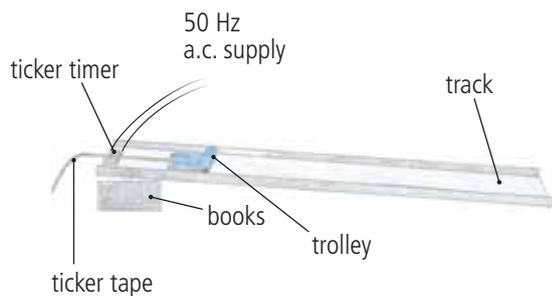


SECTION A

1. (i)

**(3 × 3)**

(ii) The following measurements were taken in this experiment:

Ticker-tape method:

No. of spaces for initial velocity

No. of spaces for final velocity

No. of spaces between centre of initial and final velocity

Length of tape for initial velocity

Length of tape for final velocity

Applied force from pan and masses

Air-track method:

Length of sail

Time for initial velocity

Time for final velocity

Time between initial and final velocity

Applied force from pan and masses **(6 + 3)**

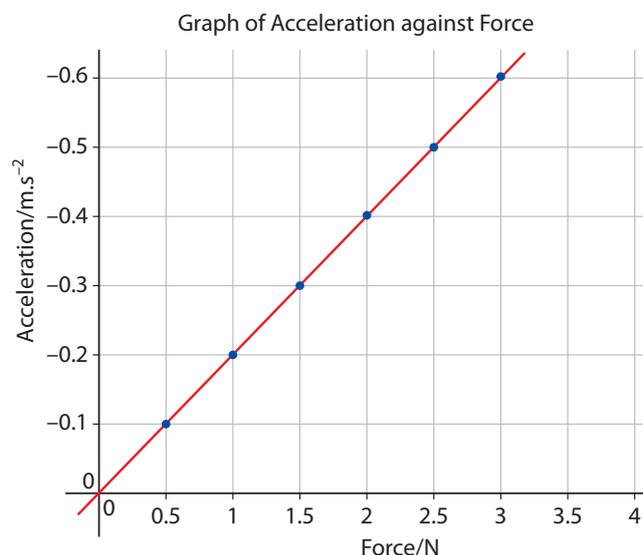
(iii) Friction could have been reduced by the following methods:

(Ticker-tape method) Oil track and trolley, keep ticker tape, ticker timer and trolley linear for feeding tape with less friction, raise track just enough to overcome friction but not accelerate trolley, use a low friction pulley and low friction string attached to pan.

(Air-track method) Use air pump to reduce friction on track, use a low friction pulley and low friction string attached to pan. **(6)**

TIP: It is not necessary to use a particular method to describe your experiment. Just make sure to describe the one you are familiar with, and it will aid in remembering certain errors and precautions as you come to them.

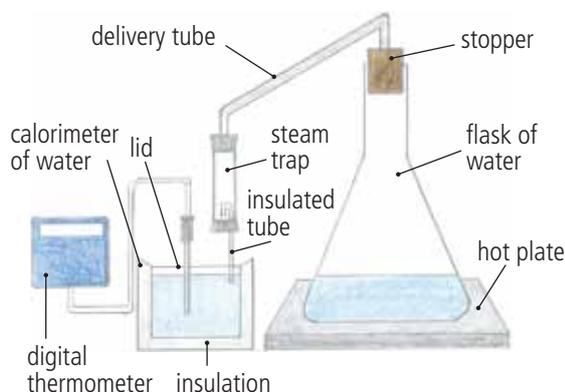
(iv)

**(4 × 3)**

- (v) The graph shows that acceleration is proportional to force as it is a straight line graph through the origin. **(4)**

TIP: A straight line graph always shows proportion in this case.

2. (i)



(6 + 3)

- (ii) The steam was dried by passing it through a steam trap to allow any liquid to settle and only dry steam to pass through an insulated delivery tube to the calorimeter. **(6)**
- (iii) Measurements to be taken during this experiment:
 Mass of calorimeter
 Mass of calorimeter and water (given)
 Mass of calorimeter and water and steam (given)
 Initial temperature
 Final temperature **(6 + 3)**

TIP: Just remember to look at any formulae to gauge what measurements should be taken. If you are missing figures for the formula, you have left something out or ignored it.

- (iv) The mass of steam can be calculated by subtracting the mass of calorimeter & water from the mass of calorimeter & water & steam:

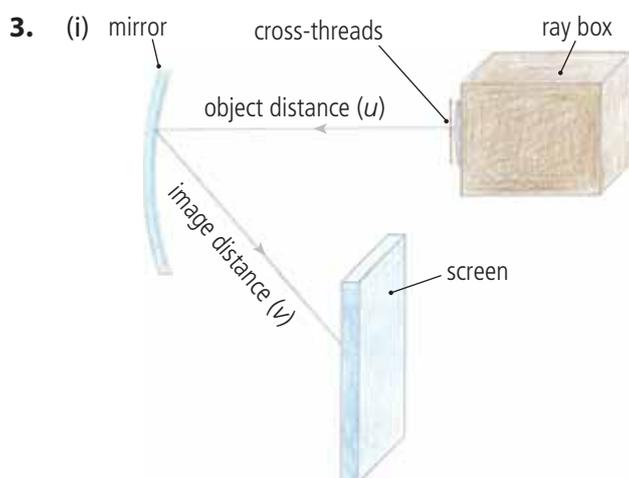
$$m_{c+w+s} - m_{c+w} = m_s$$

$$92.3 \times 10^{-3}\text{kg} - 90.7 \times 10^{-3}\text{kg} = 1.6 \times 10^{-3}\text{kg} \text{ (1.6g steam) } \mathbf{(3)}$$

TIP: By placing mass in kg, it will be easier to convert to joules later.

- (v) $Q = ml$
 $Q = (1.6 \times 10^{-3}\text{kg})(2.3 \times 10^3\text{Jkg}^{-1})$
 $Q = 3680\text{J} \mathbf{(9)}$
- (vi) Choose one safety precaution from below:
 Avoid tube blockages for steam pressure build-up.
 Keep a safe distance from hot plate and boiling water.
 Wear goggles, lab coat, gloves, etc.
 Take care when removing delivery tube from calorimeter. **(4)**

TIP: Safety precautions need only be common sense steps you would take when dealing with hot/hazardous materials.

**(6 + 2 × 3)**

- (ii) The screen distance can be adjusted until a sharp-focused image of the object is formed. At this point, the distance between mirror and screen is measured and recorded as ' v '. **(6)**
- (iii) ' u ' and ' v ' are shown on the diagram. **(2 × 3)**

TIP: As can be seen in many mandatory questions, a good labelled diagram can help later in the question for describing measurements or equipment used.

(iv) 1st reading:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{20} + \frac{1}{60} = \frac{1}{f}$$

$$\frac{1}{15} = \frac{1}{f}$$

$$\frac{15}{1} = \frac{f}{1}$$

$$15\text{cm} = f$$

2nd reading:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{25} + \frac{1}{38} = \frac{1}{f}$$

$$\frac{63}{950} = \frac{1}{f}$$

$$\frac{950}{63} = \frac{f}{1}$$

$$15.08\text{cm} = f$$

3rd reading:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{30} + \frac{1}{30} = \frac{1}{f}$$

$$\frac{2}{30} = \frac{1}{f}$$

$$\frac{30}{2} = \frac{f}{1}$$

$$15\text{cm} = f$$

4th reading:

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{60} + \frac{1}{19.5} = \frac{1}{f}$$

$$\frac{53}{780} = \frac{1}{f}$$

$$\frac{780}{53} = \frac{f}{1}$$

$$14.72\text{cm} = f$$

$$\text{Average focal length from 4 readings} = \frac{15\text{cm} + 15.08\text{cm} + 15\text{cm} + 14.72\text{cm}}{4} = \frac{59.8\text{cm}}{4}$$

$$= 14.95\text{cm} \quad \textbf{(4 × 3)}$$

TIP: By keeping all measurements as fractions, it is easy to calculate the reciprocal by turning it upside down and gaining a decimal answer at the end. As can be seen, the average is only calculated from all final focal length figures.

- (v) The student repeated the experiment to gain average values and reduce % error. It may also have been necessary as it is difficult to decide on what is the best-focused image available. By averaging the results and repeating the experiment, the results are more reliable. **(4)**

4. (i) The resistance of the wire was measured by using an ohmmeter connected at each end of the effective length of the wire. **(6)**
 (ii) The diameter of the wire was measured with a micrometer or digital Vernier callipers. **(6)**

$$\text{(iii) Average diameter} = \frac{0.21\text{mm} + 0.26\text{mm} + 0.22\text{mm}}{3} = \frac{0.69\text{mm}}{3} = 0.23\text{mm}$$

$$\therefore \text{Average radius} = \frac{0.23\text{mm}}{2} = 0.115\text{mm} = 0.115 \times 10^{-3}\text{m}$$

$$\text{Cross-sectional area} = \pi r^2 = (\pi)(0.115 \times 10^{-3})^2 = 4.155 \times 10^{-8}\text{m}^2 \quad \mathbf{(4 \times 3)}$$

TIP: You may use the area formula for diameter or radius. In this example, radius is used. However, make sure to clearly convert all units to metres before calculating area or resistivity.

$$\text{(iv) } \rho = \frac{RA}{l} = \frac{(30\Omega)(4.155 \times 10^{-8})}{(0.8\text{m})} = \frac{1.246 \times 10^{-6}}{0.8} = 1.558 \times 10^{-6}\Omega\text{m} \quad \mathbf{(10)}$$

TIP: Again, units are converted to metres as the final units of resistivity are in ohm metres.

- (v) Choose any two precautions:

Keep wire straight and taut.

Average diameter readings to allow for kinks.

Do not handle wire too much as it will affect temperature within the material.

Keep the wire away from heat sources or draughts.

Allow for parallax error in measuring length and in using micrometer.

Allow for zero-error on micrometer before using. **(2 × 3)**

SECTION B

5. **(8 × 7)**

- (a) Every mass in the universe attracts every other mass with a force, along the line of their centres, that is proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$\text{(b) } s = ut + \frac{1}{2}at^2$$

$$s = (20)(2) + \frac{1}{2}(-9.8)(2)^2$$

$$s = 40 - 19.6$$

$$s = 20.4\text{m above the ground}$$

TIP: If velocity is acting in a different direction to gravity, make sure to give them different signs, and the answer will show you where the object is, based on its sign.

- (c) (i) Law of refraction = Snell
 (ii) Electromagnetic induction = Faraday

$$\text{(d) } n = \frac{1}{\sin C}$$

$$n = \frac{1}{\sin 42^\circ}$$

$$n = 1.49$$

$$(e) \frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_{\text{total}}} = \frac{1}{20} + \frac{1}{5}$$

$$\frac{1}{R_{\text{total}}} = \frac{1}{4}$$

$$\frac{R_{\text{total}}}{1} = \frac{4}{1}$$

$$R_{\text{total}} = 4\Omega$$

TIP: Parallel resistance has to be calculated with an inverse formula such as this shown. Use the fraction function on your calculator to gain the answer before turning it upside down for the final reciprocal answer of total parallel resistance.

- (f) The volume of a fixed mass of gas is inversely proportional to its pressure, as long as temperature is constant.
- (g) A Van de Graaff generator may be used for point discharge, static electricity experiments or using with a gold leaf electroscope to show that charge resides on the outside of a conductor and is concentrated at a point.
- (h) All semiconductor devices contain p-n junctions, such as solid state detectors, integrated circuits, LEDs, diodes, etc.
- (i) A transformer steps up or steps down the a.c. voltage supplied.
- (j) Half-life is the time taken for half of a nuclei of a radioactive source to decay.
6. (i) Potential energy is energy due to position or conformation.
- (ii) Kinetic energy is energy due to movement. **(9)**

The principle of conservation of energy states that energy cannot be created or destroyed but converted from one form to another. **(3)**

In the case of a roller-coaster, the stored potential energy at the upper parts of the track are converted into kinetic energy (increased velocity) as the coaster falls back down. That is why roller-coasters tend to slow towards the top and speed up as they come back down. **(6)**

- (i) Difference in height between point A & B = 100m – 25m = 75m **(5)**

TIP: Take the 30m from 55m height to gain the 25m height at point B.

- (ii) Change in potential energy (E_p) = $E_{P(\text{point A})} - E_{P(\text{point B})} = mgh_{(A)} - mgh_{(B)}$
 $(850\text{kg})(9.8\text{m}\cdot\text{s}^{-2})(100\text{m}) - (850\text{kg})(9.8\text{m}\cdot\text{s}^{-2})(25\text{m})$
 $833000\text{J} - 208250\text{J} = 624750\text{J}$ **(6)**

TIP: You could also calculate potential energy difference by using mgh with a 75m height as this is what was lost. This will give you the same answer as shown.

- (iii) Let potential energy lost = kinetic energy gained, as per conservation of energy:

$$E_{P(\text{lost})} = E_{K(\text{gained})}$$

$$624750\text{J} = E_{K(\text{gained})}$$

$$E_{K(\text{gained})} = \frac{1}{2}mv^2$$

$$624750 = \frac{1}{2}(850)v^2$$

$$624750 = 425v^2$$

$$\frac{624750}{425} = v^2$$

$$\sqrt{\frac{624750}{425}} = v$$

$$\sqrt{1470} = v$$

$$38.34\text{m.s}^{-1} = v \text{ (2} \times \text{6)}$$

TIP: By allowing energy lost in one part to equal energy gained in another, ignoring friction/air resistance, you can just let the answer from one part equal the kinetic energy formula. By moving all parts of the formula to one side and keeping 'v' on its own, it is easy to calculate.

(iv) $u = 38.34\text{m.s}^{-1}$

$$v = 0\text{m.s}^{-1}$$

$$s = 95\text{m}$$

$$a = ?$$

$$v^2 = u^2 + 2as$$

$$(0)^2 = (38.34)^2 + 2(a)(95)$$

$$0 = 1470 + 190a$$

$$-1470 = 190a$$

$$\frac{-1470}{190} = a$$

$$-7.74\text{m.s}^{-2} = a \text{ (9)}$$

(v) $F = ma$

$$F = (850\text{kg})(-7.74\text{m.s}^{-2})$$

$$F = 6576.32 \text{ N (6)}$$

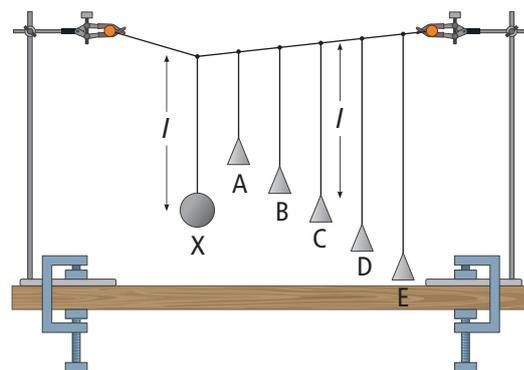
TIP: If you list the variables you have and the figure you want, it is easy to choose the correct equation of motion to use. The sign of the answer will tell you if the acceleration is positive or negative and whether the force applied is going to speed up or slow down the object.

7. Resonance is the transfer of energy between two bodies with the same natural frequency. (6)

To demonstrate resonance of sound (Barton's pendulum):

- Set up equipment as shown on the right, with pendulums A–E of various lengths.
- Attach a mass X to a string of the same length (l) as one of the pendulums.
- When you swing the mass, the pendulum of similar length l (in this case pendulum C) will begin to swing as well.

This demonstrates the resonance caused by the natural frequency applied from the swinging mass. (4 × 3, 2)



- A = wavelength (3)
- B = Amplitude (3)
- Frequency means the number of vibrations (waves) that occur per second, measured in hertz. (6)
- Three characteristics of a musical note are: pitch, loudness and quality. (6, 2, 1)
- Natural frequency is the particular frequency at which an object naturally begins to oscillate or vibrate. (6)
- $c = f\lambda$

$$340 = 250\lambda$$

$$\frac{340}{250} = \lambda$$

$$1.36\text{m} = \lambda \text{ (9)}$$

8. Capacitance is the ratio of charge to voltage on a device. The unit of capacitance is the farad. (6, 3)

- (i) Switch closed means the bulb will go on and off. (6)
 (ii) If a 12 V d.c. supply were used instead, the light would initially light up briefly but then go out. (6)

TIP: A capacitor would allow current to flow briefly while the capacitor charges up, but when it reaches the same p.d. as the supply voltage in d.c., the current will cease to flow, and the bulb will go out. This does not happen with a.c., as the capacitor never fully charges up with alternating current.

(iii) This shows us that capacitors allow a.c. current to flow through them, whereas they will block d.c. current, as the capacitor charges up and equals the potential difference of the source. (6)

(iv) $Q = 0.8\text{C}$

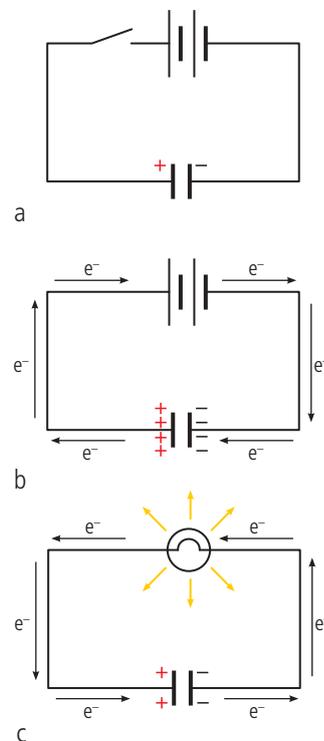
$$V = 12\text{V}$$

$$C = ?$$

$$C = \frac{Q}{V} = \frac{0.8\text{C}}{12\text{V}} = 0.067\text{F} \quad (3 \times 3)$$

To demonstrate charging a parallel plate capacitor

1. Close the circuit shown in a.
2. Electrons move from the left capacitor plate to the positive terminal of the battery.
3. Electrons also move from the negative terminal of the battery to the right capacitor plate.
4. This causes the left capacitor plate to become positively charged and the right capacitor plate to become negatively charged.
5. If the two plates of the capacitor are now of different charge, there is a p.d between them.
6. When the p.d of the capacitor = the p.d of the battery, there is no p.d between the capacitor and battery and the battery ceases to cause current flow. (Current stops in circuit and capacitor is now fully charged; b.)
7. Remove the battery and replace with a bulb (c).
8. The p.d in the capacitor now acts like a temporary battery and reverses its current flow by sending the electrons from the right plate through the bulb and back to the left plate.
9. This causes the bulb to flash as the capacitor discharges.
10. The time taken to charge the capacitor is much greater than the time taken to discharge it. (4 × 3)



Radio uses capacitors for tuning to allow certain frequencies when the capacitor is connected to a coil.

Camera flashes use capacitors to charge up before releasing all of the charge quickly through the flash bulb in one brief intense flash. (2 × 4)

9. Heat is a form of energy, measured in joules.

Temperature is the measure of the hotness or coldness of any object, measured in degrees Celsius or Kelvin. (9)

(i) $m = 500\text{g} = 0.5\text{kg}$

$$c = 4180\text{Jkg}^{-1}\text{K}^{-1}$$

$$\theta_i = 20^\circ\text{C}$$

$$\theta_f = 100^\circ\text{C}$$

$$\theta = 80^\circ\text{C}$$

$$Q = mc\Delta\theta$$

$$Q = (0.5)(4180)(80) = 167200\text{J} \quad (4 \times 3)$$

- (ii) $0.8\text{kW} = 0.8 \times 10^3\text{J per second} = 800\text{ joules per second}$ (6)
- (iii) Time to heat water = $\frac{\text{Energy required}}{\text{Energy supplied per second}} = \frac{167200\text{J}}{800\text{J}\cdot\text{s}^{-1}} = 209\text{s}$ (3 minutes 29 seconds) (6)
- (iv) Plastic is an insulator and will not conduct the heat of the kettle body or water to the handle, allowing safe pick-up of the kettle. (6)
- (v) Liquid uses convection to transfer heat throughout the kettle. (6)
- (vi) Metal is a good conductor of heat and allows the heat to conduct into the liquid efficiently for convection in liquid to occur. (6)
- (vii) Heat rises. Therefore, by placing the element at the bottom, the hot water rises up and is replaced by cooler water falling down. This means the water is evenly heated and only boils when all water has been in contact with the element. (5)

10. X-rays are electromagnetic radiation of high frequency, produced when high energy electrons strike a metal target.

Choose any two properties of X-rays:

High-frequency EM radiation.

They can penetrate many materials.

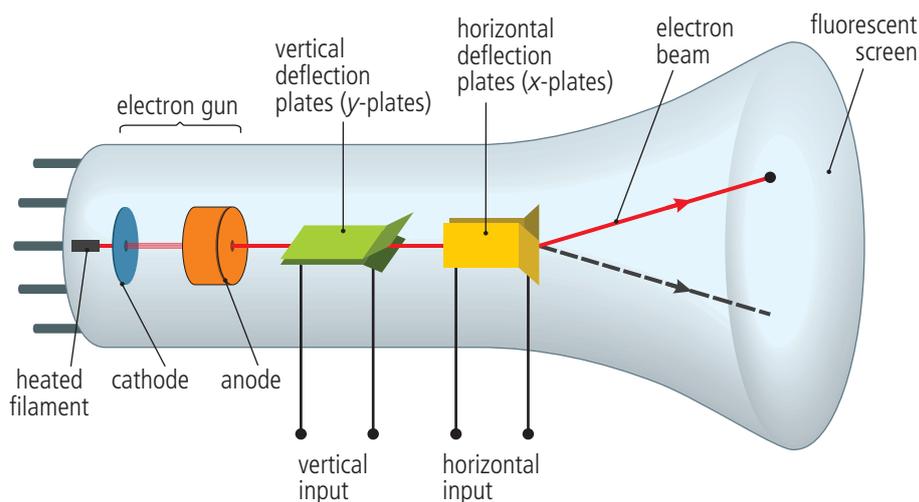
They can ionise (knock off electrons) certain materials.

They can expose photographic film.

They can cause certain substances to fluoresce. (6 + 2 × 3)

- (i) Thermionic emission occurs at the cathode. (6)
- (ii) Tungsten or a metal with a high melting point is used as the target. (6)
- (iii) A = lead shielding to avoid leakage of X-rays. (6)
- (iv) Choose one from the following list of uses:
- Medical use for scans/photos
- Medical tracing of dyes
- Industrial use in scanning objects at airports
- Industrial use in scanning for fractures and faults in materials (5)

(v)



(4 × 3)

- (vi) A vacuum is required as many electrons are travelling at high speed within the apparatus and need to avoid collision with other particles so they can reach their target efficiently. (6)
- (vii) A cathode ray oscilloscope can be used for:
- Waveform analysis of current/voltage
- EKG/EEG measurements used medically
- Basic television reception (3)

11. (8 × 7)

- (a) Alpha-particles are positively charged helium ions.
 (b) A source of alpha-particles is radium bromide.
 (c) Gold was used as the target by Rutherford.
 (d) The alpha-particles were detected by a fluorescent screen, which scintillated if alpha-particles struck it.
 (e) They observed that some alpha-particles deviated and even bounced back, showing that the atom structure contained a small dense positive nucleus.
 (f) The repulsion force between the protons in the nuclei of the gold and the helium ion caused the deflection (EM repulsion force).
 (g) The experiment showed:
 The atom is mainly empty space, as most alpha particles went straight through un-deviated
 There is a small positive dense nucleus at the centre, which caused repulsion of the alpha-particles.
 (h) Hans Geiger is most famous for his invention of the Geiger-Muller tube, which is used to detect ionising radiation.

12. (a) (i) A lever is a rigid bar, free to rotate about a fulcrum or pivot point. (2 × 3)
 (ii) The turning effect of a force is a 'moment' (torque). (6)
 (iii) A pair of equal and opposite forces is a 'couple', also known as torque. (6)

$$M = Fd$$

$$M = (20\text{N})(40 \times 10^{-2}\text{m})$$

$$M = 8\text{Nm} \quad (10)$$

TIP: Make sure to convert all distances into metres. This question is looking for turning effect from a couple of forces, so distance between forces is used rather than an individual moment calculated as the force multiplied by perpendicular distance from fulcrum (centre of bars).

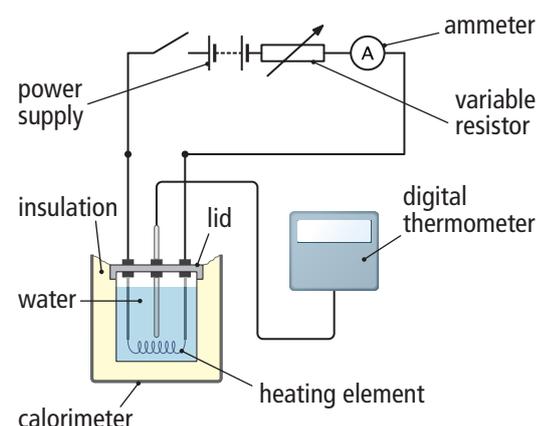
- (b) Dispersion means the separation of light into its constituent colours, frequencies or wavelengths. (6)
 Dispersion of light proves that white light is made up of many colours. (6)
 Dispersion can be caused by using a prism to refract light into its constituent colours or a diffraction grating to diffract light into its constituent colours. (2 × 3)
 A rainbow is a good natural example of light dispersing (also a diamond or oil film can be used). (4)
 Red, green and blue are the three primary colours. These are the colours necessary to produce white light. However, if any two of them are mixed, they form secondary colours of magenta, cyan and yellow. Therefore, these three colours give the necessary available combinations of colour required for stage effects. (6)
 (c) Resistance is the ratio of voltage across a conductor to the current flowing through the conductor.
 Resistance is measured in Ohms (Ω). (6, 3)

To demonstrate heating effect

- Set up the equipment as shown on the right.
- Apply a constant current through the element for a constant time and record the temperature rise.
- Keeping time and volume of water constant, apply greater amounts of current each time.

It will be seen that the temperature rise in each case will be proportional to the square of the current applied (greater current produces greater temperature rise, in the same time).

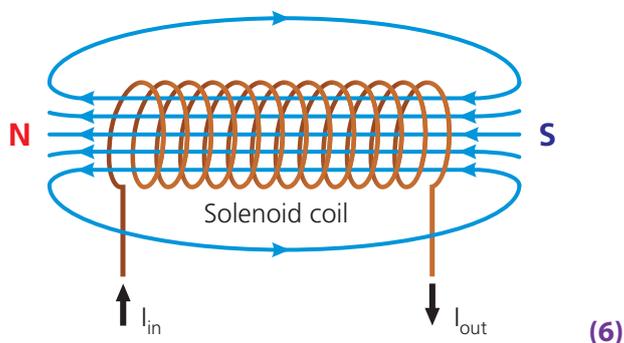
(3 × 3)



Charge carriers involved:

- (i) Gases: ions (electrons & positive holes)
- (ii) Semiconductors: electrons & positive holes
- (iii) Metals: electrons
- (iv) Solutions: positive & negative ions (6, 2, 1, 1)

(d) (i)



- (ii) Electromagnetic induction occurs when a changing magnetic field induces an emf, which in turn produces a current. (6)

To demonstrate Faraday's law of electromagnetic induction

This demonstrates Faraday's law on the relative movement of coil/magnet.

1. Set up the experiment as shown on the right.
2. As the north pole approaches the coil, the galvanometer needle twitches one way.
3. As the north pole moves away, the galvanometer needle twitches the other way.
4. If the magnet and coil are kept stationary, no movement takes place on the galvanometer.
5. It will be seen that the speed of approach of the magnet is proportional to the induced current. It will also be observed that the orientation of the magnetic pole affects the induced current direction. (4 × 4)

