stations should be built in the south.

MODULE P5: ELECTRIC CIRCUITS

P5.4 How is mains electricity produced?

Candidates will be assessed on their ability to:

1. recall that mains electricity is produced by generators;
2. recall that generators produce a voltage by a process called electromagnetic induction;
3. recall that when a magnet is moving into a coil of wire a voltage is induced across the ends of the coil;
4. recognise that if the ends of the coil are connected to make a closed circuit, a current will flow round the circuit;
5. recall that if the magnet is moving out of the coil, or the other pole of the magnet is moving into it, there is a voltage induced in the opposite direction;
6. explain that a changing magnetic field caused by changes in the current in one coil of wire can induce a voltage in a neighbouring coil;
7. describe the construction of a transformer as two coils of wire wound on an iron core;
8. recall that a transformer can change the size of an alternating voltage;
9. **be able to use the equation:**

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

10. describe how, in a generator, a magnet or electromagnet is rotated within a coil of wire to induce a voltage across the ends of the coil;
11. understand that the size of this induced voltage can be increased by:
    - increasing the speed of rotation of the magnet or electromagnet;
    - increasing the strength of its magnetic field;
    - increasing the number of turns on the coil;
    - placing an iron core inside the coil;
12. **describe how the induced voltage across the coil of a generator changes during each revolution of the magnet or electromagnet and explain that the current produced in an external circuit is an alternating current (a.c.);**
13. understand that the current from a battery is always in the same direction: it is a direct current (d.c.);
14. recall that mains electricity is an a.c. supply;
15. **explain that a.c. is used because it is easier to generate than d.c., and can be distributed more efficiently;**
16. recall that the mains supply voltage to our homes is 230 volts.

MODULE P5: ELECTRIC CIRCUITS

P5.5 How much electrical energy do we use at home?

1. explain that when electric charge flows through a component (or device), energy is transferred to the component;
2. recall that the power (in watt, W) is a measure of the rate at which an appliance or device transfers energy;
3. use the following equation to calculate energy transfer in joules and kilowatt-hours:

   - energy transferred = power x time
     (joule, J) (watt, W) (second, s)
     (kilowatt hour, kWh) (kilowatt, kW) (hour, h)

4. use the equation:

   - power = potential difference (voltage) × current
     (watt, W) (volt, V) (ampere, A)

ⓘ **Transformation of these equations is only required on the higher tier.**

5. know that a joule is a very small amount of energy, so a domestic electricity meter measures the energy transfer in kilowatt hours;
6. calculate the cost of electrical energy given the power, the time and the cost per kilowatt hour;
7. use the following equation in the context of different electrical appliances:

   - $\text{efficiency} = \frac{\text{energy usefully transferred}}{\text{total energy supplied}} \times 100\%$

Sample questions

1. Why is alternating current (a.c.) used for mains electricity?
2. What is the voltage which is supplied to homes in the UK?
3. What does 50 Hz mean?
4. If the voltage is increased in a transformer, what name is given to the transformer?
5. Why do we increase the voltage in transmission lines?
6. From 1970 to 1985, the maximum voltage in the grid went up. What is the advantage of a higher voltage?
7. Why are the cables on pylons rather than underground?
8. What are the advantages of having a national grid?
9. What does kV stand for?
10. For the electricity going into a transformer, what is the first and second coil called?
11. The generator in a power station produces electricity at 23 kV. An engineer is designing a transformer to increase this voltage to 400 kV for transmission in the national grid. If she uses 2500 coils in the primary coil of the transformer, how many coils should she use in the secondary? Show your working.
12. A step-down transformer is used to reduce the voltage of 400 kV to a lower voltage for local branches of the national grid. The transformer has 8500 coils on its primary coil, and 5800 coils on its secondary coil. What is the transmission voltage in the local branch?
13. Why is the voltage reduced for factories and homes?
14. Using information from the source, calculate what percentage of capacity the grid is using when electricity is used at maximum demand?
15. If 360 TWh is used in the UK each year, what is the average power in the supplied through the national grid?

$$\text{energy transferred} = \text{power} \times \text{time}$$

16. What percentage of the capacity is this?

17. What is the total power lost in the national grid?

18. What is the overall efficiency of power transmission?

$$\text{efficiency} = \frac{\text{energy usefully transferred}}{\text{total energy supplied}} \times 100\%$$