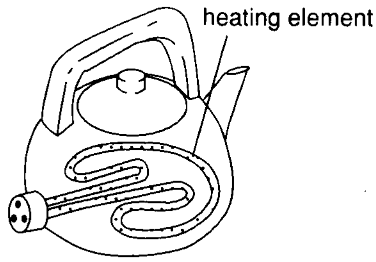
Hwa Chong Institution (High School) Name : ________________________ (   )
PHYSICS Notes Class : __________
Domestic Electricity Date : __________

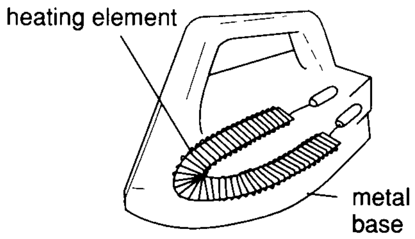
Some uses of electricity

a) Electric heating

The following figures show some examples of household appliances that are based on the heating effect of a current. The heating elements used in kettles and irons are made of nichrome wire which is coiled round an insulating fire-proof material such as silica or fire-clay. Nichrome is chosen because of its high resistivity and its ability to withstand high temperatures without being easily oxidised.



Electric kettle



Electric iron

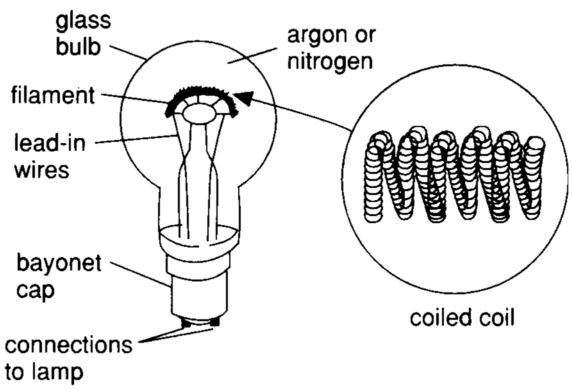
In the case of an electric kettle, the heating element is enclosed in a metal tube. Heat is generated when an electric current is passed through the heating element. The water surrounding it gets heated by conduction and convection.
In the case of an electric iron, the heat generated by the heating element is spread evenly over a metal base which is a good conductor of heat. A thermostat inside the iron controls the temperature of the heating element.

b) Electric lighting

1. Incandescent (or filament) lamps

The filament lamp works on the heating effect of a current. The wire which is used to make the filament is tungsten. Tungsten is chosen because of its high resistivity and high melting point (3400°C). Besides being made of a high resistivity material, the filament is made very thin (i.e. small cross-sectional area) to give it a higher resistance than the rest of the circuit.

When a current flows through the filament, the filament becomes white hot (about 2500°C). The higher the temperature of the filament, the greater is the proportion of electric energy that is converted to light energy. This explains why tungsten with a high melting point of 3400°C is chosen.



An incandescent (or filament) lamp

The purpose of the coiled coil is to make the filament compact as well as to reduce the convection currents being set up in the gas within the glass bulb. This glass bulb is usually filled with argon or nitrogen (both being inert gases) as tungsten oxidizes at high temperatures when exposed to air. The filament lamp has two disadvantages:

- only about 10% of the electrical energy supplied is converted to light. The rest of the energy is converted to heat. This explains why it is very warm when you use a filament lamp.
- compared with the fluorescent lamp, the filament lamp casts shard shadows and this is not desirable in schools or offices. However, it is commonly used in homes to give an impression of a more cozy and relaxed atmosphere.

2. Fluorescent lamps

Compared to filament lamps, fluorescent lamps are about three times as efficient. They are therefore more economical to use. In addition, fluorescent lamps have a lamp life of about 3000 hours compared to the 1000 hours of filament lamps.
Unlike the filament lamp, a fluorescent lamp has no filament but two electrodes. By passing electric charges between these two electrodes, the mercury vapour in the glass tube emits ultraviolet light together with other visible light. This ultraviolet light is converted to visible light by the fluorescent powder on the inside of the glass tube.

c) Electric motors

The electric motors used in household appliances like the fan, washing machine, hair dryer are based on the magnetic effect of a current.
In the magnetic effect of a current, the magnetic field of a current is used to interact with other magnetic fields or magnetic materials to produce mechanical movements.

Measurement of Electrical Energy

a) Calculating electrical power and energy

1. Electrical power (P)

$$P = IV = I^2R = \frac{V^2}{R}$$

2. Electrical energy (E)

$$E = Pt = IVt = I^2Rt = \frac{V^2}{R}t$$

Ex-1: An electric iron has a heating element of resistance 60 Ω. If the operating current flowing through it is 4.0 A, calculate (i) the supply voltage; (ii) the electrical power produced; and (iii) the heat energy produced in 5 minutes.

Ex-2: A filament lamp is rated 60 W and 240 V. Find (i) the current flowing through the lamp; (ii) the resistance of the filament; and (iii) the energy produced by the lamp in one hour.

b) Calculating the cost of electricity consumption

The cost of electricity consumption is based on the number of kilowatt-hours (kWh) of electrical energy used. The kWh are sometimes known as the domestic units of electricity.

Ex-3: Change 1 kWh to Joules.

Ex-4: If the Singapore Power charges 27.59 cents for each kWh of electrical energy used (based on the 1-Jan to 31-Mar 2012 tariff), calculate the total cost of using a 3 kW electric kettle for 20 minutes and a 100 W filament bulb for 5 hours.

Dangers of Electricity

a) Damaged insulation

All electrical appliances require two wires to form a complete circuit from the voltage supply to the appliance and back to the supply. The two wires are called the LIVE and NEUTRAL wires. The live wire is the dangerous wire because it carries a very high voltage while the neutral wire carries close to zero voltage. These two wires are insulated in vulcanized rubber and they are housed together in either a circular PVC sheathed cable or a circular braided rubber-insulated cable.

Insulating material deteriorate with time and use. For example, the electrical cables connecting the hair dryer and the electric iron are always bent and twisted because of the way the appliances are used. This will cause the electrical insulation to crack and break, thus exposing the conducting wires inside. If the vulcanized rubber covering the live wire is also damaged, the exposed live wire can cause a severe electric shock to the user if the user touches it accidentally. This can lead to serious injury and even death.

b) Overheating of cables

The overheating of cables refers to the unusually large current flowing in the conducting wires under certain conditions such as short circuit or overloading

A short circuit can result when the live wire makes contact with the neutral wire due to a damaged insulation between them. This will produce a large current and the large amount of heat generated can melt the insulation and start a fire.

c) Damp conditions

If water from the wet floor touches the live wire, it provides a conducting path for a large amount of current to flow through it and through the body of the person. The human body can only withstand up to about 50 mA but the current in this case is very much higher due to the sharp decrease in the resistance of the body.

The electrical resistance of the human body comprises two parts: the contact resistance of the dry skin and the resistance of the body itself. The contact resistance of the dry skin is of the order of 100 kΩ or more while the resistance of the body containing mainly fluids is much lower (of the order of a few hundred ohms). This explains why the dry skin acts as an insulating layer by offering high resistance. If the skin is wet, the contact resistance provided by the dry skin will be lowered drastically and the resistance of the body being very low will allow a large electric current to flow through the body, causing an electric shock and even death.

Safe Use of Electricity at Home

a) Household electricity supply

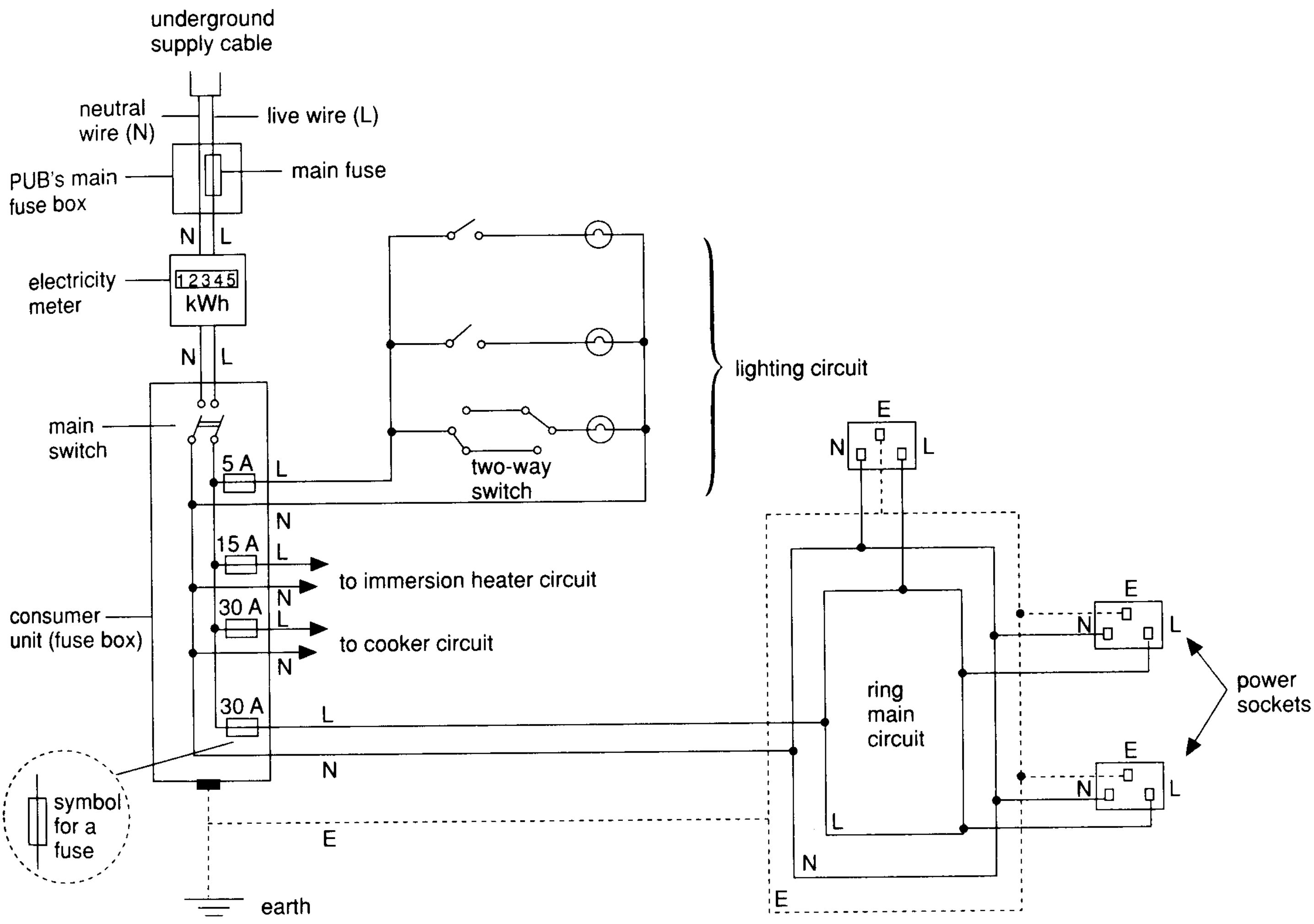
The figure shows a typical house circuit. Electricity is supplied to the house by an underground cable containing two wires, the live (L) wire and the neutral (N) wire. For any circuit, the current enters the house through one wire and returns to the local substation through the other. The live (L) wire is a dangerous wire as it carries a high voltage while the neutral (N) wire is usually at zero volt.

These two wires are connected to a mains fuse box, an electricity meter and then to a consumer unit. The consumer unit is the distribution point for the household's electricity supply. The same figure shown also shows the consumer unit containing a main switch and four fuses which lead to different circuits in the house.

These circuits are:

- lighting circuit : the lamps are always connected in parallel so that each lamp receives the mains voltage of 240 V. In addition, if any lamp should fail, the rest of the lamps will not be affected since they are connected in parallel
- immersion heater circuit
- cooker circuit
- ring main circuit : this circuit supplies electricity to all the wall sockets in the house. Besides both the live and neutral wires running a complete ring round the house, an earth (E) wire is also added for safety reasons.

The Earth Leakage Circuit Breaker (ELCB) is commonly used to protect users by cutting off the supply whenever a current leakage of 30 mA is detected in the circuit.



A typical house circuit

Fuses

The same figure above also shows fuses found in the main fuse box as well as in the consumer unit. A fuse is a safety device that is inserted into an electrical circuit to protect the equipment and wiring against any excessive current flow. It is a short thin piece of wire which becomes hot and melts when the current through it is greater than its rated value.

The thicker the wire, the more current is needed to melt it and the higher the rating of the fuse. Fuses are normally rated at 1 A, 2 A, 5 A, 10 A and 13 A.

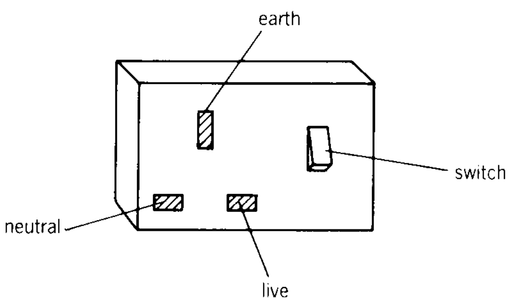
As a safety measure, the following should be considered:

- fuses to be used should have a rating of just slightly more than the current which the electrical appliance will draw under normal conditions.
- fuses should be connected to the live wire so that the appliance will not become live after the fuse has blown
- before changing any fuse, switch off the mains.

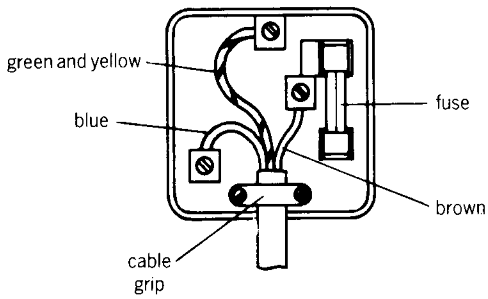
Ex : A hot water heater is rated 2880 W 240 V. Calculate the operating current and suggest a suitable rating for a fuse to be used to protect the heater from overloading.

Plugs and sockets

The figures show a typical power socket and a plug used in a house. The function of a fused plug is to connect a portable appliance (such as an electric kettle) to the power circuits via the power socket. The modern fused plug is a three-pin plug which has flat pins.



Three-pin socket

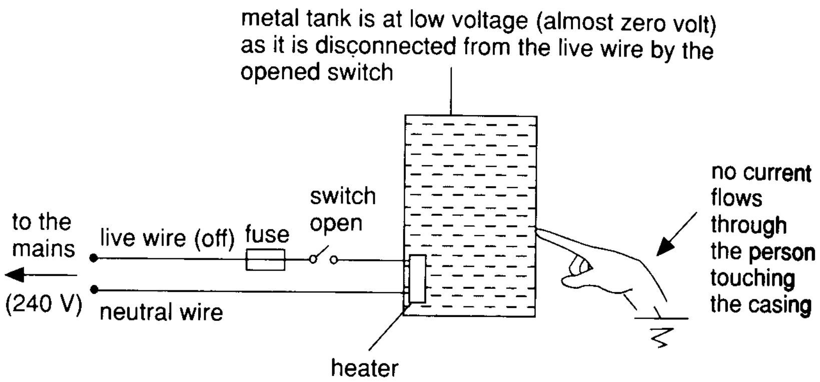


Wiring a plug

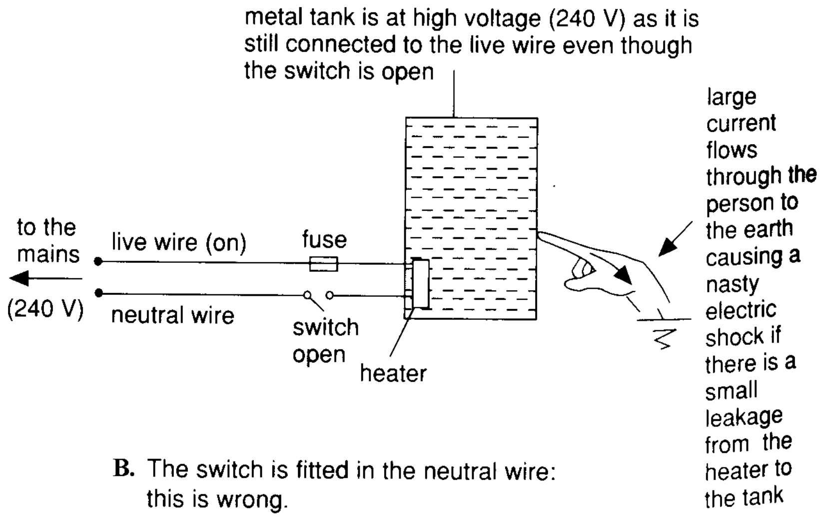
Within the plug, a cartridge fuse is fitted neatly into a carrier in the plug. The plug fuse protects the individual appliance in the event of an electrical fault. When the plug fuse 'blows', it only isolates the appliance concerned so that the other appliances plugged into the ring main circuit can still function.

Switches

All switches are designed to perform the same function of breaking or completing an electrical circuit. An important precaution is that any switch must be fitted onto the live wire, as shown in Fig A, so that the action of switching off will disconnect the high voltage from an appliance.



A. The switch is fitted in the live wire: this is correct.



B. The switch is fitted in the neutral wire: this is wrong.

If the switch is fitted onto the neutral wire, the appliance will be 'live' even if the switch is 'off'. An electric shock could then result, as shown in Fig B.

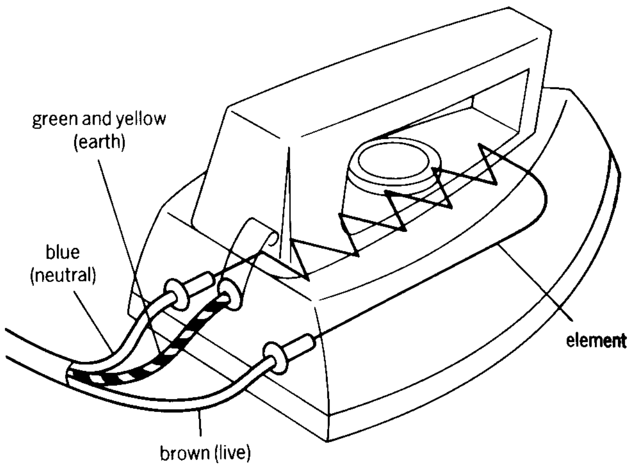
Earthing

All appliances need at least two wires (the live and the neutral) to form a complete circuit from the supply through the appliance and back to the supply.

The live (L) wire [**brown**] delivers the energy at the high alternating voltage (a.c.) to the appliance. The neutral (N) wire [**blue**] completes the circuit by forming a path for the current back to the supply. It is usually at zero volt.

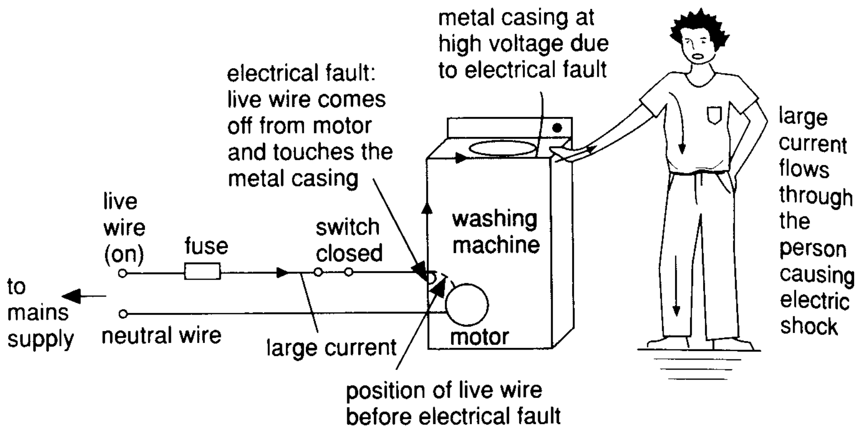
The earth (E) wire [**green with yellow**] is a low resistance wire, usually connected to the metal casing of the appliance. Earthing protects any user of the appliance from an electric shock, if the metal casing should accidentally become live (e.g. when the live wire is not properly fixed on and touches the metal casing of the appliance). The large current that flows from the loose wire through the metal casing and the earth wire (a low resistance wire) will blow the circuit fuse and cut off the supply to the appliance.

The figure on the right shows how the earth wire is connected to the body of the electric iron.

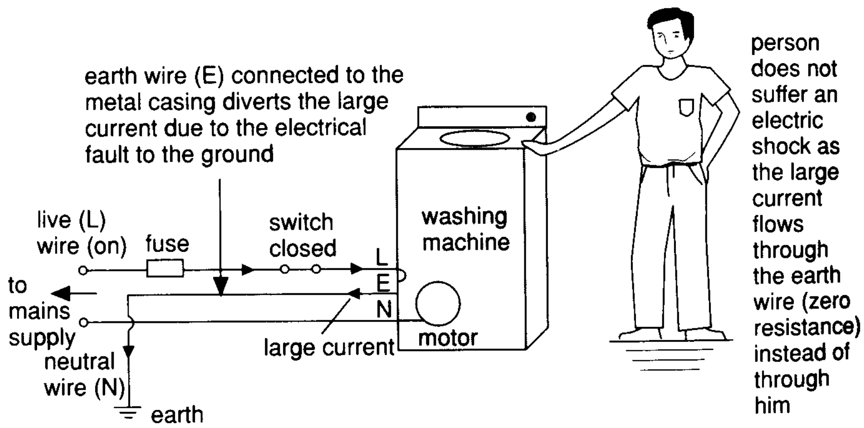


Connections in an electric iron

The following figures show the importance of earthing as a safety precaution.



A. No earthing can cause electric shocks.



B. Earthing prevents electric shocks.

Double insulation

Double insulation is a safety feature in an electrical appliance that can substitute for an earth wire. In this case, only the live and neutral wires are required for the appliance.

This safety feature provides two levels of insulation:

- the electric cable is insulated from the internal components of the appliance
- the internal metal parts which could become live if a fault developed are also insulated from the external casing

Appliances with this feature normally have non-metallic casing (such as plastics).

Sources of electrical energy

In Singapore, the majority of the electrical energy consumed is produced by burning **fossil fuels**.

Our dependency on other countries for fossil fuels and the negative effects of burning fossil fuels on the environment point to a need for alternative sources of energy. Fossil fuels are a **non-renewable** source of energy.

Renewable energy is defined as energy from sources that can be replenished naturally, such as the examples in the table.

	Solar power	**Hydroelectric power**	**Wind power**
Efficiency	High efficiency when there is daylight and minimal cloud cover	Most efficient energy source	Efficiency depends on wind direction and speed
Cost	• Solar panel cost is high • Cost of fuel is free	Cost of constructing and maintaining dam and power plant is high	Cost falling with improving technology
Environmental impact	Clean energy, but requires large areas to be cleared for solar panel installation	Clean energy, but dam construction disrupts ecosystems	Clean energy, but requires large open areas and possible noise pollution

Non-renewable energy is defined as energy from natural sources that cannot be replenished at a sustainable rate, such as the examples in the table.

	Nuclear power	**Fossil fuels**
Efficiency	High efficiency	Most countries have well-established fossil fuel power plants
Cost	Additional cost incurred for disposal of radioactive waste	Cost rising due to declining supplies
Environmental impact	Waste produced can contaminate groundwater and sources of surface water	• Mining disrupts ecosystems • Burning fossil fuels results in air pollution

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