ELECTRICITY AND ELECTRONICS

The knowledge and understanding for this unit is given below.

Circuits

1. State that electrons are free to move in a conductor.
2. Describe the electrical current in terms of the movement of charges around a circuit.
3. Carry out calculations involving **Q = It**.
4. Distinguish between conductors and insulators and give examples of each.
5. Draw and identify the circuit symbols for an ammeter, voltmeter, battery, resistor, variable resistor, fuse, switch and lamp.
6. State that the voltage of a supply is a measure of the energy given to the charges in a circuit.
7. State that an increase in the resistance of a circuit leads to a decrease in the current in that circuit.
8. Draw circuit diagrams to show the correct positions of an ammeter and voltmeter in a circuit.
9. State that in a series circuit the current is the same at all positions.
10. State that the sum of the potential differences across the components in series is equal to the voltage of the supply.
11. State that the sum of the currents in parallel branches is equal to the current drawn from the supply.
12. State that the potential difference across components in parallel is the same for each component.
13. State that V/I for a resistor remains approximately constant for different currents.
14. Carry out calculations involving the relationship **V = IR**.
15. Carry out calculations involving the relationships
    $\mathbf{R_T = R_1 + R_2 + R_3}$ **and** $\mathbf{1/R_T = 1/R_1 + 1/R_2 + 1/R_3}$.
16. State that a potential divider circuit consists of a number of resistors, or a variable resistor, connected across a supply.
17. Carry out calculations involving potential differences and resistances in a potential divider.

Electrical energy

1. State that when there is an electrical current in a component, there is an energy transformation.
2. State that the electrical energy transformed each second = VI.
3. State the relationship between energy and power.
4. Carry out calculations using **P = IV and E = Pt**.
5. Explain the equivalence between **VI,** $\mathbf{I^2 R}$ **and** $\mathbf{V^2 / R}$.
6. Carry out calculations involving the relationships between power, current, voltage and resistance.
7. State that in a lamp electrical energy is transformed into heat and light.
8. State that the energy transformation in an electrical heater occurs in the resistance wire.
9. Explain in terms of current the terms d. c. and a.c.
10. State that the frequency of the mains supply is 50 Hz.
11. State that the quoted value of an alternating voltage is less than its peak value.
12. State that a d.c. supply and an a.c. supply of the same quoted value will supply the same power to a given resistor.

ELECTROMAGNETISM AND ELECTRIC COMPONENTS

The knowledge and understanding for this unit is given below.

Electromagnetism

1. State that a magnetic field exists around a current-carrying wire.
2. Identify circumstances in which a voltage will be induced in a conductor.
3. State the factors which affect the size of the induced voltage i.e. field strength, number of turns on a coil, relative movement.
4. State that transformers are used to change the magnitude of an alternating voltage.
5. Carry out calculations involving input and output voltages, turns ratio and primary and secondary currents for an ideal transformer.

Electric components

1. Give examples of output devices and the energy conversions involved.
2. Draw and identify the symbol of LED.
3. State that an LED will only light if connected one way round.
4. Describe by means of a diagram a circuit which will allow an LED to light.
5. Calculate the value of the series resistor for an LED and explain the need for this resistor.
6. Describe the energy transformations involved in the following devices: microphone, thermocouple, solar cell.
7. State that the resistance of a thermistor usually decreases with increasing temperature and the resistance of an LDR decreases with increasing light intensity.
8. Carry out calculations using V = IR for the thermistor and LDR.
9. Draw and identify the circuit symbol for an n-channel enhancement MOSFET.
10. Draw and identify the circuit symbol for an NPN transistor.
11. State that a transistor can be used as a switch.
12. Explain the operation of a simple transistor switching circuit.
13. Identify, from a list, devices in which amplifiers play an important part.
14. State that the output signal of an audio amplifier has the same frequency as, but a larger amplitude than, the input signal.
15. Carry out calculations involving input voltage, output voltage and voltage gain of an amplifier.

Units, prefixes and scientific notation

1. Use SI units of all quantities appearing in the above Content Statements.
2. Give answers to calculations, to an appropriate number of significant figures.
3. Check answers to calculations.
4. Use prefixes (μ, m, k, M).
5. Use scientific notation.

CIRCUITS

Electric Current

Materials can be divided into two main groups, **conductors** and **insulators**. In a conductor, the electrons (sometimes referred to as charges) are free to move through the structure but in an insulator they are not.
Electric current is a measure of the flow of charge around a circuit and depends on the amount of charge passing any point in a circuit every second.
All metals are conductors and, with the occasional exception, all non-metals are insulators.

$$\mathbf{I = \frac{Q}{t}} \quad \text{or} \quad \mathbf{Q = I\,t}$$

I = electric current
Q = electric charge
t = time taken for charge to pass point

Units

Electric current is measured in ampères, **A**.
Electric charge is measured in coulombs, **C**.
Time is measured in seconds, **s**.

Example

Calculate the electric current in a circuit if 3 C of charge pass a point in a circuit in a time of 1 minute.
Ensure that all quantities are stated with the correct units.

$I = ?$ $\quad Q = 3\ C$ $\quad t = 1\ min = 60\ s$

$$I = \frac{Q}{t} = \frac{3}{60} = 0.05\ A$$

Voltage and Potential Difference (p.d.)

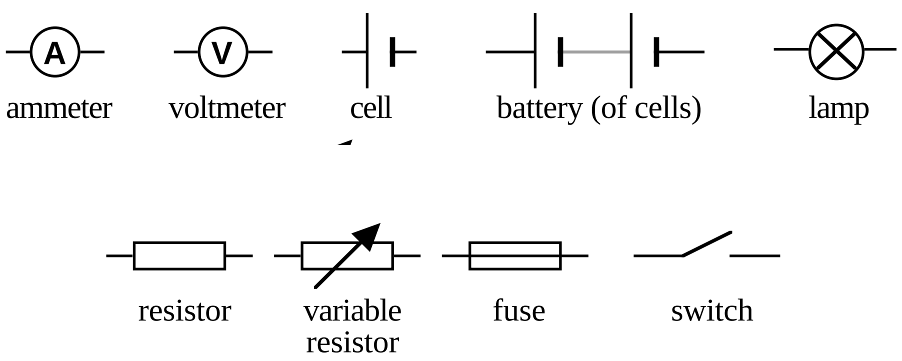
The voltage or potential difference (often referred to as the p.d.) of the supply is a measure of the energy given to the charges in a circuit.

Units

Voltage (p.d.) has the symbol **V** and is measured in **volts**, **V**.

Circuit Symbols

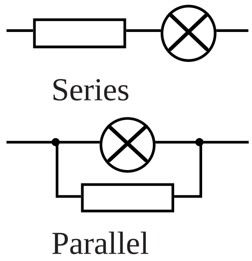
Circuit symbols are used in electrical circuits to represent circuit components or devices to make them easier to draw and understand.
Some of the circuit symbols that you will need to know are shown below.



Series and Parallel Circuits

Components in a circuit can be connected in series or parallel.
A **series** arrangement of components is where they are **in-line** with each other, that is connected end-to-end.

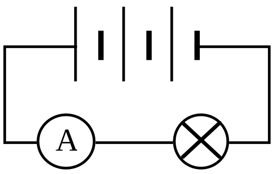
A **parallel** arrangement of components is where they are connected **across** each other where the current has more than one path through that part of the circuit.



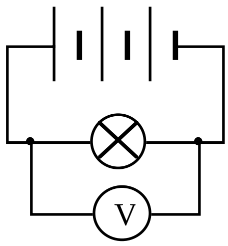
Measuring Current and Potential Difference or Voltage

Electric current is measured using an **ammeter** which is connected **in series** with the component.
Potential difference (p.d.), or voltage, is measured using a **voltmeter** which is connected **in parallel** with the component.

Measuring the **current through** the lamp

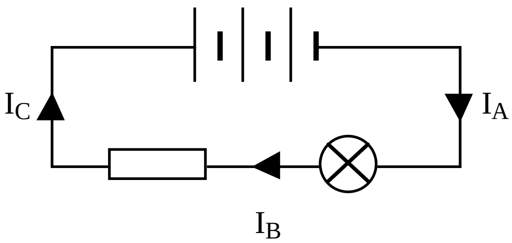


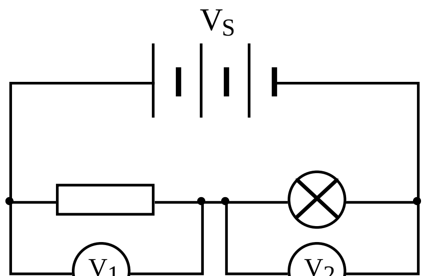
Measuring the **voltage (p.d.) across** the lamp



Current and Potential Difference or Voltage in Series Circuits

The current is the same at all points in a series circuit.
The sum of the potential differences across the components in a series circuit is equal to the voltage of the supply.



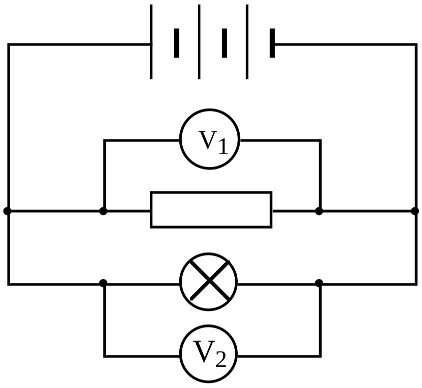


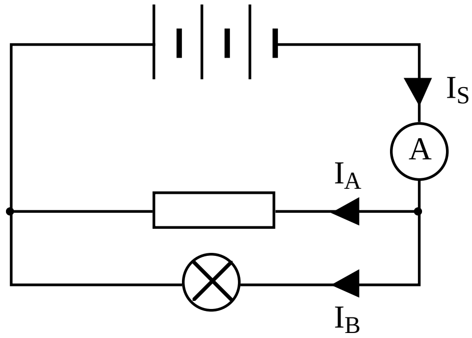
$\mathbf{I_A = I_B = I_C}$

$\mathbf{V_S = V_1 + V_2}$

Current and Potential Difference or Voltage in Parallel Circuits

The potential difference across components in parallel is the same for all components.
The sum of the currents in parallel branches is equal to the current drawn from the supply.





$$\mathbf{V_1 = V_2}$$

$$\mathbf{I_S = I_A + I_B}$$

Electrical Resistance

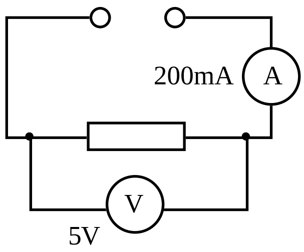
Resistance is a measure of the opposition of a circuit component to the flow of charge or current through that component. The greater the resistance of a component, the less will be the current through that component.
All normal circuit components have resistance and the resistance of a component is measured using the relationship

$$\mathbf{R = \frac{V}{I}} \quad \text{or} \quad \mathbf{V = I\,R}$$

R = resistance
V = potential difference (voltage)
I = current

Resistance is measured in ohms, Ω.
Potential difference (or voltage) is measured in volts, **V**.
Current is measured in amperes, **A**.
This relationship is known as **Ohm's Law**, named after a German physicist, Georg Ohm.
For components called **resistors**, the resistance remains approximately constant for different values of current therefore the ratio **V/I** (= R) remains constant for different values of current.

Example
Calculate the resistance of the resistor in the diagram opposite.
Ensure that all quantities are stated in the correct units.



R = ?
V = 5 V
I = 200 mA = 0.2 A

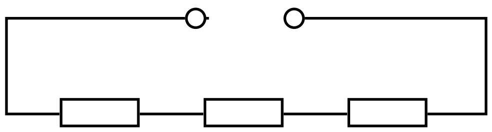
$$R = \frac{V}{I} = \frac{5}{0.2} = 25\ \Omega$$

Resistors in Series

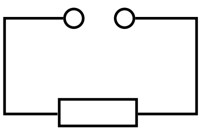
When more than one component is connected in series, the **total resistance** of all the components is equivalent to one single resistor, R_T, calculated using the relationship

$$\mathbf{R_T = R_1 + R_2 + R_3}$$

For the following circuit with three components in series,



is equivalent to



The above relationship is true for two or more components connected in series.

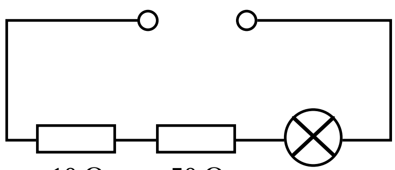
Resistors in Parallel

When more than one component is connected in parallel, the **total resistance** of all the components is equivalent to one single resistor, R_T, calculated using the relationship

$$\mathbf{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Example 1 Components in series

Calculate the total resistance of the circuit opposite.



$R_1 = 10\ \Omega$

$R_2 = 50\ \Omega$

$R_3 = 25\ \Omega$

$R_T = R_1 + R_2 + R_3$

$R_T = 10 + 50 + 25 = 85\ \Omega$

Example 2 Components in parallel

Calculate the total resistance of the components above when connected in parallel.

$R_1 = 10\ \Omega$

$R_2 = 50\ \Omega$

$R_3 = 25\ \Omega$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{10} + \frac{1}{50} + \frac{1}{25}$$

$$= \frac{5}{50} + \frac{1}{50} + \frac{2}{50} = \frac{8}{50}$$

$$\frac{1}{R_T} = \frac{8}{50} \quad \textit{therefore} \quad \frac{R_T}{1} = \frac{50}{8} \qquad R_T = 6.5\ \Omega$$

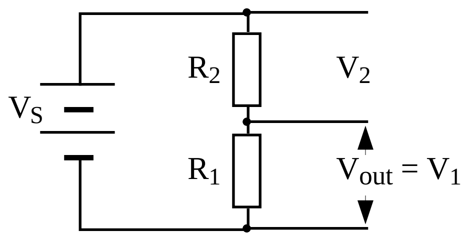
Note:

For components in series, R_T is **always** greater than the largest resistance.
For components in parallel, R_T is **always** less than the smallest resistance.

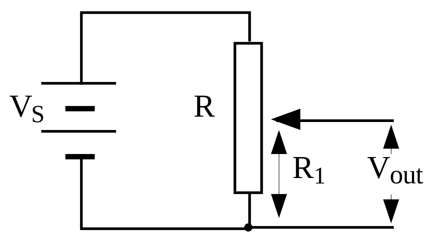
Potential Divider Circuits

A potential divider is a device or a circuit that uses two (or more) resistors or a variable resistor (potentiometer) to provide a fraction of the available voltage (p.d.) from the supply.

Fixed Resistance



Variable Resistance



The p.d. from the supply is divided across the resistors in direct proportion to their individual resistances.

Take the fixed resistance circuit - this is a **series** circuit therefore the current in the same at all points.

$$I_{supply} = I_1 = I_2$$

where I_1 = current through R_1
and I_2 = current through R_2

Using Ohm's Law:

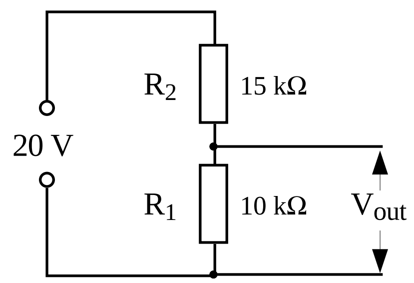
$$I = \frac{V}{R} \quad \text{hence} \quad \frac{V_S}{R_T} = \frac{V_1}{R_1} = \frac{V_2}{R_2}$$

$$\mathbf{V_1 = \frac{R_1}{R_T} \times V_S} \quad \text{or} \quad \mathbf{V_1 = \frac{R_1}{R_1 + R_2} \times V_S} \quad \text{and} \quad \mathbf{\frac{V_1}{V_2} = \frac{R_1}{R_2}}$$

$R_T = R_1 + R_2$

Example

Calculate the output p.d., V_{out}, from the potential divider circuit shown.



V_{out} = ?
R_1 = 10 kΩ
R_2 = 15 kΩ
V_S = 20 V

$$V_1 = V_{out} = \frac{R_1}{R_1 + R_2} \times V_S$$

$$= \frac{10}{10 + 15} \times 20$$

$$V_{out} = 8 \text{ V}$$

Alternatively V_{out} be determined in two stages. First calculate the current in the circuit using $V_S = I(R_1 + R_2)$. Then calculate V_{out} using this current I and $V_{out} = IR_1$.

ELECTRICAL ENERGY

In the earlier section on potential difference, it was stated that the potential difference of the supply is a measure of the energy given to the charges in the circuit.
The energy carried by these charges around the circuit is then converted to other forms of energy by the components in the circuit. Electrical components are devices that change or transform the electrical energy from the supply to the circuit into other forms of energy.
If energy is supplied to the charges in the circuit, then an electric current exists and there is an energy transformation in each of the components in the circuit.

Examples

An electric lamp is designed to emit light energy. This happens because the electric current passing through the filament causes it to get hot; hot enough to glow and emit light. A lamp therefore transforms electrical energy to heat and light energy.
An electric bar fire works in a similar way. The bar of the fire is made from a length of resistance wire similar to the filament of a lamp. The resistance wire is designed to get hot when a current passes through it. It also glows when it is hot, but not as much as the filament of the lamp.

Energy Units

Electrical energy, like all forms of energy, has the symbol **E** and is measured in **joules**, **J**.

Power and Energy

To compare different components, it is often useful to compare the **rate** at which energy is transformed, that is the energy transformed **each second**.
This electrical energy transformed each second is known as the **power**.

$$\mathbf{P = \frac{E}{t}} \quad \text{or} \quad \mathbf{E = P\,t}$$

P = power
E = energy
t = time

Units

Power is measured in watts, **W**.
Energy is measured in joules, **J**.
Time is measured in seconds, **s**.
1 watt is equivalent to the transfer of 1 joule per second.

Example
If an electric fire uses 1.8 MJ of energy in a time of 10 minutes, calculate the power output of the fire.
Ensure that all quantities are stated with the correct units.

$P = ?$
$E = 1.8\ MJ = 1.8 \times 10^6\ J$
$t = 10\ min = 600\ s$

$$P = \frac{E}{t} = \frac{1.8 \times 10^6}{600} = 3000\ W$$

Power Current and Voltage

Electrical power is also dependent on the potential difference across the component and the current through it. If 1 volt across a component pushes a current of 1 ampére, then the power will be 1 watt.

$$\boxed{\mathbf{P = V\,I}}$$

P = power in watts
V = voltage or potential difference in volts
I = current in ampéres

Example

A 230 V toaster draws a current of 4 A from the mains supply. Calculate the power output of this toaster.

P = ?
V = 230 V
I = 4 A

$P = V\,I = 230 \times 4 = 920\ W$

More Power Equations

Using the equation **P = V I** and Ohm's Law equation **V = I R**, we are able to obtain -

$$P = V\,I$$

but $V = I\,R$ and $I = \frac{V}{R}$

therefore $P = (I\,R) \times I$ and $P = V \times \frac{V}{R}$

tidying up $\boxed{\mathbf{P = I^2 R}}$ and $\boxed{\mathbf{P = \frac{V^2}{R}}}$

Example

A component data book states that a 1 kΩ resistor can safely handle a power output of 0.4 W.

a) What is the maximum current it can safely handle?
b) What potential difference would exist across the resistor at this current?

a) *I = ?*
P = 0.4 W
R = 1 kΩ = 1000 Ω

$$I^2 = \frac{P}{R} = \frac{0.4}{1000} = 4x10^{-4}$$

$$I = 0.02\ A$$

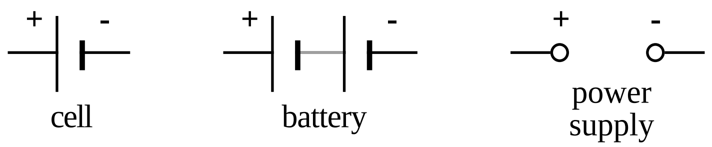
b) *V = ?*
P = 0.4 W
R = 1000 Ω
I = 0.02 A

$V^2 = P\,R = 0.4 \times 1000 = 400$ *or* $V = I\,R = 0.02 \times 1000$, $V = 20\ V$

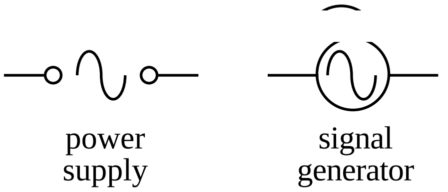
$$V = 20\ V$$

Alternating Current (a.c.) and Direct Current (d.c.)
All power supplies can be grouped into one of two categories depending on the way that they supply energy to the charges in a circuit.
A d.c. supply produces a flow of charge through a circuit in one direction only. An a.c. supply produces a flow of charge that regularly reverses its direction through a circuit.
The direction of the current depends on the direction of the 'push' from the supply, therefore power supplies can provide a direct voltage or an alternating voltage which would result in a direct current (d.c.) or an alternating current (a.c.).

d.c. supplies

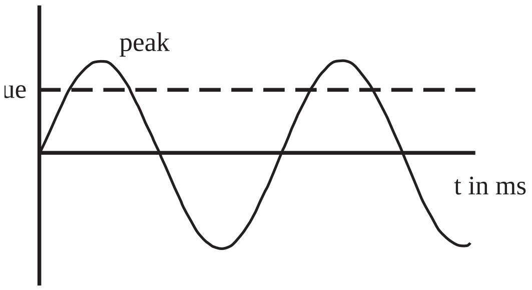


a.c. supplies

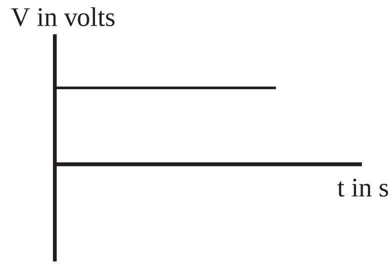


Mains Supply Frequency
The mains electrical supply in the U.K. is an alternating supply with a quoted votage of 230 V and a frequency of 50 Hz, that is it completes one cycle 50 times per second.

Peak Value and Quoted (Effective) Value of A.C.
A **d.c.** supply provides a constant 'push' to the charges as they move around a circuit whereas the **a.c.** supply does not as the voltage is continually varying.
The voltage for an alternating supply varies from zero to the peak value to zero to the peak value in the reverse direction and so on.



Varying **a.c.** supply



Steady **d.c.** supply

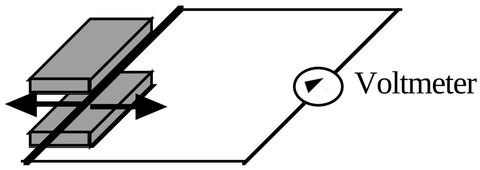
The peak value of voltage for an alternating supply cannot be used as a measure of its effective voltage as the voltage is only at that peak value for a short space of time. The effective voltage of an a.c. supply is **less** than the peak value.
For example, an alternating supply with a peak value of 10 V does not supply the same power to a circuit as a direct supply of 10 V, in fact it is less, approximately 7 V.

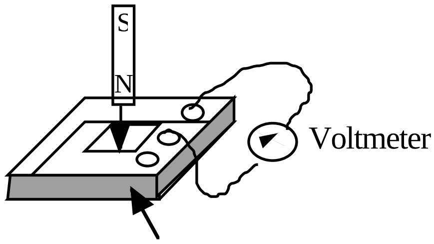
The effective value of current and voltage in an a.c. circuit is measured using a.c. meters in the circuit.
The peak value of voltage in an a.c. circuit can be measured using an oscilloscope.

ELECTROMAGNETISM

Magnetic field around a current carrying wire.
When an electric current flows through a wire then a circular magnetic field will be set up around the wire.
The direction of the magnetic field will depend on the direction of the electric current.

Induced voltage in a conductor
If a conductor cuts across the lines of a magnetic field, then a voltage will be induced across the ends of a conductor. Note the magnet can move with the conductor stationary or vice versa. An induced voltage will be produced provided the conductor experiences a **changing** magnetic field.

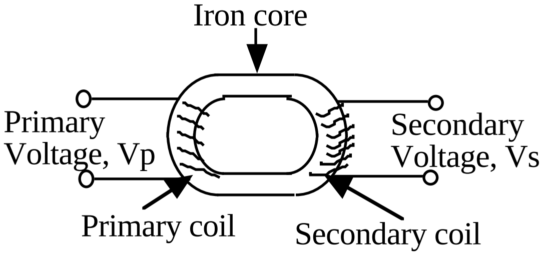


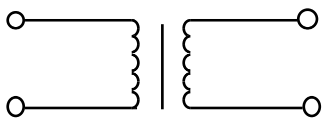


The size of the induced voltage depends on -

- the magnetic field strength
- the number of coils
- the speed of the motion
- the angle at which the conductor cuts the field

Transformers
These are extremely important devices that have numerous uses in everyday life.
(Delivery of electricity to your homes, changing voltages to the required size for televisions, computers, videos, etc.)
Transformers depend on an induced voltage being produced in a coil of wire. This coil is known as the **secondary coil.** For this to happen there must be a changing magnetic field near this coil. The changing magnetic field is produced by an alternating current passing through another coil. This coil is known as the **primary coil.**





Symbol

The input voltage, V_p, is connected to the primary coil.
The output voltage, V_s, is taken from the secondary coil.
A step up transformer is when the secondary voltage is greater than the primary voltage.
A step down transformer is when the secondary voltage is less than the primary voltage.
If N_s = the number of turns in the secondary coil
and N_p = the number of turns in the primary coil then

$$\textbf{Turns ratio} = \frac{N_s}{N_p} = \frac{V_s}{V_p}$$

Example

a) *Calculate the turns ratio for transformer whose primary voltage = 24 V and secondary voltage = 4 V.*

b) *How many turns will be on the primary coil if the secondary coil has 500 turns.*

a) $$\text{Turns ratio} = \frac{N_S}{N_P} = \frac{V_S}{V_P} \qquad \frac{4}{24} \qquad \frac{1}{6}$$

$$\text{or } N_S : N_P = 1 : 6$$

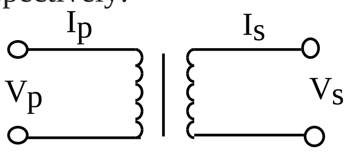
b) $$\frac{N_S}{N_P} = \frac{1}{6}$$

$$\frac{500}{N_P} = \frac{1}{6}$$

(Cross multiply) $500 \times 6 = N_P \times 1$ *Number turns on primary coil = 3000*

Transformer currents

To consider the energy input and output, the electric current must be taken into account. Consider the following transformer with alternating currents I_P and I_S flowing in the primary and secondary coils respectively:



For an **ideal** transformer (one that has no energy losses) then

$$\text{Input power} = \text{Output power}$$

$$V_P I_P = V_S I_S$$

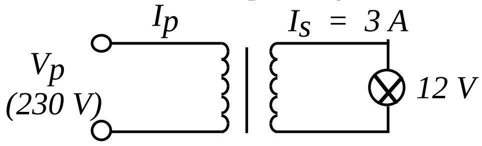
$$\frac{I_P}{I_S} = \frac{V_S}{V_P}$$ (Check this by cross multiplying)

$$\boxed{\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}}$$

Note: In a step up transformer, the 'step up' only refers to the voltage! In fact, the current steps down!

Example

A transformer is used to light a 12V bulb from mains voltage. Assuming it to be an ideal transformer find the current in its primary coil.



An ideal transformer will have no energy losses.

$$\text{Input power} = \text{Output Power}$$

$$V_p I_p = V_s I_s$$

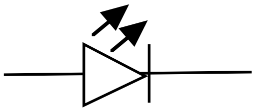
$$230 \times Ip = 12 \times 3$$

$$Ip = \frac{12 \times 3}{230} = 0.16\text{ A}$$

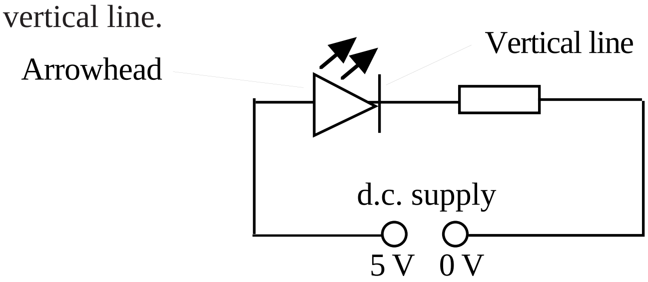
ELECTRONIC COMPONENTS

Output Devices
Examples of these include an LED, a loudspeaker, a buzzer, a seven segment display and a relay switch.

Light Emitting Diodes
Symbol:



Generally, a resistor is connected in series to limit the size of current that passes through an LED. They operate in the milliamp range.
Current can only flow through an LED in one direction.
The LED will light when the higher voltage is connected to the arrowhead and the lower voltage to the vertical line.

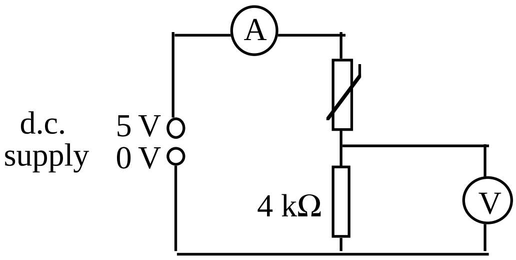


Example
Calculate the series resistor that must be used for the LED above rated at 1.5 V, 100 mA.

$$V_{supply} = 5\ V$$
$$V \text{ across } R = (5 - 1.5)\ V = 3.5\ V$$
$$I \text{ through } R = 100\ mA = 0.1\ A \quad \text{(LED and R are in series)}$$
$$R = \frac{V}{I} = \frac{3.5}{0.1} = 35\ \Omega$$

Input Devices
Examples of these are a microphone, a thermocouple and a solar cell.
They convert sound, heat and light energy to electrical energy, respectively.
A thermistor is a device which will usually decrease in resistance with increasing temperature.
A light dependent resistor, LDR, will decrease in resistance with increasing light intensity. (**L**ight **D**ecreases its **R**esistance).

Example
Calculate the readings on the meters shown below when the thermistor has a resistance of
a) 1 kΩ (warm conditions) and b) 16 kΩ. (cold conditions)



a) $R_T = (1 + 4)\ k\Omega = 5\ k\Omega$

$$I = \frac{V}{R_T} = \frac{5}{5000} = 0.001\ A$$
$$V = IR = 0.001 \times 4000 = 4\ V$$

b) $R_T = (16 + 4)\ k\Omega = 20\ k\Omega$

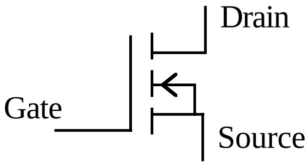
$$I = \frac{V}{R_T} = \frac{5}{20000} = 2.5 \times 10^{-4}\ A$$
$$V = IR = 2.5 \times 10^{-4} \times 4000 = 1\ V$$

Note similar problems can arise using an LDR instead of a thermistor.

Transistors

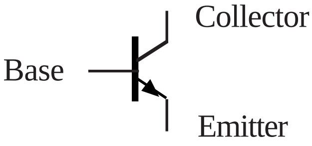
N-channel enhancement MOSFET (Metal Oxide Semiconductor Field Effect Transistor).

Symbol:



NPN Transistor.

Symbol:

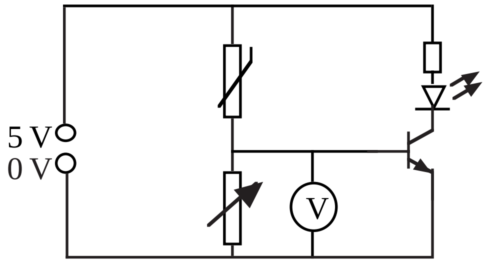


A transistor can be used as a switching device.

When the voltage across the emitter and base (or source and gate) reaches a certain value then the transistor will switch on.

Example

Temperature Warning Light



As the temperature increases then the resistance of the thermistor decreases, so the voltage across it must decrease.

This causes the voltage across the variable resistor to increase. When it reaches about 0.7 V the transistor switches on causing the LED to light. For a MOSFET, the switching voltage is around 1.8 V.

Amplifiers

Amplifiers are used in tape recorders, CD players, satellite communication, repeater stations connecting fibre optic cable, radio and television reception and transmission, mobile phones, hearing aids, heart monitors, tannoy systems, etc.

The output of an audio amplifier will have the same frequency but greater amplitude than the input signal. If not, the sound produced would not be a true representation of the input.

Voltage Gain

$$\text{Voltage Gain} = \frac{\text{Output Voltage}}{\text{Input Voltage}}$$

Note voltage gain is a ratio and has no unit.

Example

Calculate the gain of an amplifier with input voltage = 50 mV and output voltage = 8 V.

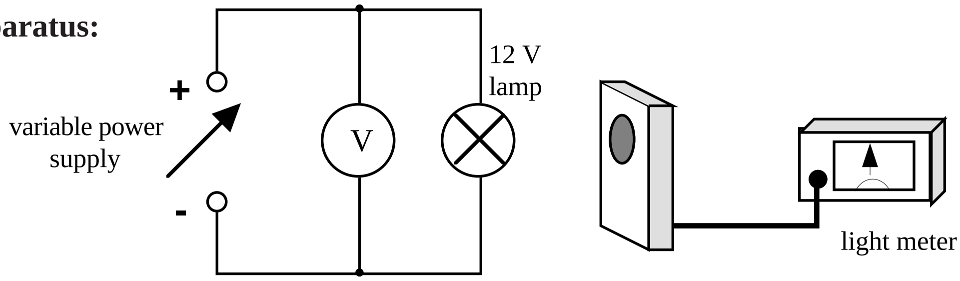
$$\text{Voltage Gain} = \frac{\text{Output Voltage}}{\text{Input Voltage}} = \frac{8}{0.05} = 160$$

ACTIVITY 1

Title: **Lamp Brightness and Supply Voltage**

Aim: To investigate how the brightness of a lamp varies as the p.d. across the lamp is varied.

Apparatus:



Instructions

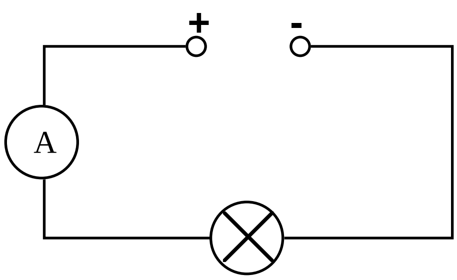
- Set up the simple circuit above using the equipment shown.
- Place the light meter close to the lamp and keep it in the same position.
- Adjust the power supply to give 4 V across the lamp and note the brightness of the lamp using the light meter.
- Without moving the light meter, repeat in steps of 2 V up to 12 V across the lamp.
- Graph your results of brightness against p.d. across the lamp.
- Explain any change in brightness of the lamp with p.d. in terms of the energy supplied by the power supply.

ACTIVITY 2

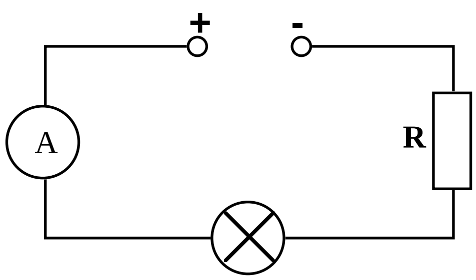
Title: **Resistance and Current**

Aim: To find out the effect that changing the size of the resistance in a circuit has on he measured current.

Apparatus: Set of resistors of different resistance value.



Circuit 1



Circuit 2

Instructions

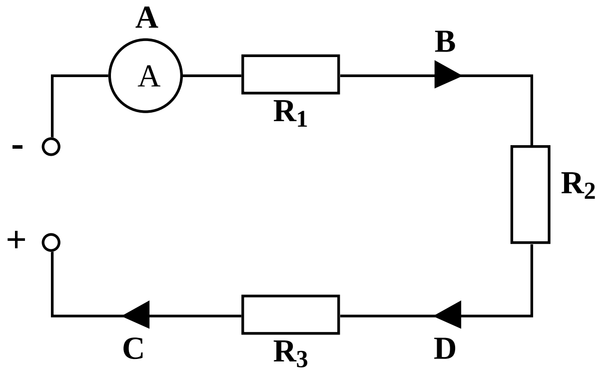
- Set up Circuit 1 above using the equipment shown and record the current reading.
- Set up Circuit 2 above with the first resistor connected as shown.
- Record the resistance added and the corresponding current.
- Without changing the supply voltage, repeat for the other resistances given.
- Record your results in a table.

ACTIVITY 3A

Title: **Current in Series Circuits**

Aim: To determine the behaviour of the current in a series circuit.

Apparatus:



Instructions

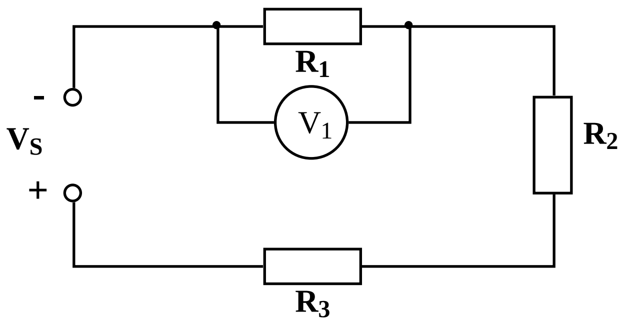
- Set up the circuit above with the ammeter at position **A** and record the current reading.
- Without changing the supply voltage, repeat the above measuring the current at positions **B**, **C** and **D**.
- Record your results in a table.

ACTIVITY 3B

Title: **Potential difference (p.d.) in Series Circuits**

Aim: To determine the behaviour of the voltage (p.d.) in a series circuit.

Apparatus:



Instructions

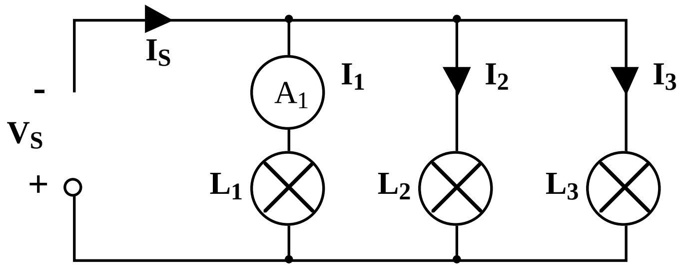
- Set up the circuit above with the voltmeter across $\mathbf{R_1}$ and record the p.d. reading $\mathbf{V_1}$.
- Without changing the supply voltage, repeat the above measuring the p.d. across $\mathbf{R_2}$ and $\mathbf{R_3}$.
- Use the voltmeter to measure the supply voltage, $\mathbf{V_S}$.
- Record your results in a table.

ACTIVITY 4A

Title: **Current in Parallel Circuits**

Aim: To determine the behaviour of the current in a parallel circuit.

Apparatus:



Instructions

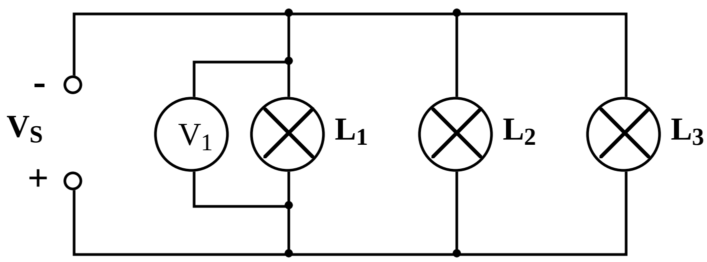
- Set up the circuit above with the ammeter in series with lamp $\mathbf{L_1}$ and measure current $\mathbf{I_1}$.
- Without changing the supply voltage, repeat the above measuring the current through lamps $\mathbf{L_2}$ and $\mathbf{L_3}$.
- Use the ammeter to measure the supply current, $\mathbf{I_S}$.
- Record your results in a table.

ACTIVITY 4B

Title: **Potential Difference (p.d.) in Parallel Circuits**

Aim: To determine the behaviour of the potential difference across components in a parallel circuit.

Apparatus:



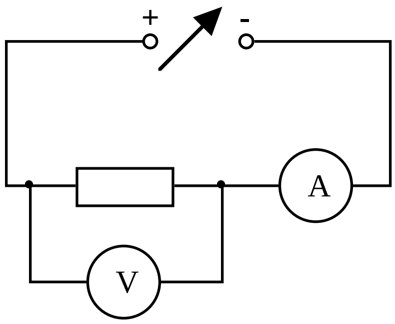
Instructions

- Set up the circuit above with the voltmeter across lamp $\mathbf{L_1}$ and measure p.d. $\mathbf{V_1}$.
- Without changing the supply voltage, repeat the above measuring the p.d. across lamps $\mathbf{L_2}$ and $\mathbf{L_3}$.
- Record your results in a table.

ACTIVITY 5

Title: **Current and Potential Difference** (Outcome 3)

Apparatus: Resistors, ammeter, voltmeter, variable power supply.



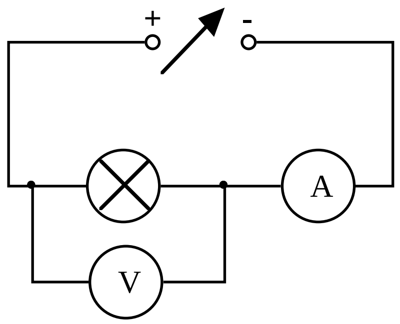
Instructions

- Set up the circuit above with one of the resistors and a variable power supply.
- Set the supply voltage to 1 V and measure the current through the resistor and the p.d. across it.
- Using the same resistor, increase the supply voltage to 2 V and repeat the above measurements.
- Repeat the above, increasing the supply by 1 V each time up to 5 V.
- Use an appropriate format to show the variation of the potential difference with the current.

ACTIVITY 6

Title: **Variation of Resistance and Current for a Lamp Filament** (Outcome 3)

Apparatus: 12 V lamp, variable power supply, ammeter, voltmeter, connecting leads.



Instructions

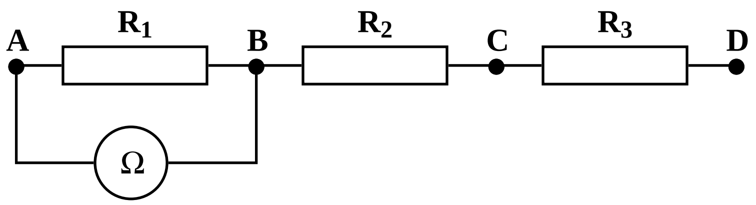
- Set up the circuit above.
- For a range of voltages up to 12 V, record the potential difference and corresponding current.
- For each set of results, calculate the resistance of the lamp.
- Use an appropriate format to show the variation of the resistance with the current.

ACTIVITY 7A

Title: **Resistance in Series**

Aim: To verify the series resistor relationship $R_T = R_1 + R_2 + R_3$ for 3 resistors in series.

Apparatus: 3 resistors of different values.



Instructions

- Connect the three resistors in series as shown in the diagram.
- Connect the ohmmeter across resistor $\mathbf{R_1}$ (AB) and record its resistance.
- Repeat for R_2 and R_3.
- Calculate the sum of the three resistances R_1, R_2 and R_3 and record your result.
- Connect the ohmmeter across all three resistors (AD) and record the total resistance, $\mathbf{R_T}$.
- Show that your results verify the relationship $R_T = R_1 + R_2 + R_3$.

ACTIVITY 7B

Title: Resistance in Parallel

Aim: To verify the parallel resistor relationship $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ for two resistors in parallel.

Apparatus: 2 resistors of different values.

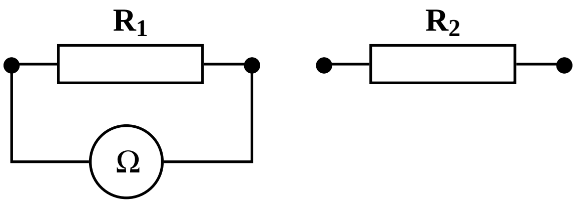


Diagram 1

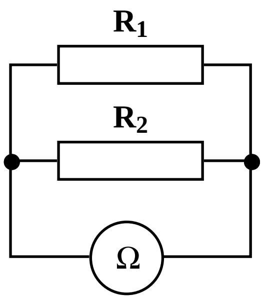


Diagram 2

Instructions

- Connect the ohmmeter across resistor $\mathbf{R_1}$ and record its resistance (Diagram 1).
- Repeat for resistor $\mathbf{R_2}$.
- Connect R_1 and R_2 in parallel and record the total parallel resistance R_T (Diagram 2).
- Complete this table:

$\mathbf{R_1}$	$\mathbf{R_2}$	$\mathbf{\frac{1}{R_1}}$	$\mathbf{\frac{1}{R_2}}$	$\mathbf{\frac{1}{R_1} + \frac{1}{R_2}}$	$\mathbf{R_T}$	$\mathbf{\frac{1}{R_T}}$

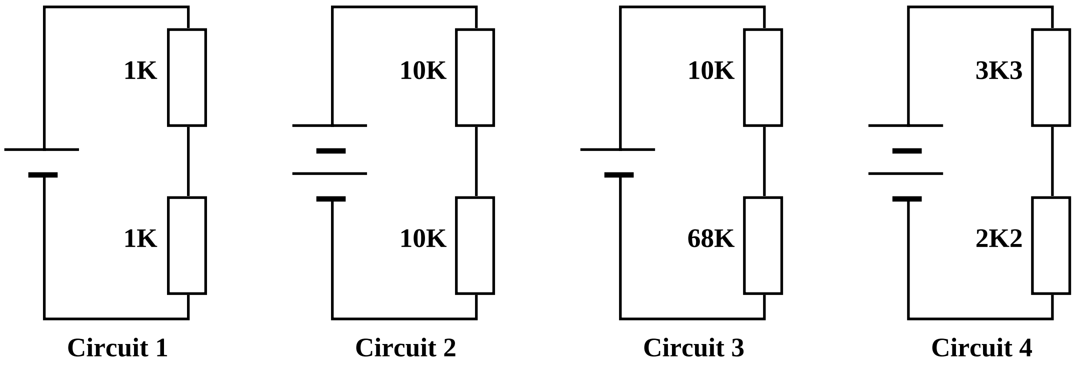
- Show that your results verify the relationship $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$.

ACTIVITY 8

Title: **Potential Divider Circuits**

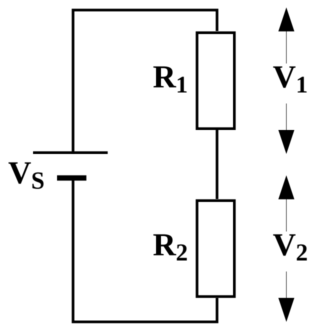
Aim: To verify the relationships between the resistances and the voltages in potential divider circuits.

Apparatus: Set of resistances of different values.
Mounted 1.5 V cells.



Instructions

- Connect each circuit in turn.
- In a table, record the values of V_1, V_2, V_S, R_1 and R_2.
- Calculate the total resistance of each circuit R_T.
- Calculate the ratios $\frac{V_1}{V_2}$, $\frac{R_1}{R_2}$, $\frac{V_1}{V_S}$, $\frac{R_1}{R_T}$.
- Write down the relationships that are true for ALL potential divider circuits.



Instructions

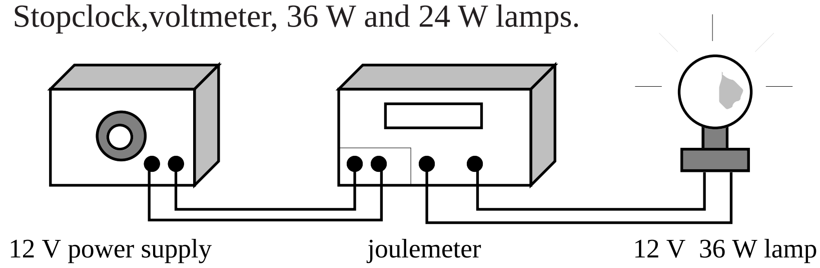
- Build a potential divider circuit using any of the two resistors that you have.
- **Predict** the values of V_1 and V_2 using the theory of the potential divider.
- Confirm your prediction by experiment.

ACTIVITY 9

Title: **Power and Energy**

Aim: To verify the relationship between energy and power.

Apparatus: Stopclock,voltmeter, 36 W and 24 W lamps.



Instructions

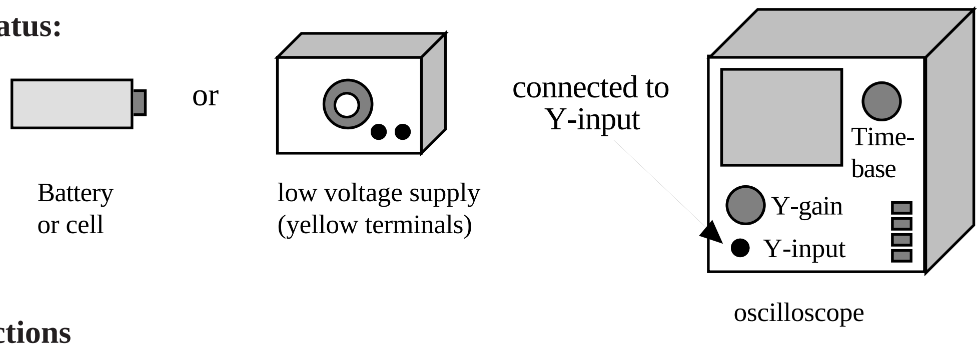
- Set up the apparatus above using the equipment shown.
- Switch on and ensure that the voltage across the lamp is 12 V using the voltmeter.
- Reset the joulemeter and start the stopclock at the same time.
- After 100 s, switch off the power supply and note the reading on the joulemeter.
- Repeat using the 24 W lamp.

ACTIVITY 10

Title: **Oscilloscope with a Battery and a Low Voltage Power Supply**

Aim: To examine the oscilloscope trace produced by different energy sources.

Apparatus:



Instructions

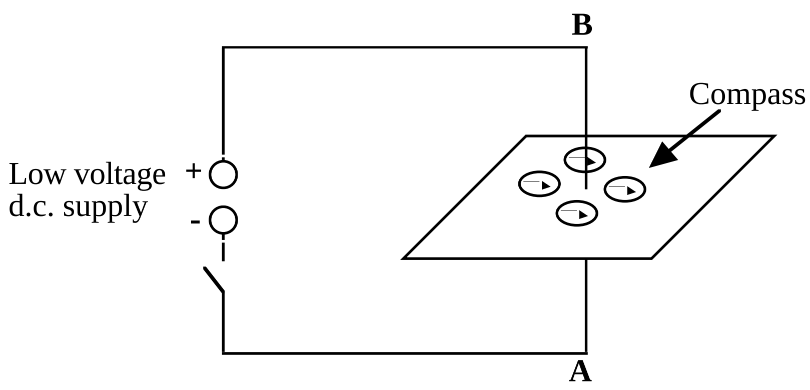
- Switch on the oscilloscope and adjust to give a horizontal line in the centre of the screen.
- Connect the battery or cell to the Y-input of the oscilloscope and draw the trace produced on screen.
- Record the voltage value of the cell or battery.
- Reverse the connections of the battery and draw the new trace produced on the screen.
- Replace the battery with the low voltage power supply, using the yellow terminals of the power supply.
- Adjust the oscilloscope to produce a steady, recognisable trace on the screen.
- Draw the trace produced on the screen this time.
- Record the voltage value as quoted on the a.c. supply.

ACTIVITY 11

Title: **Electromagnetism**

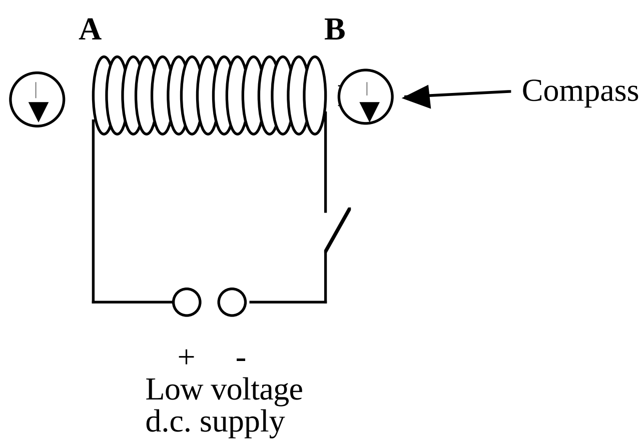
Aim: To demonstrate the magnetic effect of a current carrying wire.

Apparatus: Four compasses, a length of wire, a card and a low voltage d.c. supply.



Instructions

- Set up the apparatus as shown in the diagram above.
- Close the switch and note the direction of the compass needles.
- Draw the direction of the compass needles with the electron current flowing from
  a) A to B
  b) B to A.
- Repeat the procedure for the coil of wire shown below.
- Write up a brief report of your findings.

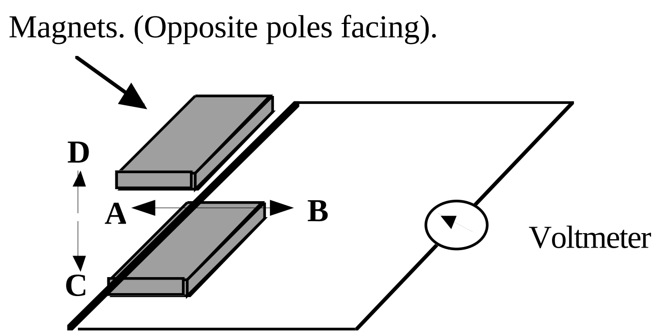


ACTIVITY 12

Title: **Induced voltage in a conductor**

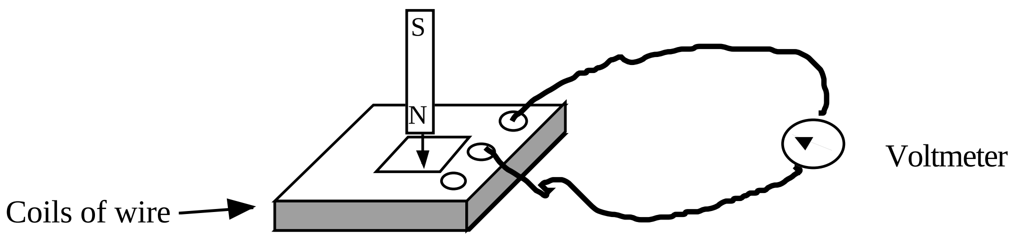
Aim: To investigate the factors that affect the size of an induced voltage in a conductor.

Apparatus: 2 magnadur magnets, centre zero voltmeter, wire, a bar magnet, a 120 turn coil, a bicycle dynamo and a C.R.O.



Instructions

- Move the wire to and fro along the line a) AB
  and b) CD.
- Note the effect on the meter when
  a) the number of wires cutting the field is increased
  b) the speed of movement is increased
  c) the strength of magnetic field is increased.
- Note the kind of voltage produced across the wire.
- Repeat the procedure with the magnet moved in and out of the coil as shown below.



- Make a list of your conclusions from the above experiments.

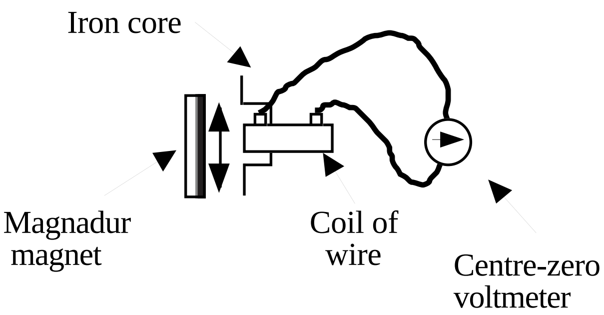
ACTIVITY 13

Teacher Demonstration

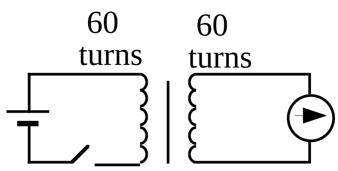
Title: **Transformers**

Aim: To find out how transformers work.

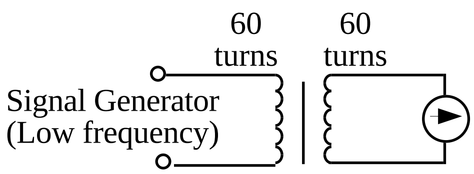
Apparatus: One magnadur magnet, 2 iron C cores, 2 coils (60 turns), one 1.5 V cell, one centre-zero voltmeter, one C.R.O. and one signal generator.



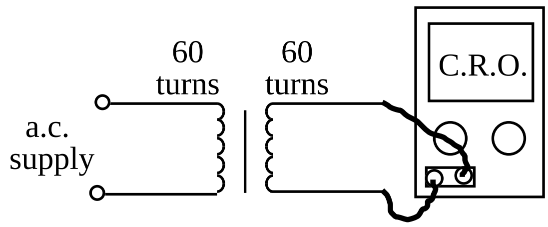
Demonstration 1



Demonstration 2



Demonstration 3



Demonstration 4

Instructions

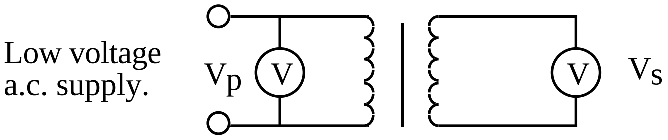
- State the condition required to produce a voltage across the coil of wire in demonstration 1.
- In demonstration 2, explain the meter movement when
  a) the switch is closed
  b) the switch remains closed
  c) the switch is opened.
- Describe what happens to the meter when a low frequency a.c. is applied to the primary coil as shown in demonstration 3.
- Draw the output CRO trace from the transformer when an alternating voltage is supplied to the input coil as in demonstration 4.
- Explain why a transformer will only work continuously with a.c.

ACTIVITY 14

Title: **Transformers**

Aim: To find the relationship between the number of turns in the primary and secondary coils and the voltage across the primary and secondary coils.

Apparatus: One voltmeter (a.c.), low voltage supply, 2 iron C-cores and 60, 120, 250 and 500 turn coils.



Instructions

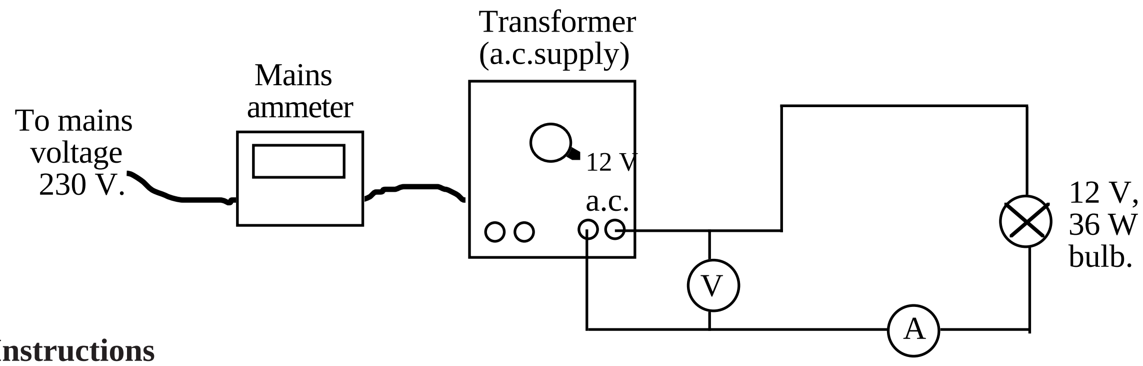
- Set up the apparatus as shown above.
- Supply an input voltage of 2 volts to the primary coil.
- Vary the number of turns on the primary and secondary coils using the 60, 120, 250 and 500 turn coils provided.
- For each set up measure the primary and secondary voltages.
- Take at least five different sets of results.
- Present your results in a table.
- Find the relationship between the quantities.

ACTIVITY 15

Title: **Transformers**

Aim: To compare the input and output power of a transformer.

Apparatus: One mains ammeter, 12 V ac supply (transformer), one voltmeter, one ammeter, two 12 V bulbs (36 W, 24 W).



Instructions

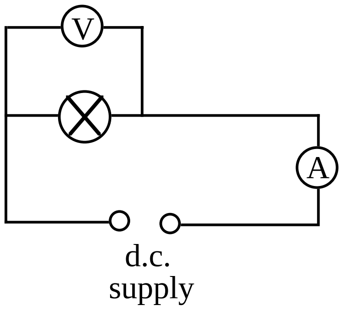
- Note the values of the input and output currents and voltages.
- Calculate the input and output powers.
- Repeat with a 24 W bulb.
- Tabulate your results.
- In which case is the transformer more efficient?
- Is this an **ideal** transformer?

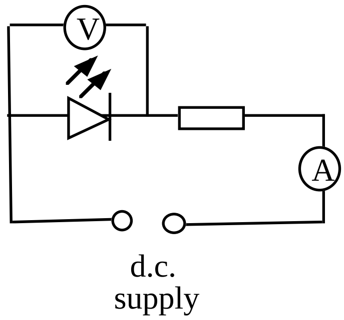
ACTIVITY 16

Title: **LEDs and Bulbs**

Aim: To compare the properties of an LED and bulb.

Apparatus: One voltmeter, one ammeter, one 6 V bulb, d.c. supply, mounted LED plus component holder (Unilab).





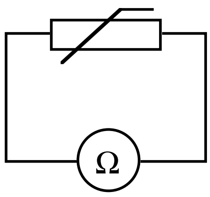
Instructions
- Set up the circuits, in turn, as shown above.
- Turn the supply to 5 V.
- Measure the current through and the voltage across the bulb and LED.
- Reverse the supply voltage in each case.
- Examine the filament and the LED with a magnifying glass.
- Tabulate your results.
- State the main differences between an LED and a bulb.

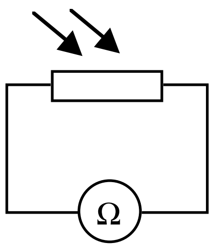
ACTIVITY 17

Title: **Thermistors and Light Dependent Resistors (LDR)**

Aim: To investigate the properties of a thermistor and an LDR.

Apparatus: One LDR, one thermistor and one ohmmeter.





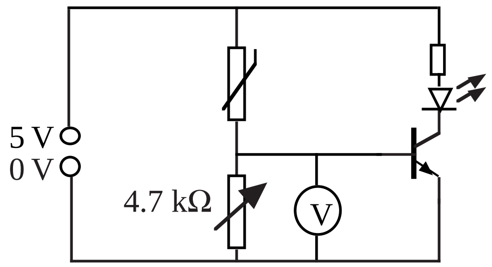
Instructions
- Connect a thermistor to an ohmmeter.
- Adjust the scale until a reading is obtained.
- Gently hold the thermistor with you fingers and note what happens to its resistance.
- Repeat the procedure with an LDR, noting its resistance in bright and dark conditions.
- Write down any rules that govern the resistance of each device.

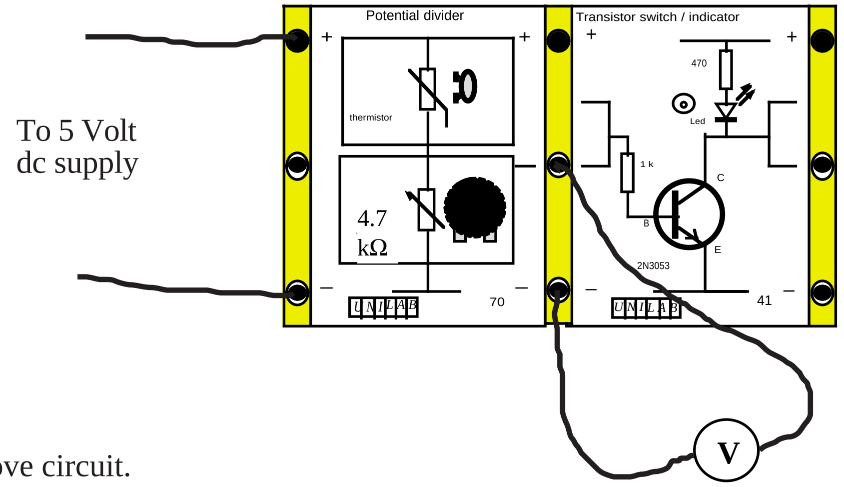
ACTIVITY 18

Title: **Transistors**

Aim: To investigate the switching action of an npn transistor.

Apparatus: See below.





Instructions

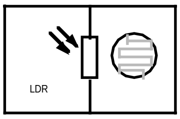
- Set up the above circuit.
- Adjust the variable resistor until the LED just goes out.
- **Gently** hold the thermistor with your fingers and note the voltmeter reading just as the LED lights.
- Explain how the circuit works.
- Design a circuit which would switch on a fan (motor) at a certain temperature. State any additional apparatus required.
- Draw a circuit diagram which would allow the LED to come on when the temperature **falls.**
- Explain how this circuit functions.

ACTIVITY 19

Aim: To investigate the switching action of a transisitor used in conjunction with a light sensor.

Instructions

- Using the same circuit replace the thermistor with an LDR.
- Adjust the variable resistor until the LED just goes on.
- Now cover the LDR.
- Draw this circuit and explain how it works.
- Build a circuit which would allow an LED to come on in the dark.

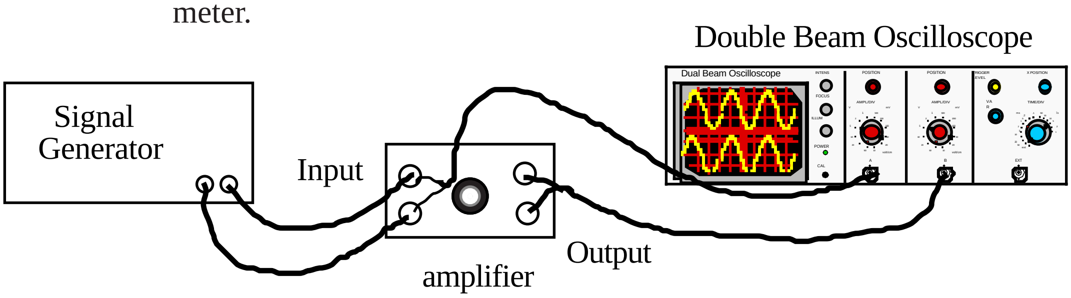


ACTIVITY 20

Title: **Amplifiers**

Aim: a) To compare the output and input signal of an audio amplifier.
b) To calculate the voltage gain of an amplifier.

Apparatus: One signal generator, one amplifier and one double beam oscilloscope a.c. meter.



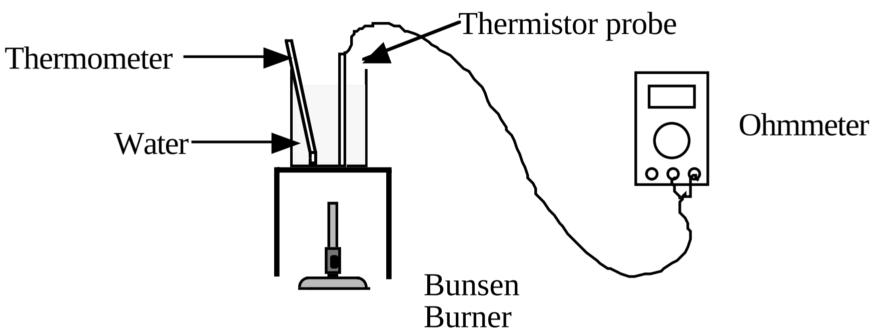
Instructions

- Set up the above circuit.
- Measure the peak voltages of the input voltage and the output voltage. (Use the Y-gain controls).
- Calculate the voltage gain of the amplifier.
- Make a note of how the input and output frequencies compare.
- Vary the input voltage and note the corresponding output voltage. (Use an a.c. meter to make these measurements)
- Plot a graph of output voltage against input voltage.

ACTIVITY 21

Title: **Variation of Resistance of Thermistor with Temperature** (Outcome 3)

Apparatus: Bunsen burner, tripod stand, beaker, thermometer, thermistor and ohmmeter.



Instructions

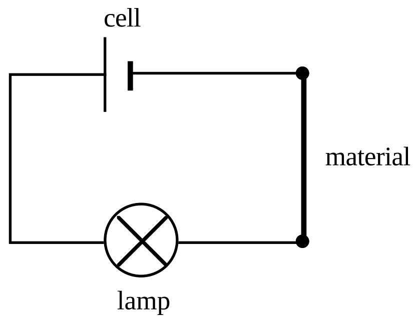
- Set up the apparatus as shown.
- Vary the temperature of the water using a gentle bunsen flame.
- Note the temperature and the resistance of the thermistor.
- Repeat for intervals of 10 $^{\circ}$C.
- Use an appropriate format to show the variation of the resistance of the thermistor with temperature.

ADDITIONAL ACTIVITY 1

Title: **Conductors and Insulators**

Aim: To determine whether a material is an electrical conductor or an insulator.

Apparatus:



Instructions

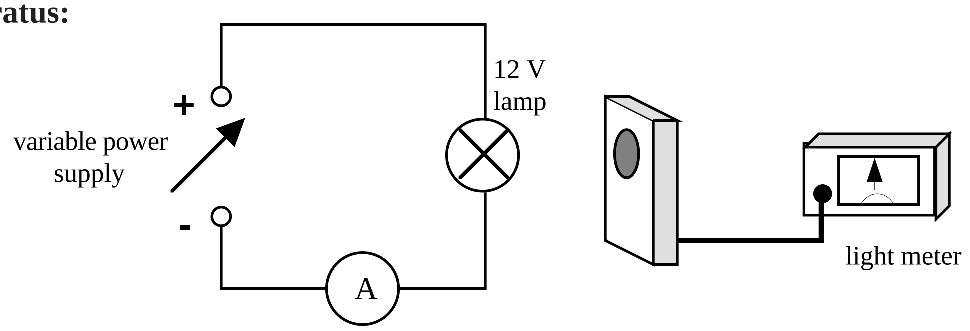
- Set up the simple circuit above using the equipment shown.
- For each of the material samples given, identify whether it is a conductor or insulator.

ADDITIONAL ACTIVITY 2

Title: **Lamp Brightness and Supply Current**

Aim: To investigate how the brightness of a lamp varies as the current through the lamp is varied.

Apparatus:



Instructions

- Set up the simple circuit above using the equipment shown.
- Place the light meter close to the lamp and keep it in the same position.
- Adjust the power supply to find the maximum and minimum currents through the lamp that will light the lamp.
- For 5 evenly spaced values of current, measure the brightness of the lamp using the light meter. Do not move the light meter between readings.
- Explain any change in brightness of the lamp with current in terms of the energy supplied by the power supply.

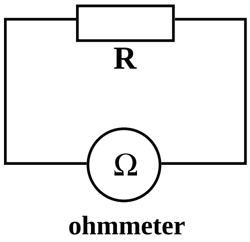
ADDITIONAL ACTIVITY 3

Title: Voltage, Current and Resistance

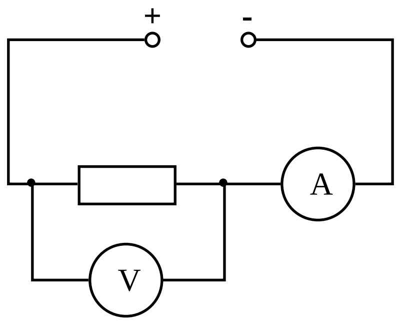
Aim: To find the relationship between the resistance, voltage and current.

Apparatus: Set of resistors of different resistance values.

Circuit 1



Circuit 2



Instructions

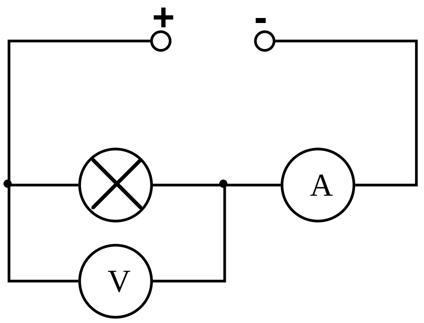
- Set up Circuit 1 above to measure the resistance of each of the resistors.
- Record the resistance of each of the resistors.
- Set up Circuit 2 above with the first of the resistors in the circuit.
- Measure the current through the resistor and the potential difference across it.
- Record the values of the current and the corresponding potential difference.
- Repeat for the other resistors.
- For each of the resistors, calculate the ratio **V/I**.
- Compare with the resistance value as measured in Circuit 1.

ADDITIONAL ACTIVITY 4A

Title: Electrical Power

Aim: To verify the relationship between power, current and voltage.

Apparatus: 3 ×12 V lamps of power ratings 5 W, 24 W and 36 W.



Instructions

- Set up the circuit above and switch on.
- Adjust the power supply until the voltmeter reads 12 V. The lamp is now working at its correct voltage.
- Record the voltage and current values in the table below and show that your results verify the relationship between power, current and voltage.

Lamp Rating (W)	Voltage (V)	Current (A)	V x I
5			
24			
36			

ADDITIONAL ACTIVITY 4B

Title: Other Power Equations

Aim: To verify the relationships between power, current, voltage and resistance.

Instructions

- Using your results from Activity 2A, complete the following table.

Lamp	Voltage (V)	Current (A)	Resistance (Ω)	$V \times I$	$I^2 R$	$\frac{V^2}{R}$
5 W						
24 W						
36 W						

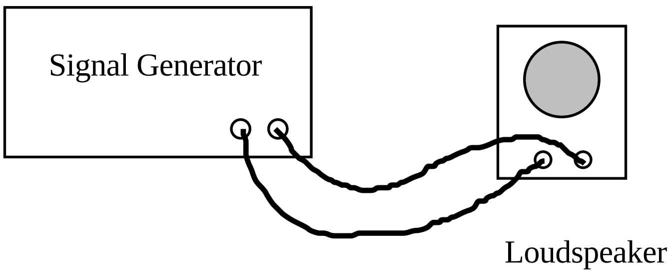
- Compare the value of each of the terms **V I**, I^2R and $\frac{V^2}{R}$ to the power rating of the lamp.

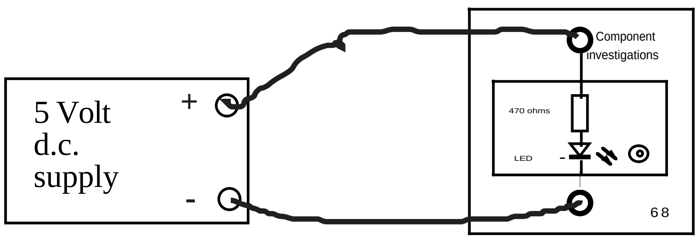
ADDITIONAL ACTIVITY 5

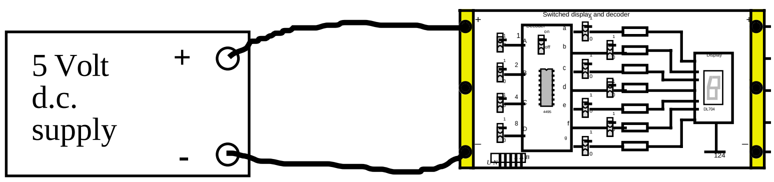
Title: **Electronic Components**

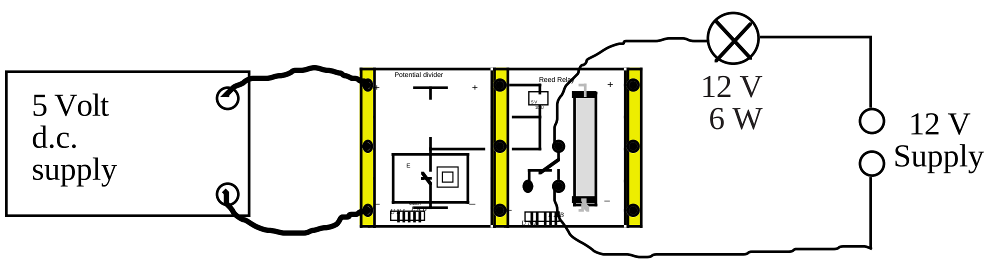
Aim: To examine some output devices and state the energy changes involved.

Apparatus: One signal generator, one loudspeaker, 5 V d.c. supply, Unilab component holder and LED, one seven-segment display, one relay switch, 12 V supply and a 12 V, 6W bulb.









Instructions

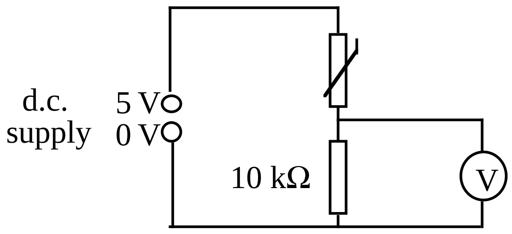
- Set up the apparatus shown above.
- Draw the symbols for a speaker, an LED and a relay switch.
- Write down the energy changes for each.

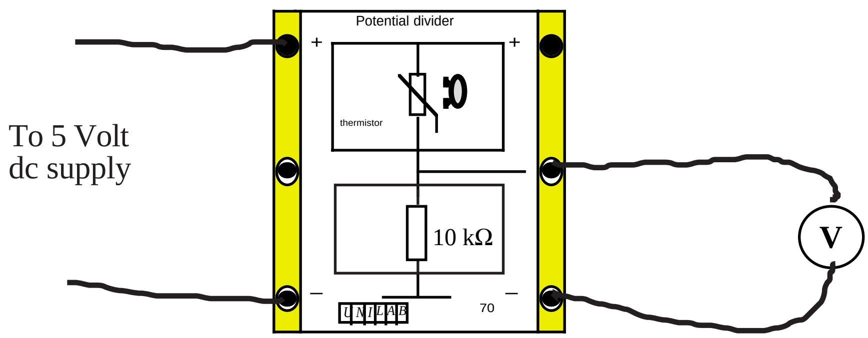
ADDITIONAL ACTIVITY 6A

Title: **Thermistors and LDRs in Potential Divider Circuits**

Aim: To monitor the voltage across a potential divider circuit containing a thermistor.

Apparatus: See below





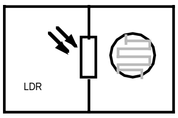
Instructions

- Set up the circuit as shown above.
- Warm the thermistor with your fingers and note what happens to the voltmeter reading.
- Repeat after swapping the positions of the resistor and the thermistor.
  Explain your results.

ADDITIONAL ACTIVITY 6B

Aim: To monitor the voltage across a potential divider circuit containing an LDR.

Instructions



- Repeat Activity 23A using an LDR in place of the thermistor.
- Also replace the10 kΩ resistor with one of value 1kΩ.
- Explain what happens to the voltmeter reading in dark and bright conditions.

CIRCUITS PROBLEMS

Electric Current

1. a) Explain what is meant by the term ‘electric current’.
   b) Write down the relationship between charge and electric current.
   c) Give the names of the units used to measure the three quantities.

2. One bar of an electric heater draws a current of 4 A from the mains supply.
   a) How much charge flows through the bar each minute?
   If a second bar is switched on, the charge flowing through the bar each minute increases to 440 C.
   b) Calculate the new current drawn from the mains when both bars are switched on.

3. The manufacturer of the battery in a car states that the battery is rated at 40 ampère-hours. This is one way of telling the user how long the battery will be able to provide electric current to operate appliances.
   eg. this could deliver 40 A for 1 hour or 8 A for 5 hours etc.
   a) Calculate the total charge that this battery can deliver, in coulombs.
   b) The parking lights of the car draw a current of 2 A from the battery. If these lights were left on when the car was parked, calculate the minimum time it would take for the battery to go flat.
   c) State any assumption you are making in your answer to part b).

Conductors and Insulators

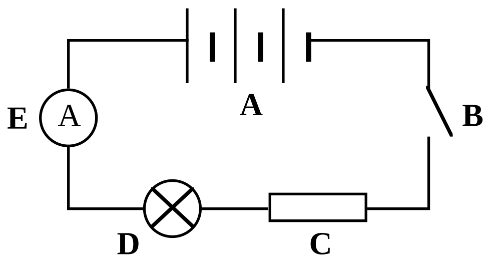
4. The following set of items have to be divided into conductors and insulators.
   paper clip, rubber, pencil refill ‘lead’, wooden ruler, scalpel, glass rod, tongs
   a) Describe a simple experiment which you could carry out to determine whether the items were conductors or insulators.
   b) i) What family of materials, in general, do all conductors fall into?
   ii) What item in the above list is the exception to this ‘rule’?

Voltage and Current

5. a) Describe the difference between the voltage (or potential difference) and the current in a circuit.
   b) Give the name of the unit used to measure voltage or potential difference.

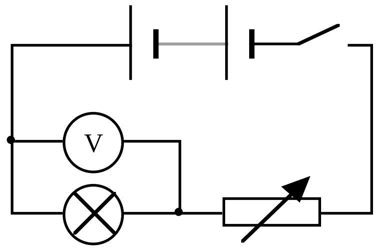
Circuits, Symbols and Meters

6. a) In the circuit below, name the components labelled A, B, C, D and E.



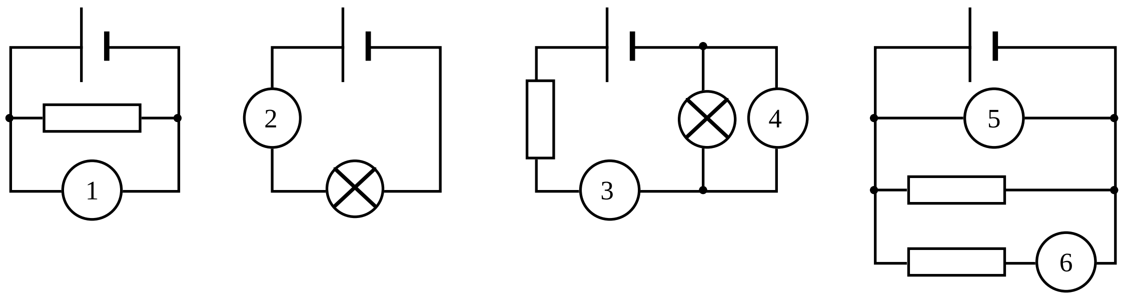
b) State whether this is a series or parallel circuit.

7. Look at the circuit below.



a) Write down the names of the components that are connected in series.
b) Write down the names of the components that are connected in parallel.

8. In the circuits below, identify the meters 1, 2, 3, 4, 5 and 6.



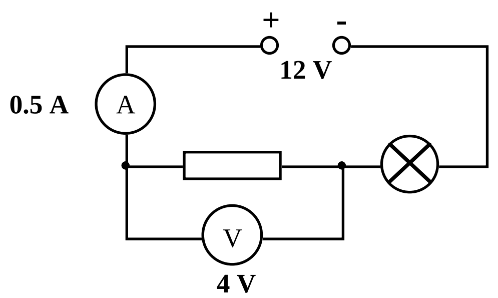
9. a) Write down the rule for the current at all points in a series circuit.
b) Write down the relationship between the supply voltage and the potential differences (voltages) across the individual components in a series circuit.

10. a) Write down the relationship between the supply current and the currents in the branches of a parallel circuit.
b) Write down the potential difference (voltage) rule for all components that are connected in parallel.

11. a) Which of the following statements is/are true for **series** circuits.
b) Which of the following statements is/are true for **parallel** circuits.

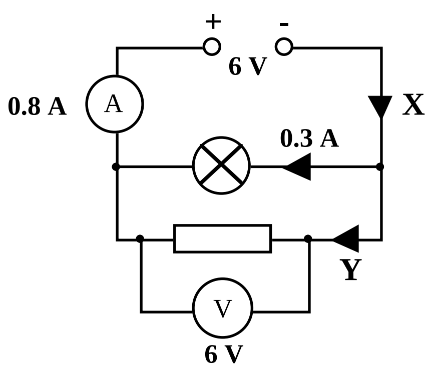
A There is only one pathway round the circuit.
B There is more than one pathway around the circuit.
C The potential differences around the circuit add up to the supply voltage.
D The potential difference (voltage) is the same across all components.
E The current is the same at all points in the circuit.
F The current through each component adds up to the supply current.

12. In the circuit below the ammeter reading is 0.5 A and the voltmeter reading is 4 V.



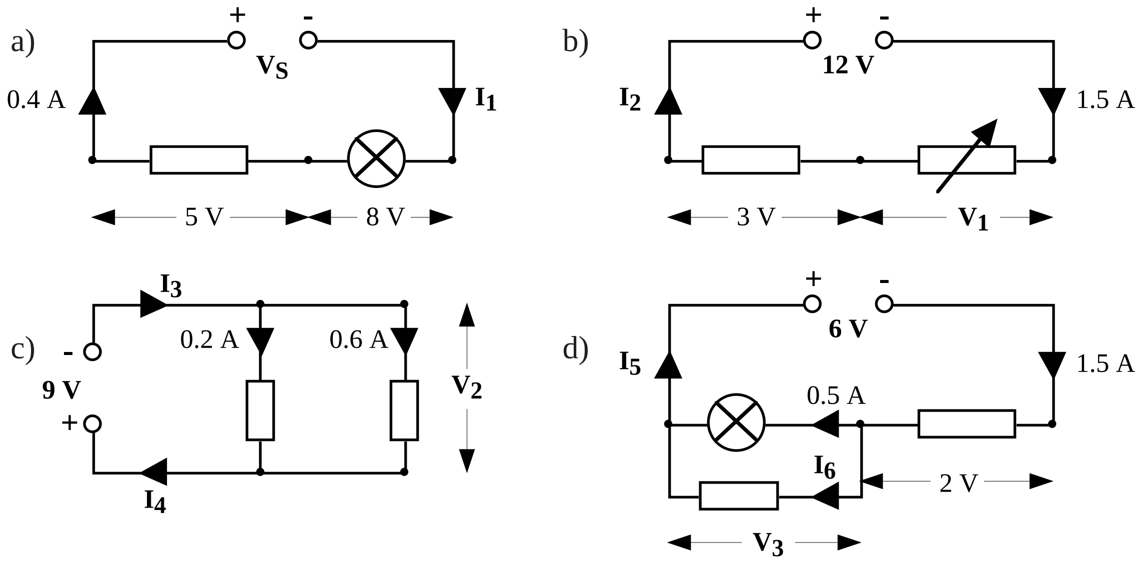
a) State whether this is a series circuit or a parallel circuit.
b) i) What is the current through the lamp?
ii) What is the potential difference across the lamp?

13. In the circuit below the ammeter reads 0.8 A, the current through the lamp is 0.3 A and the voltmeter reads 6 V.



a) Is this a series or a parallel circuit?
b) i) What are the current values at **X** and at **Y**?
ii) What is the potential difference across the lamp?

14. Find the missing currents and voltages in the following circuits.



Electrical Resistance

15. Rewrite the following list of potential differences (voltages) in millivolts and arrange in order of increasing value.

    0.65 V, 980 mV, 0.07 V, 3.2 V, 2963 mV

16. Rewrite the following list of currents in amperes and then arrange in order of increasing value.

    5805 mA, 2 mA, 29 mA, 120 A, 8.9 A, 0.03 A

17. In a series circuit, the ammeter reading was noted for different values of resistor in the circuit.
    a) Which electrical quantity does the ammeter measure?
    b) Copy and complete the table below, placing the ammeter readings in the correct order.
    0.6 A, 2.4 mA, 1.2 A, 240 mA.

Resistor (Ω)	Current ( )
5	
10	
20	
2.5 k	

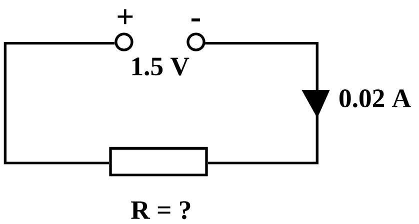
18. The current in a lamp bulb was 2 A when connected to a 12 V battery. Calculate the resistance of the lamp bulb.

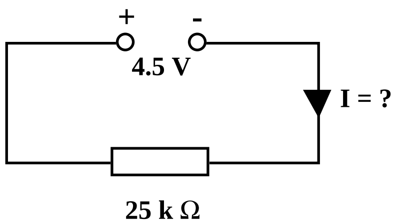
19. When connected across a 3 V supply, the current in a resistor was 60 mA. What is the value of the resistor?

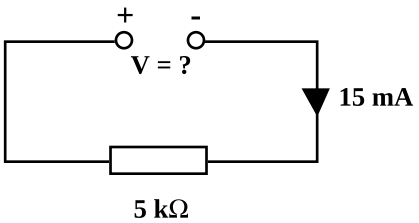
20. A 220 Ω resistor is connected across a 2 V supply. What is the current in the resistor?

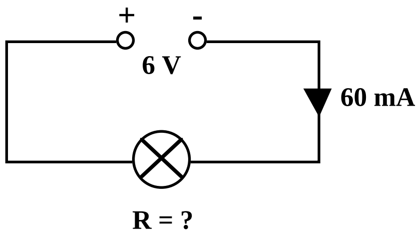
21. A 12 V transformer is connected to a circuit of resistance 1.2 kΩ. What is the current in the circuit?

22. Calculate the missing quantities in the circuits below.

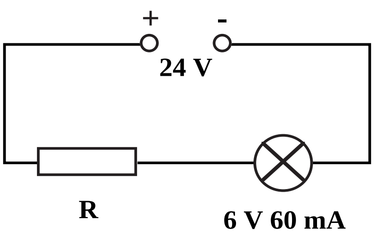
a)


b)


c)


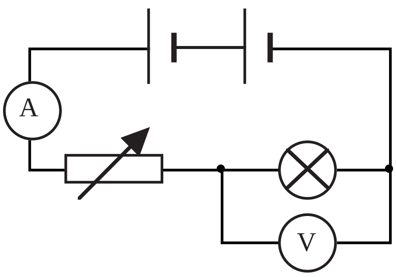
d)


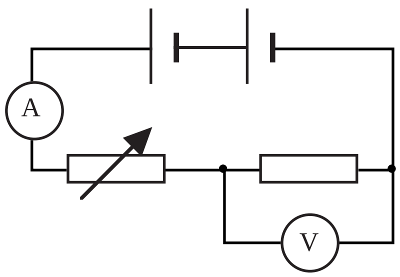
23. The diagram below shows a 6 V 60 mA lamp working off a 24 V supply.



a) What must be the potential difference across the resistor if the lamp is operating correctly?
b) Calculate the value of the resistance of resistor R.

24. Potential difference and current were measured in both circuits below for different values of current





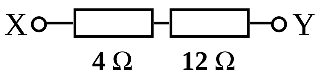
The results for each circuit are shown over the page.

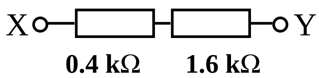
V (V)	I (A)	V/I (ohms)
2.4	0.24	
3.1	0.30	
3.6	0.34	
4.8	0.40	

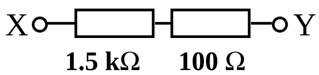
V (V)	I (A)	V/I (ohms)
2.4	0.24	
3.0	0.30	
3.4	0.34	
4.0	0.40	

a) Copy and complete both tables.
b) What is the purpose of the variable resistor in the above circuits?
c) What conclusion can be drawn about the resistance of the lamp bulb as the current increases?
d) What conclusion can be drawn about the resistance of the resistor as the current increases?
e) **Explain** the difference in the behaviour of the lamp bulb and the resistor as the current increases.

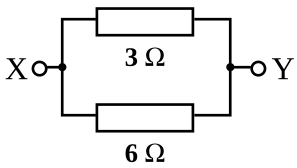
25. Calculate the total resistance between X and Y for the following.

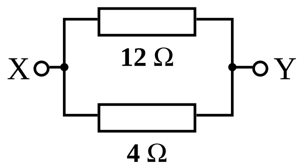
a)


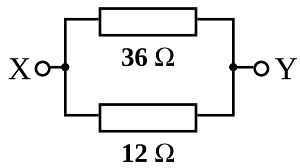
b)


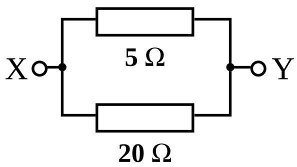
c)


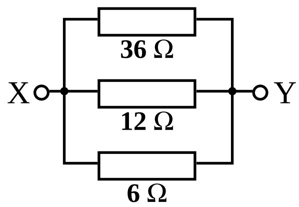
26. Calculate the total resistance between X and Y for the following circuits.

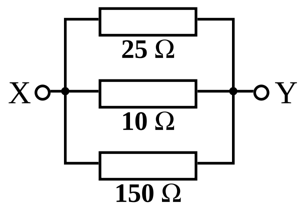
a)


b)


c)


d)


e)


f)


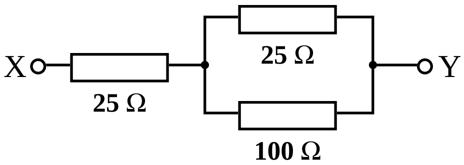
27. a) What will be the resistance of ten 20 Ω resistors when they are connected in **series**?
b) What will be the resistance of ten 20 Ω resistors when they are connected in **parallel**?

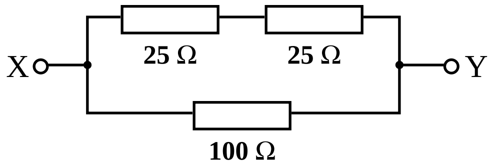
28. You are given the four resistors below.
1 Ω, 10 Ω, 100 Ω, 1000 Ω

a) What is their total resistance when they are connected in series?
A less than 1 Ω
B between 1 Ω and 10 Ω
C between 10 Ω and 100 Ω
D between 100 Ω and 1000 Ω
E greater than 1000 Ω

b) What is their total resistance when they are connected in parallel?
   A less than 1 Ω
   B between 1 Ω and 10 Ω
   C between 10 Ω and 100 Ω
   D between 100 Ω and 1000 Ω
   E greater than 1000 Ω

29. Calculate the resistance between X and Y in the following resistor networks.

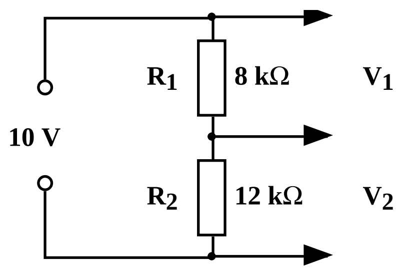
a)


b)


Potential Divider Circuits

30. State what is meant by a potential divider circuit.

31. The following potential divider circuit was set up using the values shown.



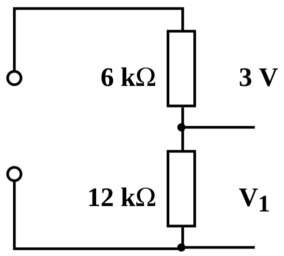
a) Calculate the current in the circuit through R_1 and R_2.

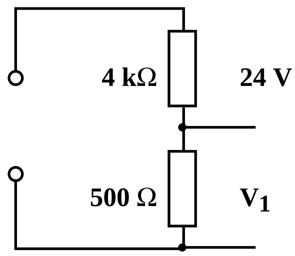
b) Calculate the value of the potential differences (voltages) V_1 and V_2, across each resistor.

c) Use your results to show that the relationship $\frac{V_1}{V_2} = \frac{R_1}{R_2}$ is true.

d) Use your results to show that the relationship $V_1 = \frac{R_1}{R_1+R_2} V_S$ is also true.

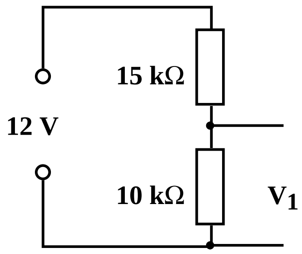
32. Calculate the value of V_1 in the following circuits.

a)


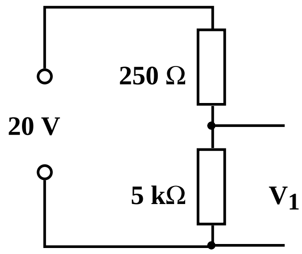
b)


33. Calculate the value of V_1 in the following circuits.

a)

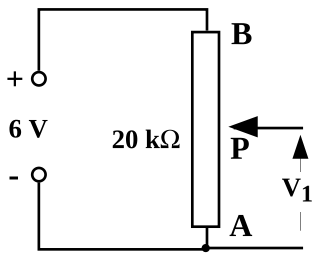


b)



34. A fixed 6 V d.c. power supply has to be reduced to give constant output of 1.5 V using a potential divider.
Design a potential divider circuit that will give a constant output of 1.5 V from the 6 V supply.

35. A 20 kΩ potentiometer AB is connected across a 6V d.c. power supply as shown below.



The sliding contact, P, can be moved to any point along the potentiometer AB.

a) What will be the output voltage, V_1, when the sliding contact, P, is at
   i) position A
   ii) position B
   iii) midway between A and B?

b) What would be the output voltage, V_1, if the sliding contact P was one third of the length along the potentiometer from A?

c) What would be the resistance between points A and P if the potentiometer was adjusted to give an output voltage of 3.5V?

ELECTRICAL ENERGY PROBLEMS

Power and Energy

36. a) If an electric current is passed through a conducting wire, what energy transformation takes place?
    b) Many electrical appliances in the home are designed to make use of this energy transformation. Name four of these appliances.

37. A light bulb has a power rating of 60 W.
    a) How much electrical energy is transformed by the bulb in 1 s?
    b) State the energy changes involved when the lamp is switched on.

38. The electric motor on a ceiling fan uses 207 kJ of electrical energy in 30 minutes.
    a) Calculate the power rating of the motor in the fan.
    b) State the energy changes involved when the ceiling fan is switched on.

39. How much electrical energy is used by the following appliances?
    a) A 400 W drill used for 45 s
    b) A 300 W food processor used for 20 s
    c) An 800 W iron used for 40 minutes
    d) A 2.4 kW kettle that takes 5 minutes to boil the water inside it.

40. What is the power rating of an appliance which transforms -
    a) 500 J in 5 s
    b) 1200 J in 20 s
    c) 1.8 MJ in 10 minutes?

41. How long would a 2 kW electric kettle take to boil the water inside if it uses 100 kJ of electrical energy?

Power, Current, Potential Difference or Voltage and Resistance

42. a) Draw a circuit diagram to show how you would measure the power output of a lamp bulb using a voltmeter and ammeter.
    b) If the meter readings were 6 V and 600 mA, what would be the power of the lamp?
    c) How much energy would this lamp use in 1 hour?

43. A colour television set is rated at 300 W.
    a) Calculate the current drawn by the television when connected to the 230 V mains supply.
    b) How much energy would this television use if it was left on overnight for 8 hours?

44. a) Using the equations V = IR and P = VI, show that if a current I flows through a heating element of resistance R, the power of the heater is given by $P = I^2R$.
    b) What is power rating of a 30 Ω heating element when 8 A passes through it?

45. Calculate the power rating of the following devices in a car -
    a) A radio of resistance 6 Ω drawing a current of 2 A.
    b) the rear window heater of resistance 3 Ω drawing a current of 4 A.

46. An electric fire is rated at 2 kW, 230 V.
   a) What is the current in the heating element when it is switched on?
   b) Calculate the resistance of the heating element.

47. A 100 Ω resistor has a maximum safe power rating of 4 W. Calculate the maximum current it can safely handle.

48. Calculate the resistance of a hairdryer element which has a power rating of 960 W when drawing a current of 4 A.

49. By combining the equations V = IR and P = VI, show that the power can also be given by $P = \frac{V^2}{R}$.

50. Calculate the power rating of a heater which has a resistance of 53 Ω working off the mains voltage of 230 V.

51. The fuses used in electrical plugs in the UK come in 2 main sizes - 3 A and 13 A.
   a) What is the purpose if the fuse in the plug connected to an appliance?
   b) What energy change does a fuse depend on to work correctly?
   c) Complete the table below and select which of the above fuses would be most suitable for each of the appliances.

Appliance	Power	Voltage (V)	Current (A)	Most suitable fuse
Food Mixer		230	0.3	
Lamp	100 W	230		
Heater	2.5 kW	230		
Hi-fi unit		230	1.5	

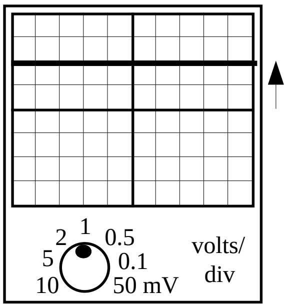
52. A current of 6 A flows along a flex of total resistance 0.2 Ω to an electric heater which has an element of resistance 60 Ω.
   a) Calculate the heat generated each second in
      i) the flex
      ii) the element.
   b) i) What energy change is taking place in both the flex and the element?
      ii) Why does the element become hot and the wire remain cool?
   c) i) What size of fuse, 3 A or 13 A, should be fitted to the plug connected to this heater?
      ii) Explain what would happen if the wrong fuse was fitted to the plug.

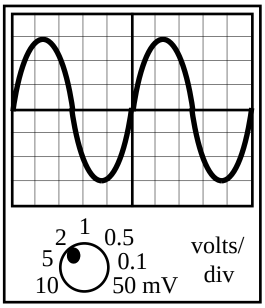
A.C. or D.C.

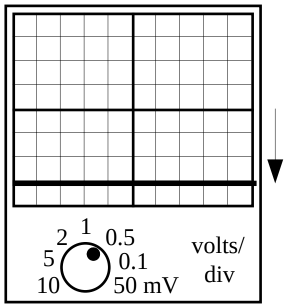
53. Explain the difference between a.c. and d.c. Your answer should state what is represented by the terms a.c. and d.c. and include the words ‘electron’ and ‘direction’.

54. Give two examples each of
   a) a.c. power supplies
   b) d.c. power supplies.

55. a) For each of the following traces shown, state whether they are a.c. or d.c..

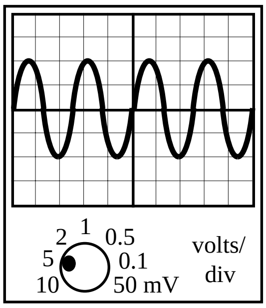
i)


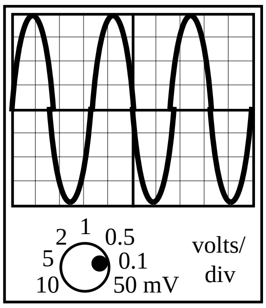
ii)


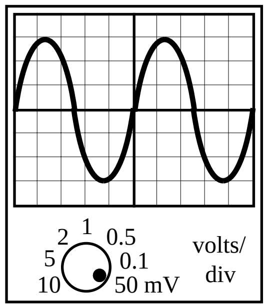
iii)


55. b) Calculate
    i) the applied voltage for trace i) where the Y-gain setting is set at 1 V/division
    ii) the applied voltage for trace iii) where the Y-gain setting is set at 0.5 V/division
    iii) the peak voltage for trace ii) where the Y-gain setting is set at 2 V/division.

56. Calculate the peak voltages of the traces below using the Y-gain settings shown.

a)


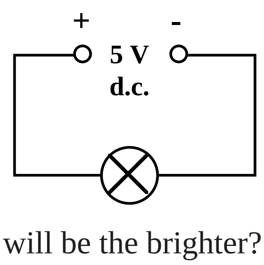
b)


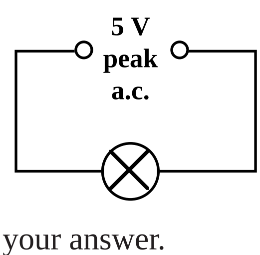
c)


57. a) State whether the mains supply is a.c. or d.c..
    b) What is the frequency of the mains supply?

58. Trace a) in question 21 is produced from the mains supply. If the settings on the oscilloscope are not changed, sketch the trace that would be produced by the following a.c. supplies.
    a) Peak voltage 5 V at a frequency of 25 Hz
    b) Peak voltage 20 V at a frequency of 75 Hz.

59. Two identical bulbs are lit by the supplies shown below.





    a) Which bulb will be the brighter? Explain your answer.

b) The d.c supply is altered so that both bulbs have the same brightness. The a.c. supply remains at the 5 V peak value.
Was the d.c. supply increased or decreased?

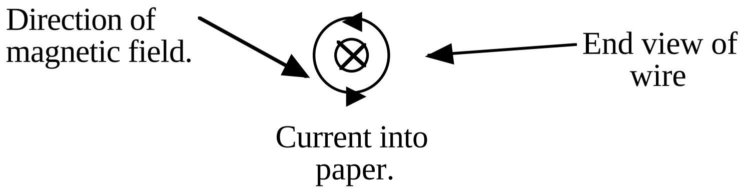
60. An a.c. supply is labelled 12 V. The peak voltage is measured using an oscilloscope.
a) Which of the following is likely to be the measured peak voltage:
17 V, 12 V, 8.5 V, 6 V?
b) Explain your answer.

61. The mains supply is quoted as 230 V.
If connected to the mains supply, which of the following devices would display a value of 230 V:
a) an oscilloscope
b) an a.c. voltmeter?

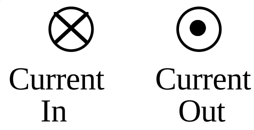
62. Briefly explain the meaning of the term ‘effective voltage’ which is applied to an a.c. supply.

ELECTROMAGNETISM PROBLEMS

63. The diagram below shows the direction of a magnetic field around a current carrying wire.



a) Copy and complete the diagram below showing the direction of the magnetic fields around both current carrying wires.



b) If the wires are free to move, suggest what might happen.
(Remember the arrows point in the direction of North to South)

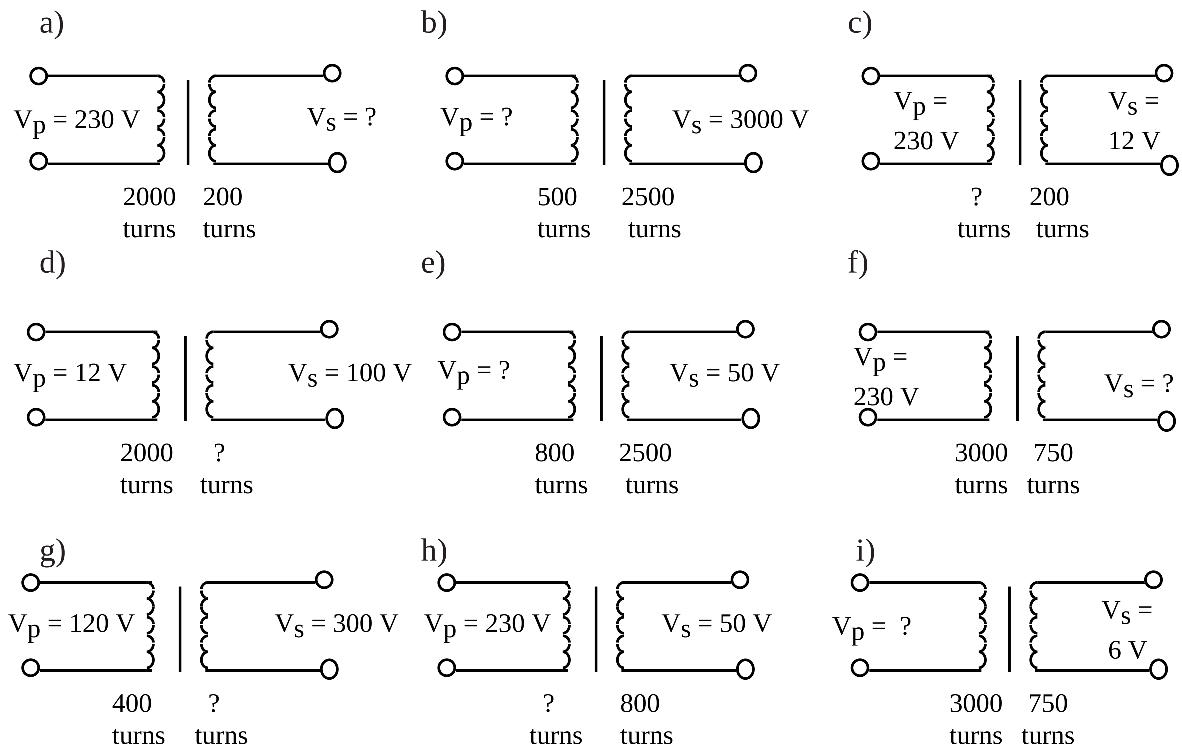
64. a) Explain how a voltage could be induced in a coil of wire.
b) Give three methods of increasing the size of this induced voltage.

65. Give 4 uses of transformers in every day life.

66. Explain why a transformer will only give a continuous output when used with a.c.

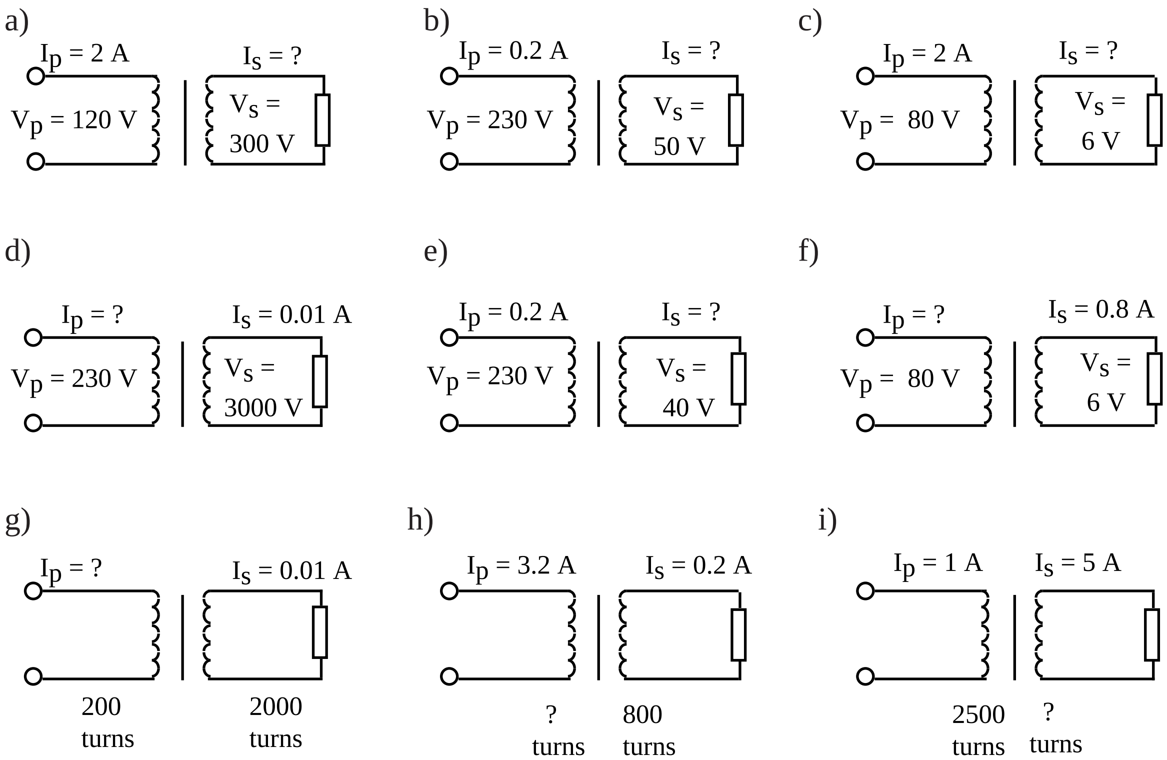
67. Write down the relationship between the voltages and number of turns in the coils of a transformer.

68. Use the above relationship to solve the problems below:



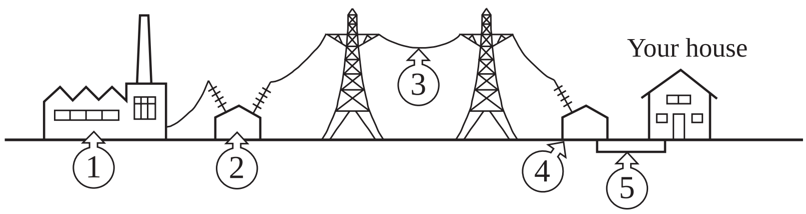
69. Describe what is meant by an ideal transformer.

70. Assuming the transformers below to be ideal, calculate the unknown values in each case.

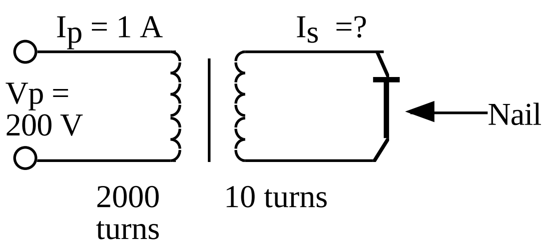


71. An engineer requires a transformer to step down a voltage from 3000 V to 230 V. Calculate the required turns ratio.

72. The diagram below represents thow electricity reaches our homes. Name and state the pupose of numbers 1, 2, 3,4 and 5.



73. The transformer below can be used to generate very high temperatures in the nail attached to the output of the secondary coil. Explain how this can be possible despite it being a step down transformer.

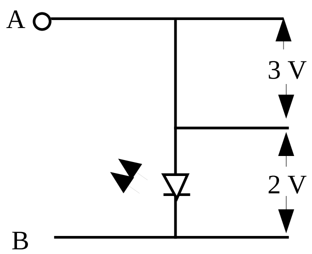


ELECTRONIC COMPONENT PROBLEMS

74. Draw the symbols for
    a) a relay switch
    b) a loudspeaker
    c) an LED.

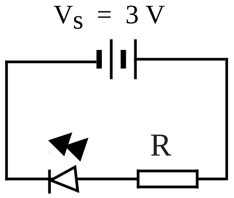
75. Why must a resistor be connected in series with a light emitting diode when using a 5 V supply?

76. An LED and resistor are connected in series to a 5 V supply as shown. The maximum allowed current through the LED is 12 mA. The voltages are given.



    a) +5 V and 0 V are to be connected to the circuit. Which will be connected to A and B if the LED is to light?
    b) Calculate the maximum current through the resistor.
    c) What is the value of the resistor needed to protect the LED?

77. An LED is connected as shown and the following data for the LED is shown.



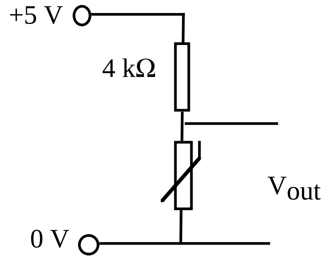
I_{max} = 20 mA
V_{max} = 1 V

Calculate the least value of resistance of the resistor R, placed in series with the LED, which would allow it to work properly.

78. Calculate the following protective resistors from the following data.
    a) V_s = 6 V LED (V_{max} = 1.5 V I_{max} = 50 mA).
    b) V_s = 10 V LED (V_{max} = 2.0 V I_{max} = 100 mA).
    c) V_s = 5 V LED (V_{max} = 1.5 V I_{max} = 50 mA).

79. State what happens to the resistance of:
    a) a thermistor subjected to increasing temperature
    b) an LDR as the light intensity falling on it increases.

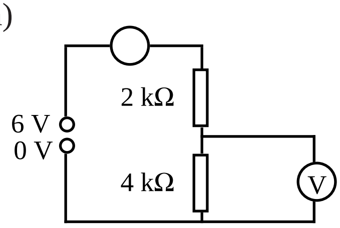
80. a) A thermistor is connected in series to a resistor is connected to a 5 V supply as shown. What will happen to the output voltage as the temperature of the thermistor rises?



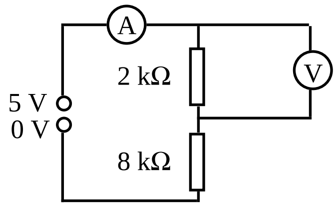
b) What difference would there be to the output voltage if the thermistor and the 4 kΩ resistor were interchanged?

81. Calculate the current and voltage reading in the following circuits.

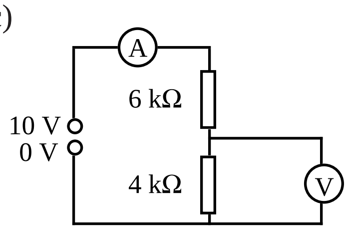
a)



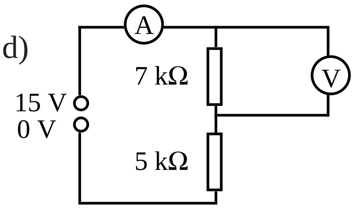
b)



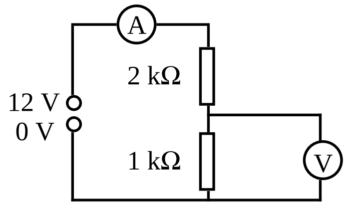
c)



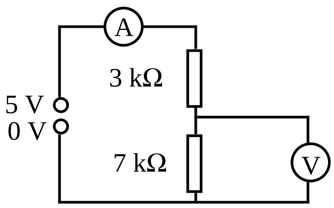
d)



e)

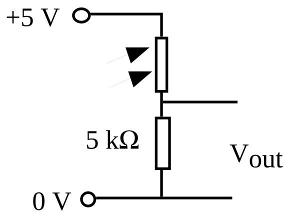


f)



82. An LDR is connected to a 5 kΩ resistor as shown.
The values of its resistance for particular conditions are shown below.

Condition	Resistance
Light	100 Ω
Dark	20 kΩ

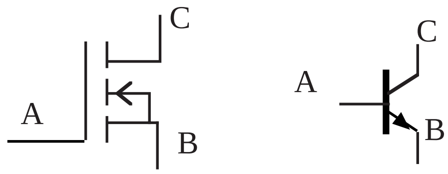


What will be the output voltage when the LDR is
a) in the dark b) in sunlight?

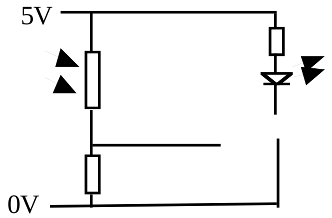
83. a) An LDR of resistance 100 kΩ in darkness is placed in series with a 1 kΩ resistor. The supply voltage is 6 V d.c.
i) Draw the above circuit.
ii) Calculate the voltage across each component.

b) The LDR is placed in the light giving it a resistance of 4 kΩ. Calculate the new voltage cross each component.

84. The diagrams opposite show two different types of transistors.
a) Copy and name each symbol.
b) Label points A, B and C.

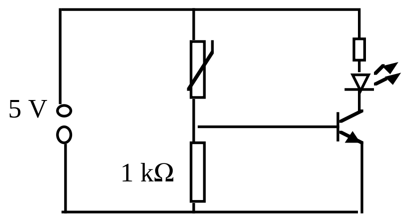


85. A circuit which automatically switches on in light conditions is shown with one important component missing



a) Copy and complete the diagram, adding the missing component.
b) Explain how the circuit works.

86. The circuit below shows a temperature sensing device.



a) Calculate the voltage across the base-emitter of the transistor:
 i) in the cold when the resistance of the thermistor is 9 kΩ.
 ii) at 100 °C when its resistance is 1 kΩ.
b) Hence explain how the circuit works.
c) How could you alter the sensitivity of the device?

87. Design a circuit which would allow an LED to light when it gets too dark.

88. State the energy changes for the following input devices.
a) a microphone b) a thermocouple c) a solar cell.

89. State the purpose of an amplifier.

90. Give four examples of electronic systems that use amplifiers.

91. Explain why a good audio amplifier should only increase the amplitude of the input signal and not the frequency.

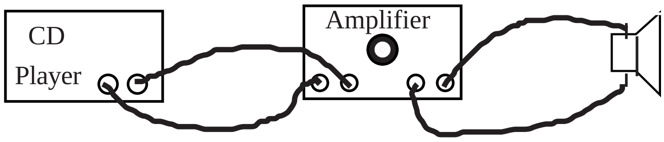
92. State the expression for the voltage gain of an amplifier.

93. An amplifier has a gain of 20. Calculate the output voltage if the input voltage is 200 mV.

94. Find the unknown values using the expression for the gain of an amplifier.

a) Gain = 200 V_{in} = 5 mV V_{out} = ?
b) Gain = ? V_{in} = 10 mV V_{out} = 5 V ?
c) Gain = 200 V_{in} = ? V_{out} = 1.5 V

95. Describe how the voltage gain of the amplifier shown below could be measured experimentally.



Your description should include

i) a diagram showing any extra apparatus required
ii) the measurements taken
iii) how you would use these measurements to calculate the gain. (Note the input and output will be a.c.).

NUMERICAL ANSWERS

Circuits

2. a) 240 C b) 7.3 A
3. a) 144 000 C b) 72 000 s or 20 hours c) constant current
4. b) i) metals ii) pencil 'lead' is carbon
11. a) A, C, E b) B, D, F
12. a) series b) 0.5 A c) 8 V
13. a) parallel b) i) X: 0.8 A, Y: 0.5 A c) 6 V
14. a) $I_1 = 0.4$ A b) $V_1 = 9$ V, $I_2 = 1.5$ A
    c) $I_3 = 0.8$ A, $I_4 = 0.8$ A, $V_2 = 9$ V d) $I_5 = 1.5$ A, $I_6 = 1$ A, $V_3 = 4$ V
15. 70 mV, 650 mV, 980 mV, 2963 mV, 3200 mV
16. 0.002 A, 0.029 A, 0.03 A, 5.805 A, 8.9 A, 120 A
17. a) current b) 1.2 A, 0.6 A, 240 mA, 2.4 mA down the table
18. 6 Ω
19. 50 Ω
20. 0.009 A
21. 0.01 A
22. a) R = 75 Ω b) $I = 1.8\times10^{-4}$ A c) V = 75 V d) R = 100 Ω
23. a) 18 V b) 300 Ω
24. a) Table 1: 10, 10.3, 10.6, 12 down the table
    Table 2: 10 for all entries down the table
25. a) 16 Ω b) 2 kΩ c) 1.6 kΩ
26. a) 2 Ω b) 3 Ω c) 9 Ω d) 4 Ω e) 3.6 Ω f) 6.8 Ω
27. a) 200 Ω b) 2 Ω
28. a) E b) A
29. a) 45 Ω b) 33 Ω
31. a) $5\text{x}10^{-4}$ A or 0.5 mA b) $V_1 = 4$ V, $V_2 = 6$ V
32. a) $V_1 = 6$ V b) $V_1 = 3$ V
33. a) $V_1 = 4.8$ V b) $V_1 = 19$ V
35. a) i) $V_1 = 0$ V ii) $V_1 = 6$V iii) $V_1 = 3$ V b) $V_1 = 2$ V c) $R_{AP} = 11.7$ kΩ

Electrical Energy

37. a) 6 J
38. a) 100 W b) 60 W c) 3000 W
39. a) 115 W
40. a) 18000 J b) 6000 J c) 1.92×10^{6} J d) 7.2×10^{8} J
41. 50 s
42. b) 0.36 W c) 1296 J
43. a) 1.3 A b) 8.64×10^{6} J
44. b) 1920 W
45. a) 24 W b) 48 W
46. a) 8.7 A b) 26 Ω
47. 0.2 A
48. 60 Ω
50. 998 W
51.

69 W	230	0.3	**3 A**
100 W	230	**0.43**	**3 A**

	2.5 kW	230	**10.9**	**13 A**
	345 kW	230	1.5	**3 A**
52.	a) i) 7.2 J	ii) 2160 J	c) i) 13 A	
55.	a) i) d.c.	ii) a.c.	iii) d.c.	
	b) i) 2 V	ii) 1.5 V	iii) 6 V	
56.	a) 10 V	b) 0.4 V	c) 150 mV	
57.	a) a.c.	b) 50 Hz		
60.	a) 17 V			
61.	a) a.c. voltmeter			

Electromagnetism

68. a 23 V
    b) 600 V
    c) 3833 turns
    d) 16,667 turns
    e) 16 V
    f) 58 turns
    g) 1000 turns
    h) 3680 turns
    i) 24 V

70. a) 0.8 A
    b) 0.92 A
    c) 26.7 A
    d) 0.13 A
    e) 1.15 A
    f) 0.06 A
    g) 0.1 A
    h) 50 turns
    i) 500 turns

71. N_s/N_p = 13/1

73. I_S = 200 A

Electronic Components

76. a) A - +5 V B - 0 V
    b) 12 mA
    c) 250 Ω
77. 100 Ω
78. a) 90 Ω
    b) 80 Ω
    c) 70 Ω
81. a) 0.001 A, 4 V
    b) 0.0005 A, 1 V
    c) 0.001 A, 4 V
    d) 0.00125 A, 8.75 V
    e) 0.004 A, 4 V
    f) 0.0005 A, 3.5 V
82. a) 1 V
    b) 4.9 V
83. a) LDR - 5.9 V R - 0.1 V
    b) LDR - 4.8 V R - 0.2 V
86. a) i) 0.5 V
    ii) 2.5 V
93. 4 V
94. a) 1 V
    b) 500
    c) 0.0075 V