__EUROPEAN SCHOOLS__

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PHYSICS PROGRAMME

4th and 5th years

Approved by the Board of Governors
on 23 and 24 april 1996 in London

I. INTRODUCTION

The physics course in years 4 and 5 is:

A development of some of the topics taught in integrated science during the first three years.

A final programme of physics study for a large group of pupils.

An intermediate programme for pupils who will study physics to Baccalaureate level in the 6th and 7th years.

Hence there is a spiral structure in the physics curriculum of the European Schools. Many topics are introduced in integrated science, put into a general physical context in the present syllabus, and studied in more detail during the last two years. The order in which the material is presented in the programme is one of the many possible orders in which the teacher may choose to cover the subject in class.

II. AIMS

A. *General*

a. To foster curiosity about physical phenomena and confidence in experimental methods of investigating them.

b. To promote in the citizens of the next generation an awareness of the many economic aspects of modern life about which physical reasoning can inform a sound objective evaluation, and to develop informed judgment about "scientific evidence" presented in advertising, for example.

c. To help develop the habit of formulating meaningful questions which separate the central from the trivial when considering observations and processes in the domain of the physical sciences.

d. To maintain awareness of the common ground shared by all the sciences, in terms both of methodology and of subject matter (for example energy).

e. Where time permits, to draw attention to the historical development of Physics.

f. To prepare for further study in science in general and particularly in Physics.

g. To widen the active and passive vocabulary and to develop linguistic competence within the subject domain.

h. To help make accessible to pupils the intellectual satisfaction which can come from an appreciation of the elegance, power and beauty of the scientific conception of the universe.

B. *Specific*

B.1 Methodological

a. To develop the habit of careful observation, in structured situations (experiments) but also in informal circumstances. The motivation to design experiments is often the result of an observation outside the laboratory which stimulates a more controlled examination of a given phenomenon.

b. To begin to develop the skill of experimental design, both in general terms (awareness of what apparatus is available and what it can do) and in terms of principle (enumeration of relevant variables, only varying one quantity at a time, etc.).

c. To encourage clear recording of all essential material resulting from an experiment.

d. To seek pattern in results by analytical examination and particularly by application of mathematical skills in search of deductions which are of general application. Particular attention should be paid to the use of tables and graphs in the presentation of results, and of the interpretation of linear graphs.

e. To grow the habit of communicating experimental results and general observations with precision and economy.

f. To learn the habit of looking for possible causal connections behind the observed phenomena and postulating sustainable reasons for what is observed; the formulation and testing of hypotheses. The ability to appreciate pattern in data depends on having a theoretical framework for interpreting observations, which cannot therefore take place without scientifically informed background.

g. To develop perseverance and concentration, together with the awareness that much knowledge may be gained from apparent anomalies in a general pattern.

B.2 Technical

a. To develop safe and well-organized working methods in the laboratory.

b. To deepen knowledge of and dexterity in the use of physical equipment.

c. To learn to set up apparatus according to a description or an illustration.

d. To acquire habits of recording results quickly and accurately in a structured fashion, and of repeating observations which give cause for doubt.

e. To learn to apply principles supported by experiment in order to analyse and solve theoretical or practical problems, or to understand the behaviour of things or situations which have not been the subject of experimental study.

f. To foster acquaintance with the notion of physical models, and to be aware of their advantages and of their limitations.

B.3 Knowledge and understanding

a. To develop a knowledge of physical quantities and their interrelation, in the following domains:

i) Force, pressure, work, energy, power and hydrostatics

ii) Time, distance, velocity and acceleration

iii) Charge, current, voltage, and resistance

iv) Electric, magnetic and gravitational action at a distance

v) Heat, temperature and the associated properties of matter

vi) Periodic phenomena and the idea of a wave

vii) Nuclear physics and radioactivity

b. To particularly note and appreciate the importance of conserved quantities (charge, energy) in drawing these apparently disparate phenomena together.

c. To understand the units in which quantities are measured, and their relationship one to another, whit particular emphasis on the official units of the System International and their symbols; and to have a realistic idea of the orders of magnitude occurring under normal circumstances.

III. ASSESSMENT

Time spent on assessment must be geared to total course time available (2 periods per week).

Assessment will consist of

a) Observation of pupils who are engaged in experimental work, and evaluation of its quality.

b) Marking of experimental reports and of problems tackled in class and outside.

c) Monitoring of the quality of pupils' oral contributions in class discussion.

d) Where the organization of the individual schools permits it, formal examinations possibly of two periods duration at suitable times.

e) In addition, in the 5 year, an examination, in accordance with the general rules of the European Schools and the appropriate decisions of the Board of Governors. This examination is harmonized across all language sections concerned, and set and approved by all the teachers concerned in teaching the course in a given year.

The written examinations should test the pupil's grasp of the fundamental quantities and relationships, and their ability to apply their knowledge to a situation which may be novel to them. The accent should be on the application of principles rather than the reproduction of learned processes.

Examinations should be set and marking schemes devised in such a fashion that the pupil of average ability in the subject who has worked well can achieve a satisfactory mark. The mark scheme should not give excessive weight to work which has been simply memorized.

However, in setting examinations, it will be necessary also in years 4 and 5 to keep in mind that everyone is obliged to take this subject. Examinations should therefore reflect the general nature of this population, and questions will need to be cast so that the bulk of the examination is of a fairly basic nature.

This is not to say that the course needs to avoid treating and discussing more interesting material, simply that the examination should not contain too many questions or sections of questions dedicated to the more refined and sophisticated applications.

A detailed suggestion for classifying and analysing questions and part questions is provided as an appendix.

Guidelines for the writing of examination questions.

1. Questions should have a good balance of elements; not too much which is cheap recall, and not too much which demands very original thinking. They should examine *principally the general understanding of physical principles*, and not memory or the ability to substitute into a formulae.

2. The balance described above should be such that a pupil of average ability in the subject, who has worked well, can *comfortably* get a mark of 6, and could get 7 or even 7.5 with sufficient application.

3. Notwithstanding the above, an attempt should be made to provide material in each question which is accessible to students of lower ability (cheap recall at the average level); but this should no account for more than 20% of the total marks. A similar stipulation should apply to harder material designed to enable good students to show what they can do.

4. Questions should not be so long as to intimidate the pupil with the task of reading them thoroughly and understanding the material.

Identifiable elements in examination questions.

These principles are adapted, and examples chosen, to reflect the special problems associated with the examining of physics, but their application is not limited to physics. Many of the ideas have a more general application. The text is based on original work by Eric Rogers.

1. ***Cheap recall***

The question requires the quoting of a fact or formula which has been learned, or a direct application of such a fact or formula.

Example: Give the formula for the sum of two resistances in parallel. Find the resistance of a parallel combination of an 8 - ohm resistance and a 12 - ohm resistance.

2. ***Simple recall***

The question requires the application of a learned element, but in a context which has not necessarily been encountered in class.

Example: *What statement can be made about the combined resistance of two series resistances? If one these resistances is 5 ohms and the other is variable, find the value of the second if the battery current is to be 0.33A, given that it its a 12v battery.*

3. ***Experimental recall***

The question requires candidates to display recall of an experiment which they have performed or seen performed.

Example: *Describe the method you would adopt to measure the specific heat capacity of a liquid using an electric heating element. Give a diagram of the apparatus and a brief description of the procedure. What precautions might you take to minimize errors?*

4. ***Explanation***

The question asks candidates to explain a situation in their own words.

Example: *A ten-ohm resistance is connected to a battery, and then, without disconnecting it, a five-ohm resistance is added in parallel with the first resistance. Explain without the use of mathematical formulae whether the combination of the two will have a resistance of less than 5 ohm, between 5 ohm and 10 ohm, or more than 10 ohm, giving clear reasons.*

Note: such questions sometimes admit a very large range of possible 'right' answers, and thus require care in marking to distinguish between good, fair and poor answers at the level at which the examination being set. In particular, it may sometimes be appropriate to award full marks for a good answer, even if that answer does not treat the subject exhaustively.

5. ***Expensive recall* - creative thought**

The question requires candidates to recall different things learned, perhaps from different areas of the subject, and to put them together so as to draw conclusions going beyond material which has been covered in class.

Example: *Two engineers are discussing whether overhead power lines would be better made from Aluminium or from Copper. What sort of things would affect their decision?*

PROGRAMME HEADING	*MATERIAL AND IDEAS TO BE COVERED* ***definitions, units, formulae and "Savoir-Faire"***	*AVENUES OF APPROACH*
Section M. Mechanics **M1 Force.** **1.1 Basic notions.**	<u>Part 1 :</u> *4th YEAR PROGRAMME* A **force** is identified by its effects: it can change the state of movement of things, or change their shape. Forces can be measured by observing the extension caused in a spring. Pupils should recognise some common forces and know about their behaviour: **Gravity force:** attracts all massive objects towards the earth with a force of 10 Newtons per kilogramme of mass approximately. Varies with geographical situation. **Contact force:** acts between two surfaces in contact, which repel each other because of their proximity. Direction normal to the common surface. **Friction force:** acts parallel to a common surface, so as to resist movement or attempts at movement. Qualitative study. ***FORCE*** Symbol: F Unit: Newton N Force of Gravity: $F_g = m.g$ At the Earth's surface: $g \approx 10$ N/kg Time: 6 periods (M1)	Other forces might include muscular forces and magnetic forces. Graphical methods and slopes may be conveniently introduced. The coefficient of friction can be studied by pupils who work fast, as might the idea of addition of non-parallel forces.

PROGRAMME HEADING	*MATERIAL AND IDEAS TO BE COVERED* ***definitions, units, formulae and "Savoir-Faire"***	*AVENUES OF APPROACH*
M2. Work, power and energy.	The physical meanings of these terms must be distinguished from their everyday meanings.	
2.1 Terminology.		
2.2 Work.	**Work** is done when a force moves its point of application (Examples should be limited to displacements parallel to the direction of the force, and should include work done in lifting and in sliding). No work is done when the displacement is perpendicular to the direction of the force. **Work.** Symbol: **W** Unit: Joule J=N.m Definition: **W** = $F.\Delta x$ *when* $F \parallel \Delta x$ Note: **W** = 0 *when* $F \perp \Delta x$	Lifting experiments might include work with pulleys and/or levers, and the inclined plane may be included, with or without (according to level) the notion of composition of forces.
2.3 Energy.	**Energy** is the capacity to do **work** **General note:** *The teaching of energy should pervade all teaching during years 4 and 5. Teachers may introduce the different forms of energy at different points in the programme, and some of them will be treated at more than one point. This programme accordingly lays down no strict order for introducing these different forms, provided that all the forms of energy described are dealt with before the end of the 5th year.*	

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2.4 Relation between work and energy.	When work is done, an equivalent amount of energy is converted from one form to another. This energy is therefore also measured in Joules. It can take many forme e.g. kinetic, chemical potential, gravitational potential, etc. The loss of any energy of one form is accompanied by an equal increase in other forms. This is the **principle of conservation of energy.** **Energy** Symbol: E Unit: **Joule J** Practical unit: **Kilowatt.hour kWh** (non-S.I.) $W = \Delta E$ Note: Gravitational potential energy $E_p = m.g.h$	A good group might consider also the elastic potential energy stored in a stretched spring or elastic cord, introducing another graphical solution and the idea of the average of a linearly varying force.
2.5 Power.	**Power** may be presented as the energy transferred each second. The concept of power leads to the introduction of the **kWh** as a practical unit of energy. **Power** Symbol: P Unit: Watt W=J/s. Definition: $P = \Delta E/\Delta t = W/\Delta t$	Possible experiments include stair-climbing and the bicycle ergometer. Sports applications (high jump, shotput) may be considered, also e.g. power output of a climbing aircraft or a weight driven clock.

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2.6 Efficiency.	In a perfectly efficient operation, the useful energy produced would be equal to the total energy expended. In practice, a certain proportion of the energy expended is wasted. The proportion of energy usefully converted is called the **efficiency**. **Efficiency** Symbol: η Definition: $\Delta E_{\text{usefully produced}} = \eta \cdot \Delta E_{\text{expended}}$ ($\eta \leq 1$) Time: 8 periods (M2)	Human muscle efficiency (of the order of 25%) may be considered.
M3 Pressure. **3.1 Basic notion.**	A force whose effect is distributed over and normal to a surface defines a **pressure. Introduced as Newtons of force on each unit of area.**	Hydraulic ram.
3.2 Hydrostatic pressure.	Because of the force of gravity acting on them, liquids and gases exert a pressure whose magnitude depends (as well as on the intensity of the gravitational force) directly on the depth and on the density of the fluid. This force acts equally in all directions. The difference of pressure on the upper and lower surfaces of a body gives rise to an **upthrust.**	Hydraulic brakes: Archimedes upthrust and flotation. Atmospheric pressure; the'ocean of air'.

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	Pressure Symbol: P Unit/:**Pascal Pa** Definition: $P=F/A$ Time: 6 periods (M3)	
Section K: The study of movement. **K1. Uniform movement.**	When a object moves with **constant velocity,** it covers equal distances in a straight line in equal times. The magnitude of the velocity is introduced as the distance travelled each second. The graph of distance against time is a straight line.	Air track and rail experiments; ticker-timer experiments.
K2. Non-uniform movement.	The study of non-uniform movement requires the introduction of **average velocity** (introduced as total distance divided by total time), as contrasted with **instantaneous velocity** (introduced at this level as the quasi-constant velocity over a very short time interval).	Concrete examples, e.g. composite journeys.

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K3. Accelerated movement.	**Velocity** Symbol: ***v*** Unit: **m/s** Definition: $v = \Delta x / \Delta t$ If velocity changes uniformly with time, the **acceleration** is said to be **constant** or **uniform,** and is introduced as the velocity change every second. In this case, the value of the average velocity is given by the **mean** of the initial and final velocities. The v/t graph is a straight line. The acceleration of free fall is approximately uniform, of value 10 $m.s^{-2}$ on earth. **Acceleration** Symbol: ***a*** Unit/: m/s^2 Definition: $a = \Delta v / \Delta t$ **Average Speed** Symbol: $\langle v \rangle$ Definition: $\langle v \rangle$ = **Total distance /Total time** **For uniformly accelerated movement:** $\langle v \rangle = \frac{1}{2}(v_{initial} + v_{final})$ ***$g \approx 10\ m/s^2$ at the surface of the Earth.***	Experimental measurement of free fall acceleration for different masses. Qualitative effect of air friction. Graphical methods based on the v/t graph. A fast group might examine the x/t graph also. Real-world links include effects of deceleration and reaction time on braking.

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	Time: 11 periods (K)	
Section E: Electricity. **E1. Electrostatics.** **1.1 Electric charge.**	**Charges** are of two kinds called ***positive*** and ***negative***. These charges exert forces on each other. Charges of the same kind repel one another; those of different kinds attract one another.	Experiments on charging by rubbing. Static discharge on getting out of a car. The Faraday cage. The gold leaf (or other) electroscope.
1.2 Model of the atom.	The **atom** consists of positively and negatively charged particles, normally in equal numbers. It is possible to remove some negatively charged particles (**electrons**) from the atom; the result of this is that the body from which they are removed is left **positively charged,** and the body which received them becomes **negatively charged.**	
1.3 Measurement and conservation of electric charge.	The charge a body possesses may be measured by the **number of excess electrons**, but each of these has a very small charge; the practical unit of charge is that of a large (but specific) number of electrons. Charge cannot be created or destroyed. The charge of the electron is known as the **elementary charge**	Using different cloths (and paper etc.) to charge the same plastic material. The golf-leaf electroscope and the charge-meter (d.c. amplifier).
1.4 Separation of charge.	The influence of a charged body can cause the **separation of charges** in an otherwise uncharged conductor.	

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	Charge Symbol: Q Unit: Coulomb **C**	
E2. Electrodynamics **2.1 Current.**	Electrons can move through certain materials (which are called ***conductors***), notably metals, but not through others (which are called ***insulators***). This movement constitutes an electric **current**, introduced as the **amount of charge passing through a conductor each second**. Electric charge can carry and deliver energy.	Mechanical models.
	Current Symbol: I Unit: **Ampère A** Definition: $I = \Delta Q / \Delta t$	
2.2 Voltage	**Voltage** is introduced as the **energy delivered by each Coulomb** to a device (e.g. to a bulb or motor).	Complete experimental treatment leading to the rules of behaviour of voltage and current in circuits, based on a suitable model.

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	Voltage Symbol: U Unit: **Volt V= J/C = W/A** Definition: $U = \Delta E/\Delta Q$ **Electrical Power** $P = U.I$	Links with the mechanical power and energy. Power in fluorescent and incandescent bulbs.
2.3 Electric circuits.	**Conservation of charge** implies that the current in a series circuit has the same value at all points, while in a parallel circuit the total current is the sum of the currents in the different branches. Current is measured with an ammeter connected in series with the circuit. The total voltage across a series circuit is the sum of the individual voltages, and the voltage across parallel circuit is the same as the individual voltages across its elements. Voltage is measured with a voltmeter, connected in parallel with a circuit element. **Series Circuit:** $I_1=I_2=I_3=...$ $U=U_1+U_2+U_3+...$ **Parallel Circuit:** $I=I_1+I_2+I_3+...$ $U_1=U_2=U_3=...$	Traffic or river flow rate. Practical work with simple circuits. Water analogue. Displacement of ions during electrolysis. The immersion heather, the electric motor lifting loads. (Link with efficiency, M 2.5, and with gravity force).

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	Time: 10 periods (E)	
Section N: Nuclear Physics. **N1. Origin of radiation.**	The **nucleus** of the atom is a compact entity consisting of **protons** and **neutrons**. The nuclei of some atoms can spontaneously change their constitution, and in doing so emit so-called **radiation.**	Demonstrations with the Geiger-Müller tube. Background: cosmic rays
N2. Basic notions.	Examination of this radiation's penetrating power suggest that three different types of radiation exist. These are known as α, β et γ rays, in increasing order of penetrating power. These rays are capable of disrupting the cells of the body and hence of causing illness.	Experiments on penetrating power.
N3. Activity; half-life.	An atom which has changed its constitution as described above is said to have **decayed.** The **activity** of a sample may be introduced as the number of decays occurring each second. In a given time, characteristic of the element concerned, half of the atoms (on average) will decay, no matter how many atoms there were to start with. This time is the **half-life.** **Activity** Symbol: A Unit: Becquerel Bq = s^{-1}	Ionization chamber: the A/t curve.

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N4. Stimulated decay.	Some nuclei which do not naturally decay may be induced to do so. One important way to bring this about is by bombardment with neutrons.	
N5. Chain reaction.	Such bombardment may lead to the nucleus splitting, with the emission of more neutrons. This can result in a **chain reaction**, in the course of which large quantities of energy are released. Time: 5 periods (N) **Total time estimate, year 4: 6+8+6+11+10+5 periods = 46 periods**	An examination of the benefits, drawbacks and risks of various forms of energy production.

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Section M. Mechanics.	Part 2 : *5th YEAR PROGRAMME*	
M4. Dynamics. **4.1 Equilibrium.**	**Equilibrium** exists in the absence of force. Two equal and opposite forces annul mutually, and also therefore result in equilibrium.	
4.2 Movement of a body in equilibrium.	A body in equilibrium moves with a constant speed in a straight line. $\Sigma F = 0 <=> v = constant$ $\Sigma F = m.a$ *Unit relationship:* $N = kg.m/s^2$	Airtrack and rail experiments.
4.3 Movement of a body under a steady force.	A body moving under the influence of a steady resultant force moves with **constant acceleration**, whose magnitude is directly proportional to the force and inversely proportional to the mass. The **Newton** is defined by this relationship. **Mass** is to be distinguished from **weight**: the latter is a variable force, and is normally identical with the gravitational force, whereas the former is a property of the body describing the difficulty in accelerating it.	Crumple zones and seat belts in cars, action of crash helmets. Experimental work with pulse timers and electronic or video timing methods.
4.4 Free fall under gravity.	The **acceleration due to gravity** is approximately 10 $m.s^{-2}$ on earth. Relationship with M 1.1.	

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4.5 Mutual nature of force.	No force exists alone; there exists only **mutual force between two bodies**. If A exerts a force on B, then B necessarily exerts an equal opposite force on A.	
4.6 Kinetic Energy.	The work done by the force accelerating a body in the absence of friction is converted into the body's **kinetic energy**. **Kinetic Energy** $E_k = {}^1/_2\, m.v^2$ Time: 12 periods (M4)	
Section E. Electricity. **E3. Resistance.** **3.1 Basic notions.**	Different materials offer different **resistances** to the passage of electric current. High resistances tend to reduce current, or to require a large expenditure of energy for the passage of charge (engendering high voltages). **Resistance** Symbol: R Unit: Ohm Ω Definition: $R = U/I$	Experiments with different wires, lengths, diameters... Conduction by a red-hot glass rod. Link with kinetic theory.

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3.2 Ohmic resistors.	The resistance of **conductor** at constant temperature has a constant value.	Domestic installations; earthing, safety, overheating of coiled cables. Power transmission, and the use of transformers to improve efficiency.
3.3 Resistance in circuits.	The combined resistance of series resistances is equal to their sum, whereas in a parallel circuit, adding more resistance elements reduces the effective resistance. **Series Circuit:** $R = R_1+R_2+R_3+\ldots$ **Parallel Circuit:** $1/R = 1/R_1+1/R_2+1/R_3+\ldots$	
3.4 Factors determining resistance.	The resistance of a conductor depends on its **length,** its **cross-sectional area** and the **resistivity** of the material of which it is made. **Resistivity** Symbol: ρ Unit: Ω.m, Ω.mm2/m Definition: $R = \rho . l/A$	Resistive putty.

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3.5 Non-ohmic resistance	Some circuit elements, e.g. the light dependent resistor, the diode, the thermistor, have resistances which are **not constant** for given physical dimensions, but which vary with other physical conditions (light intensity, current, temperature). A qualitative study only is required.	The transistor, logic gate or op-amp as a switch may be introduced. The rectifier.
3.6 Circuit applications of non-ohmic components.	The components mentioned above may be used for rectification, on for producing a voltage varying with physical conditions which can be used for switching purposes. Some applications should be examined, for example, frost warning, automatic switching of lights etc.	
	Time: 12 periods (E3)	
E4. Magnetism and electromagnetism. **4.1 Permanent magnets.**	Objects which attract certain materials placed in their vicinity (e.g. Iron, Cobalt, Nickel...) are called **magnets**. There exists a **magnetic field** in the region in which the attraction is effective. Those parts of a magnet exerting the strongest attraction are called the **poles** of the magnet; they always appear in pairs, and experiment shows them to be of two kinds. Two similar poles repel one another, and two dissimilar poles attract one another. Hence a magnet suspended in the field of another will adopt a preferential orientation. Such behaviour is also observed in a magnet suspended above the earth, which may therefore be considered to be surrounded by a magnetic field: one pole (the *north-seeking* pole) will point roughly northwards, and the magnet may thus be used as a compass.	Revision of Integrated Science work. Identification of ferromagnetic materials. Broken magnets. Demagnetization by heating. Model with a test-tube full of Iron filings.

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4.2 Magnetic field of a current.	A straight current-carrying wire and a coil both produce magnetic fields. A practical rule should be taught to determine the directions of these fields. The field of a coil is increased in strength by the presence of a ferrous core.	Oersted's experiment. Deflection of a beam of charged particles. Current balance.
4.3 Electromagnetic force.	A current-carrying conductor placed in a magnetic field may experience a force. This make it possible to construct electric **motors.**	
4.4 Electromagnetic induction.	A conductor moved in a magnetic field may experience a force. This makes it possible to construct **dynamos.** Time: 6 periods (E4)	
Section H. Heat and energy. **H1. Heat.**	**Heat** is form of energy (and therefore measured in joules), which is associated with the kinetic energy of the molecules of a body. **Temperature** is measured in degrees with a thermometer, and is also associated with molecular movement. Energy moves spontaneously (as heat) from regions of high to regions of low temperature. Temperature *changes* are measured in **Kelvins** (1K = 1°C).	Warming experiments with water heated by electrical and by mechanical means. Solar panel, Trombé walls. Energy efficiency and environmental protection; advantages and disadvantages of the use of fossil fuels.

PROGRAMME HEADING	*MATERIAL AND IDEAS TO BE COVERED* ***definitions, units, formulae and "Savoir-Faire"***	*AVENUES OF APPROACH*
	Heat Energy Symbol: Q Unit: Joule J **Temperature** Symbol: T,θ Unit: Degrees Celsius °C Kelvins K *Note: The two units are the same when measuring temperature differences.*	
H2. Specific heat capacity.	The **temperature change** of a body is proportional to the energy supplied to it. The **specific heat capacity** of a substance may be introduced as the energy required to increase the temperature of 1Kg of a given substance by 1K.	
H3. Latent heat.	Change of state (melting, evaporating) requires input of energy which does not produce a change of temperature. This energy is called **latent heat**. The **specific latent heat** may be introduced as the energy required to change the state of 1Kg of substance.	

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	Specific Heat Capacity Symbol: c Unit: J/kg.K Definition: $Q = m.c^o\Delta\theta$ **Specific Latent Heat** Symbol: L Unit: J/kg Definition: $Q = m.L$	
H4. Molecular theory.	The calorific phenomena described above may be explained with the aid of a **molecular model.** Time: 8 periods (H)	
Resumé of energy.	The pupil should by now have met the following forms of energy, and should be able to discuss energy conversions involving them. In cases of energy forms marked with an asterisk (*), quantitative work should be possible: Gravitation potential energy*, chemical potential energy, heat energy*, kinetic energy*, electrical energy*, nuclear energy. Various examples of energy changes should be examined.	

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Section V. Vibrations and waves.		
V1. Basic notions.	Movements are frequently observed which are **periodic** in character. Such movements are called **oscillations** or **vibrations**. The **period** is the time to complete one cycle of movement, the **frequency** is the number of cycles or vibrations per second, and the **amplitude** is the maximum displacement from the equilibrium of position.	Hereabeats, rhythms of diurnal and annual movement of earth and other heavenly bodies, movement of strings in musical instruments, rotation of a turntable.
V2. Resonance.	It is possible (and common) for one oscillator's to provoke a response in another oscillator which is **linked** to it in some way. This response can be very large if the natural frequencies of the two oscillators are the same, and this phenomenon is known as **resonance.** Examples might include pushing a child on a swing, vibration of bus windows, etc. No formal or quantitative study should be undertaken.	Pushing child on a swing, linked pendula etc.
V3. Waves.		
3.1 Basic notions.	A periodic disturbance may **propagate** in an elastic medium, giving rise to a **wave** whose form repeats itself at regular time intervals and regular distance intervals. The **wavelength** λ is the distance between two corresponding points on a wave. The wave **velocity** may also be defined. For sound, this is about 340 m/s.	"Echelle du Perroquet", ripple tank demonstrations. Measurement of the speed of sound.

PROGRAMME HEADING	*MATERIAL AND IDEAS TO BE COVERED* ***definitions, units, formulae and "Savoir-Faire"***	*AVENUES OF APPROACH*
	Frequency Symbol: f Unit: Hertz Hz = s^{-1} Definition: $f = 1/T$ *where* T = *period* **Wavelength** Symbol: λ Unit: m **Velocity of propagation** Symbol: v, c Unit: m/s $v = f \cdot \lambda$	
3.2 Diffraction.	Waves can pass around an obstacle or spread out after passing through a gap; this behaviour is called **diffraction**, and its extent depends on the wavelength and on the size of the gap or obstacle. This has practical consequences for radio reception. Time: 9 periods (V) **Total time estimate, year 5: 12+12+6+8+9 = 47 periods.**	Demonstrations in the ripple tank and with microwaves.