UNIT 10 Practical Electricity

Recommended Prior Knowledge

Pupils tackling this unit ought to be acquainted with the concept of energy from unit 5, the basic ideas of current electricity in unit 4, electromagnetism in unit 7. This unit ought to be taught near the end of the course. Pupils are quite likely to have been aware of the installation of mains electricity or the rewiring of a house but may not be very familiar with the physics which lies behind much of what they have seen. Similarly, the use of the C.R.O. in medical establishments will be familiar but they are unlikely to know how it works.

Context

This unit applies the rather theoretical aspects of electricity, which have already been dealt with, to more practical circumstances which pupils will be quite familiar with. The supply of electricity to homes, offices and industry is a major convenience of the modern world and the electricity supply industry is important in every country in the world. The use and operation of the C.R.O. leads on to some electronic devices and circuits. These are the very foundation of both the electronics industry and the information revolution for which the use of computers and modern communications have been essential.

Outline

The unit begins with some of the uses of electrical energy on a domestic scale. The formula for power can be used to calculate the rating for the fuse which a particular appliance requires; circuit breakers are dealt with here. The mechanics of charging for electricity is explained and so is the wiring of plugs and the dangers posed by selected electrical hazards. The cathode-ray oscilloscope is described in some detail. Potential dividers, capacitors and reed relays are explained and then used in certain electronic circuits. The last section describes logic gates, transistors, bistable circuits and astable circuits, which are an optional part of the course and may only be of interest to some teachers or students.

	Learning Outcomes	**Suggested Teaching Activities**	**Online Resources**	**Other resources**
21(a)	Describe the use of electricity in heating, lighting and motors.	Emphasise that the overwhelming majority of electrical energy is used in this way. Consider industrial and domestic uses: kettles, furnaces, cookers, street lights, table lights, theatre lights, illuminated signs, lighting in greenhouses and zoos, drills, lifts, food-mixers, saw-mills. Consider less obvious and mixed examples: refrigerators, washing machines and so on. Pupils can make their own list and report to the class on the Physics principles by looking around their home or neighbourhood.	Uses of electricity: http://www.teachnet.ie/pcoakley/consumers.htm	Can these operate on an a.c. supply? Are there other uses of electricity – charging batteries, operating electronics? Can these use an a.c. supply?
21(b)	Do calculations using the equation *power = voltage x current*, and *energy = voltage x current x time.*	Consider: *energy = voltage x charge* (unit 4) and divide both sides by *time.* The definition: *V = P/I* is just as satisfactory as the more traditional: *V = E/Q* and the volt may be taken as the watt/ampere.	Electrical power: http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/mainselectricityrev5.shtml	

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		In some ways these definitions are superior as pupils are more likely to be familiar with current than with charge. Since *E* = *Pt* so *E* = *Vit.*		
21(e)	Explain the use of fuses and circuit breakers and fuse ratings and circuit breaker settings.	Produce in class some domestic devices: kettle, drills, radios. Read the power from the label and calculate the current drawn. What fuse rating is required? Consider car headlamps (12 V) and rechargeable appliances. Buy a reel of low rating fuse wire (~2A) and allow pupils to see it blow or measure how the fusing current depends on the length of fuse wire.	Fuses and circuit breakers: http://hyperphysics.phy-astr.gsu.edu/hbase/electric/bregnd.html#c1	Consider R.C.C.B.s (residual current circuit breakers).
21(c)	Calculate the cost of using electrical appliances where the energy unit is the kWh.	Pupils realise that the cost of electricity is likely to depend on the power of the device and the time for which it is used. Hence it depends on *P x t*. Electricity suppliers tend to use the kWh but emphasise that this is a special non-SI unit which equals 3.6 MJ. Show pupils an electricity meter and read it. Explain that it keeps a running tally of the energy used. Allow pupils to heat up water electrically, measuring power and time, and then calculate the cost of heating up a cup of coffee or tea or a swimming-pool.	Electricity bills: http://www.gcse.com/energy/kWh5.htm	Show pupils an actual and recent bill and explain how the final cost is calculated. Are there any standing charges? Is there any cheap rate electricity at night? Are there taxes?
21(g)	State the meaning of the terms live, neutral and earth.	Explain that the earth wire is a safety feature; the device can function without it although it is not safe to let it do so. It is the live and neutral wires which constitute the circuit.	Mains wiring: http://www.student.cardonald.ac.uk/materials/physics/Physics/Domestic%20electricity%20and%20wiring%20a%20plug/frameset.html	The live wire is the one whose voltage varies and this is responsible for the flow of current. The neutral wire (~0 V) completes the circuit. This is why it is the live connection must be broken to make a device safe.

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21(f)	Explain the need for earthing metal cases and for double insulation.	Emphasise that earthing operates in conjunction with the fuse; a live metal case connected to earth is **not** safe until the large earth current drawn through the live blows the fuse. Appliances with double plastic cases have nothing to earth and do not need to be earthed. Show them the double square symbol on such a device. Some devices have a plastic "earth" pin. This operates the safety shield on the socket.	Earthing: http://www.bbc.co.uk/schools/gcsebitesize/physics/electricity/mainselectricityrev2.shtml Double insulation: http://cipco.apogee.net/foe/fsg2di.asp	
21(i)	Explain why switches, fuses and circuit breakers are wired into the live conductor.			
21(h)	Describe how to wire a mains plug.	Allow the pupils to wire plugs (**keep a special set for the pupils with a screw drilled into the earth pin. This prevents a pupil who has wired the plug incorrectly from inserting it into a socket**).		.
21(d)	State the hazards of damaged insulation, overheating of cables and damp conditions.	Draw attention to the dangers of frayed wires and cut insulation. Explain that domestic water is quite a good conductor. Do not trail leads under carpets.	Electrical safety: http://siri.uvm.edu/ppt/topics/electhazardspotting.htm	
24(a)	State that electrons are emitted by a hot metal filament.	State this as a fact. It can be shown by thermionic diodes connected to sensitive galvanometers – if available. Or in the fine beam tube the low pressure hydrogen indicates the path taken by the emitted electrons.	Thermionic emission: http://www.matter.org.uk/tem/electron_gun/electron_gun_simulation.htm Thermionic diodes: http://www.nationmaster.com/encyclopedia/Thermionic-valve	
24(b)	Explain that to cause a continuous flow of emitted electrons requires (1) high			

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	positive potential and (2) very low gas pressure.			
24(c)1	Describe the deflection of an electron beam by electric fields.	The path of an electron beam in an electric field can be shown by appropriate thermionic tubes if available but emphasise that the path of the electrons will not be circular in a uniform electric field. The positive plate attracts the negative electrons into a (parabolic) path.	Electric field deflection: http://physics.bu.edu/~duffy/PY106/Electricfield.html	
24(c)2	Describe the deflection of an electron beam by magnetic fields.	The magnetic deflection is in accordance with Fleming's left-hand rule, bearing in mind that electrons are negatively charged. Emphasise that a uniform magnetic field can deflect an electron beam into a circular path whereas a uniform electric field cannot.	Magnetic field deflection: http://www.regentsprep.org/Regents/physics/phys03/cdeflecte/default.htm	
24(d)	State that the flow of electrons (electron current) is from negative to positive and is in the opposite direction to conventional current.	Electrons carry negative charge in the direction of travel which is equivalent to taking positive charge in the opposite direction.	Negative electrons: http://www.kpsec.freeuk.com/electron.htm	Compare receiving electrons with receiving a bill; a bill is negative money and receiving one is a financial loss.
24(e)	Describe in outline the basic structure and action of a cathode-ray oscilloscope (detailed circuits are not required).	Show the pupils a dismantled, old C.R.O. if available. Emphasise that two pairs of parallel, charged plates deflect the electron beam. Emphasise that the left to right motion is controlled by an internal circuit whilst the up and down motion of the beam is controlled by the externally applied voltage.	C.R.O: http://www.broadeducation.com/htmlDemos/AbsorbElect/UseOscilloscope/page.htm	The speed of sound in a short, metal rod or even air can be obtained by using a C.R.O. to measure the small time interval.
24(f)	Describe the use of a cathode-ray oscilloscope to display waveforms and to measure p.d.'s and short intervals of time (detailed circuits are not required).	Use a C.R.O. to display different waveforms from a signal generator. A medical C.R.O. must have a voltage input. There must be an electrical transducer in a heart monitor. Explain how time intervals can be obtained from distances	C.R.O. settings: http://www.kpsec.freeuk.com/cro.htm	

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		measured across the screen and the timebase setting. Pupils will need to practice with specific values.		
24(g)	Explain how the values of resistors are chosen according to a colour code and why widely different values are needed in different types of circuit.	This just has to be explained but point out that the colours are almost but not quite the traditional seven colours of the rainbow which pupils are likely to know. Make a set of resistors on cards and allow pupils to read their values.	Resistor colour code: http://www.uoguelph.ca/~antoon/gadgets/resistors/resistor.htm	Doubling the length and the cross-sectional area of a resistor keeps its resistance constant but both the mass to be heated and its surface area will be four times larger. It stays cooler.
24(h)	Discuss the need to choose components with suitable power ratings.	Give examples of using different values for different purposes but remember that the resistance and e.m.f. determines the current. This, in turn, determines the power generated within the resistor.		
24(i)	Describe the action of thermistors and light-dependent resistors and explain their use as input sensors.	State these behaviours as a fact but emphasise that both the heat in (n.t.c.) thermistors and the light in L.D.R.s is used to free electrons from the structure which in turn reduces the resistance. It helps pupils to remember how the resistance changes. P.t.c. thermistors behave differently.	Thermistors: http://www.antonine-education.co.uk/Physics_AS/Module_3/Topic_2/topic_2.htm L.D.R.s: http://www.antonine-education.co.uk/Electronics_AS/Electronics_Module_1/Topic_5/topic_5__resistive_input_transdu.htm	Try to avoid using a variable resistor on its own as a potential divider until the idea is properly understood. When it is used the resistance of one end increases whilst that of the other end becomes smaller. This is confusing at first.
24(j)	Describe the action of a variable potential divider (potentiometer).	Set up a circuit and show that the total p.d. across two unequal resistors is unequally divided (the mouse ends up with the mouse's share; the lion takes the lion's share). Use a variable resistor as one of the resistors and adjust it. What happens to the voltage of the middle point?		

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		Use a switch, a thermistor and an L.D.R. instead of the variable resistor.		
24(k)	Describe the action of a capacitor as a charge store and explain its use in time delay circuits.	Demonstrate it. Charge up a capacitor in one circuit and then discharge it through a coulombmeter in another circuit. It emphasises the point if the two circuits are physically separate and the capacitor has to be physically moved across the room. Then use a single circuit with a single-pole double-throw switch. If a coulombmeter is unavailable use an L.E.D. and a large capacitor; try to get a small flash. Put a capacitor (~1 μF) in series with a resistor (~5 MΩ) and connect to a d.c. supply (~6 V). Measure the p.d. across the capacitor with a high resistance voltmeter or C.R.O. and see how quickly the voltage reaches a given value (say 4 V). Repeat with a 10 MΩ resistor. Compare the times.	Capacitors: http://www.antonine-education.co.uk/Electronics_AS/Electronics_Module_1/Topic_9/physics_of_capacitors.htm Time delay circuits: http://www.bbc.co.uk/schools/gcsebitesize/design/systemscontrol/pneumaticsrev5.shtml	
24(l)	Describe the action of a reed switch and reed relay.	Use a reed switch to switch on a circuit. Operate the reed switch with a bar magnet. Operate it with a, clearly separate, solenoid. See how close the solenoid has to be to the reed switch before the current in the solenoid will operate the reed switch.	Reed switch: http://www.eleinmec.com/article.asp?23	
24(m)	Explain the use of reed relays in switching circuits.	Emphasise that a reed relay is a reed switch with its own built-in solenoid. Show one being used. Use a d.c. circuit containing the solenoid to operate a low voltage a.c. motor. Emphasise the presence of two distinct circuits which are only linked magnetically.		
24(n)	Describe and explain circuits operating as light-sensitive	Use circuits with switches, thermistors or L.D.R.s in series with the solenoid of the reed relay		A reed switch could be used to switch on a light

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	switches and temperature operated alarms (using reed relays or other circuits).			when a door is opened or closed. The magnet is fixed to the door.
24(o)	State the meaning of the terms processor, output device and feedback.	These terms are best explained in the contexts in which they are used in the course. The circuits which process voltages (information) are processors and the output devices are those parts of the circuit where the final answer appears. Both the bistable circuit and the astable circuit function because the output from one device becomes the input of another; the output is fed back into the input.		
25(a)	Describe the action of a bipolar npn transistor as an electrically operated switch and explain its use in switching circuits.	Set up a transistor switching circuit, e.g. use an L.D.R./resistor potential divider to control the base current and use the collector current to power a lamp. Emphasise that the transistor is being used as a switch in one circuit powered by the current in the other.	Transistor switching circuits: http://hyperphysics.phy-astr.gsu.edu/hbase/electronic/transwitch.html	
25(b)	State in words and in truth table form, the action of the following logic gates, AND, OR, NAND, NOR, and NOT (inverter).	Model AND and OR gate behaviour using switches in series or parallel in one circuit to operate a reed relay in a second circuit (which includes a lamp). Emphasise that the second circuit has its own power supply. Model NOT, NAND and NOR gate behaviour by using the reed relay to switch off the second circuit. Emphasise that when the first circuit is switched off the second is powered by its own supply. Compare with logic gate circuits and emphasise that a logic gate has its own power supply. A NOT gate does not magically turn 0 V (0) into say 6 V (1).	Logic gates: http://www.kpsec.freeuk.com/gates.htm	It is worth setting up a few logic gate circuits and explaining how they work. Use a NOT gate and an L.D.R. to switch on a light when it is dark. Use an AND gate to switch on a heater when it is cold and dark.

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25(c)	State the symbols for the logic gates listed above (American ANSI Y 32.14 symbols will be used).			
25(d)	Describe the use of a bistable circuit.	Set up a bistable circuit with two NAND gates (or a transistor bistable circuit). Put an L.E.D. at one output and a buzzer at the other. Use push switches. Observe that one switch switches the buzzer on and the L.E.D. off, whilst the other has the reverse effect.	Bistable circuits: http://resourcefulphysics.org/download/2508/bistable_circuits.doc	Such a circuit can be used as a burglar alarm or an emergency off switch for an escalator.
25(e)	Discuss the fact that bistable circuits exhibit the property of memory.	Explain that the circuit "can remember" which switch was most recently operated.		
25(f)	Describe the use of an astable circuit (pulse generator)	Set up an astable circuit with NOR gates and capacitors (or a transistor astable circuit). Connect the output to a buzzer or an L.E.D. Observe the pulsating sound or the flashing light. Vary the value of the resistors and observe the effect on the pulsing frequency. Vary the value of the capacitors and repeat the observation. Check for inverse proportionality in each case.	Astable circuit: http://www.bbc.co.uk/schools/gcsebitesize/design/systemscontrol/electronicsrev8.shtml	
25(g)	Describe how the frequency of an astable circuit is related to the values of the resistive and capacitative components.			