PUPIL
RESEARCHER
INITIATIVE

PHEPPS

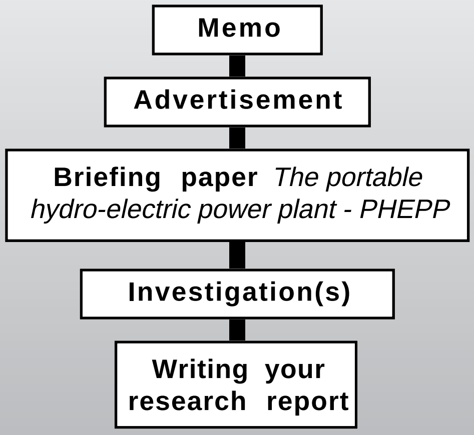
Pupil Research Brief

Teachers' Notes

Syllabus Coverage *Subject Knowledge and Understanding*

- ❑ electricity is generated by rotating a coil of wire in a magnetic field, or by rotating a magnet inside a coil of wire
- ❑ if a wire, or coil of wire, 'cuts through' a magnetic field, or vice-versa, a voltage (potential difference) is produced between the ends of the wire
- ❑ this induced voltage causes a current to flow if the wire is part of the complete circuit
- ❑ the size of the induced voltage increases when:
  - the speed of the movement increases
  - the strength of the magnetic field is increased
  - the number of turns of the coil is increased
  - the area of the coil is increased
- ❑ fossil fuels are non-renewable energy resources
- ❑ when non-renewable energy resources are used up they cannot be replaced
- ❑ renewable energy resources include sunlight, the wind, waves, running water and the tides
- ❑ renewable energy resources will not run out
- ❑ renewable energy resources can be used to produce electricity

Route through the Brief



Introduction

In this Brief pupils take on the role of researchers in a university engineering department. They are asked to conduct some research into the design of a Portable Hydro-electric Power Plant (PHEPP). This is based on real work carried out at Lancaster University. The pupils have to investigate the factors affecting the e.m.f. produced by a generator. They also look at the design of the blades for the turbine so that the most efficient design to turn the generator as fast as possible is achieved.

Experimental and investigative skills

- planning experimental procedures
- obtaining evidence
- analysing evidence and drawing conclusions
- evaluating evidence

Prior knowledge

Before attempting this Brief pupils should have some knowledge of electromagnetic induction and possibly have been shown a bicycle dynamo in action. Pupils should also be acquainted with the construction of a simple d.c. electric motor.

Teachers' Notes continued

Running the Brief

Pupil grouping

Pupils could work in a number of groupings during this Brief. Suggestions are :

Initial briefing	-	whole class; teacher-led introduction
Memo and advertisement	-	whole class; led by teacher
Paper: The portable hydro-electric power plant - PHEPP	-	pairs or small groups, depending how the investigation tasks are allocated by the teacher
Communication - writing research reports	-	individuals, if the report is assessment purposes. Whole class plenary session for feedback from teams, with each team contributing a different investigation task.

Pupils could work in small groups investigating all the aspects of the PHEPP design, or each group could investigate one variable (for example, number of turns on the coil) while keeping the others constant. If this approach is adopted, each group needs to share its findings with the whole class at a plenary session so that all pupils can write a full report of the research team's findings.

Timing

It is expected that this Brief could take approximately 3 hours of classroom time - longer if pupils attempt to build working models of a PHEPP.

Activities

The teacher should issue the pupils with the **Study Guide** which provides pupils with a summary of what they should produce as they work through the Brief. It can also act as a checklist so that pupils can monitor their own progress. The head of the PHEPP research team (the teacher) hands out copies of the **memo** and the **advertisement from "Research News"** to the researchers (the pupils). These outline the task of preparing a proposal to the Research Council for funding to develop a small scale electricity generator. The research team is to carry out a series of experiments to investigate the factors affecting the performance of a generator driven by a turbine. Background information is provided in the **internal briefing paper : The portable hydro-electric power plant - PHEPP**. Pupils should read through this, taking notes.

In section 3 (Outline research programme) of the internal briefing paper, one set of suggestions is concerned with investigating the variables in the design of the generator (the number of turns on the coil etc.) and the other set of suggestions names the variables that are to be investigated in the design of the water turbine (number of blades etc.). Pupils should be put into groups and allocated their tasks. Once the investigations are completed the results from each group should be reported to the whole class and collated by the teacher. Pupils should then write a report of these findings. The report should also include a section outlining the benefits and drawbacks of using a range of methods for generating electricity, such as burning fossil fuels, hydro-electric power, solar cells, wind turbines, geothermal energy, wave power and tidal power. Pupils will need to do some research for this section, interrogating whatever secondary sources of information are available to them.

Investigation details

The internal briefing paper suggests four possible investigations into ways of getting maximum voltage from the PHEPP generator, by looking at:

1 the number of turns on the coil
2 the strength of the magnetic field
3 the area of the coil
4 the turning speed of the PHEPP

and three investigations into getting maximum turning speed for the PHEPP, by varying such factors as:

5. blade numbers
6. blade sizes
7. blade shapes

Changing the number of turns on the coil (investigation 1) and changing the speed of rotation (investigation 4) are readily achieved. Altering the magnetic field strength (investigation 2) and altering the area of the coil (investigation 3) are more difficult to accomplish, especially if the motor kits mentioned in the **Technical details** are used. Pupils may tackle investigation 3 by making their own model generators and so make a number of coils with different cross-sectional areas.

Teachers' Notes continued

The relationship between induced e.m.f. and the different variables is :

$E = BAN\,\omega \sin \omega t$

E	induced e.m.f. at time t
B	magnetic flux density
A	area of the coil
N	number of turns on the coil
ω	angular velocity of the rotating coil

The investigations into the water turbines (investigations 5, 6 and 7) are more straightforward. The pupils need not use spheres to carry the blades, as in the real PHEPP design, but could use corks and make the incisions in them to carry the blades. The blades themselves could be made of plastic. Pupils will need to devise a means of measuring the speed of rotation of the blades, and make sure that the speed of water movement is the same for each test, so as to make the tests fair.

Using IT. Voltmeter sensors, light gates or light sensors can be used to measure the turning speed of a model generator. Voltmeter sensors can be used to measure the voltage produced with different generator designs. A spread sheet could be used to produce graphs from the data collected, and to model the 'scaling up' of the design, suggested on page PH.06.

Technical details

(i) The investigation to determine the effect of the number of turns of the coil can be done with Westminster kits, but since the potential differences induced are very small the experiments need very sensitive meters, such as microvoltmeters. Voltmeter sensors could also be used.

(ii) Changing the magnetic field strength can be achieved by using magnets of different strength, but note that simply binding 2 magnets together does not double the field strength. Pupils may be asked to devise a means of comparing the strengths of magnets. The higher achieving pupils could be introduced to the Hall Probe method of determining magnetic field strength.

(iii) Small electric motors can be used as generators for the scale models of the PHEPP.

(iv) One method of measuring the speed of the PHEPP would be to tie a measured length of thread round its axle and time how long it takes for the thread to wind round the axle. Other methods could involve datalogging using a voltmeter sensor, light gates or light sensors. These could be done as demonstrations or for individual/group project work.

Safety issues

PLEASE NOTE: It is also important that you prepare your own risk assessments for the practical work in this Brief in the usual way.

Model building

If pupils design and build a model generator or PHEPP, then a check will be required before use.

Assessment issues for *Experimental and Investigative Science* (National Curriculum for England and Wales, Northern Ireland Curriculum)

P	Planning	O	Obtaining evidence
A	Analysing evidence	E	Evaluating evidence

Investigations 1-4 involve pupils in devising investigation plans to measure the effect on output voltage of changing the relevant variable (see **Investigation details** above). All mark levels are possible in **Skill Area P**. Marks for Skill Areas **O, A and E** will depend on the approach taken to **Skill Area P.**

Investigations 5, 6 and 7 require pupils to investigate ways of getting maximum turning speed for the PHEPP by varying

- the number of blades
- the blade size
- the blade shapes

Construction difficulties are likely to restrict achievement for most pupils in **Skill Area P**, although some could achieve higher marks if their models show that they have taken into account a range of factors such as controlling water flow over the blades and ways of changing blade number, size or shape systematically. They should also devise a way of reliably measuring turning speed. Achievement in **Skill Areas O, A and E** is likely to be constrained by their approach in **Skill Area P**.

Scottish syllabus coverage

Standard Grade Physics - *Energy Matters*

Teachers' Notes continued

Further pupil research opportunities

Building a model PHEPP generator and evaluating and improving it in realistic conditions in the laboratory provides good opportunities for project work.

Note on large-scale HEPs

Large scale hydro-electric power stations are not as 'environmentally friendly' as often stated. They require large areas of land to be flooded in order to impound enough water to guarantee supply. The result is a loss of huge amounts of vegetation and so the carbon dioxide these plants would use is not removed from the atmosphere. This amount of carbon dioxide could, over the decades, be equivalent to that released by a fossil-fuelled power station.

The small-scale PHEPPs, however, do not have such disadvantages, since they are meant to be sited in existing fast-flowing rivers, and since they are portable they have no permanent impact on the environment.