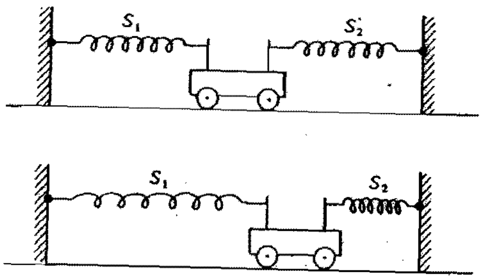
1.17S A stone of mass 80 g is released (from rest) at the top of a vertical cliff. After falling for 3 s, it reaches the foot of the cliff, and penetrates 9 cm into the ground. What is **(a)** the height of the cliff, **(b)** the average force resisting penetration of the ground by the stone?

(**SUJB**: *all other Boards*)

1.18S A trolley of mass 0.80 kg is held in equilibrium between two fixed supports by identical springs (S_1 and S_2) as shown in the diagram; each spring has an extension of 0.10 m. In the second diagram, the trolley is shown moving to the right a distance of 0.05 m. The relation between the force (F) in newtons and the extension (x) in metres for each spring is given by $F = 20x$.

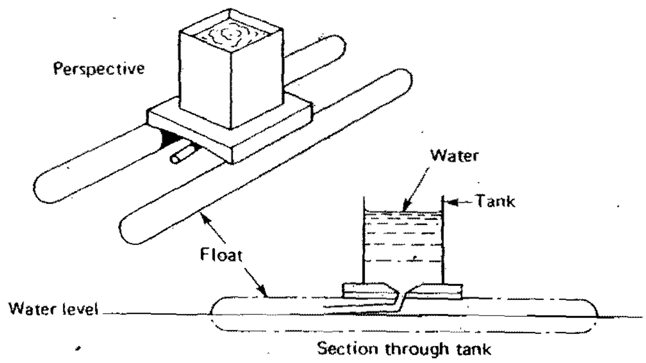


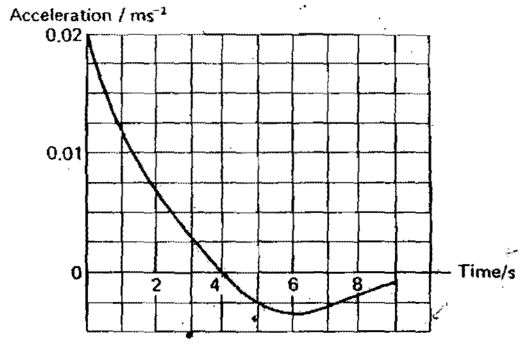
(a) What is the **change** in the force exerted by spring S_1 caused by moving the trolley to the right as in the second diagram?
(b) If the trolley is now released what will be the magnitudes of (i) the resultant force acting upon the trolley at the moment of release, and (ii) the initial acceleration of the trolley?
(c) Showing the steps in your calculation, determine the total energy stored in S_1 and S_2 when the springs are stretched (i) as in diagram 1, (ii) as in diagram 2.

(d) What is the kinetic energy of the trolley as it passes through the equilibrium position?

(**O and C Nuffield**: *all other Boards*)

1.19S A child's toy boat is built with two floats and is propelled by water draining out from a high tank through a hole, as indicated in the perspective and sectional drawings.





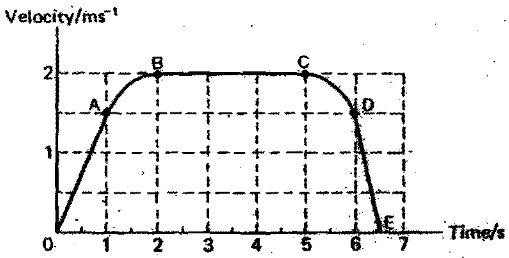
(a) The boat is initially at rest. Why does the water draining out of the tank cause it to accelerate?
(b) The graph shows how the boat's acceleration varies with time. (i) Find from the graph an approximate value for the maximum speed reached by the boat. Give your reasoning and show clearly how you arrive at your answer. (ii) It can be deduced from the graph that the tank takes at least six seconds to empty. How is this deduction made?

(**O and C Nuffield**: *all other Boards*)

1.20S A bullet of mass 0.020 kg is fired from a rifle. The barrel of the rifle is 0.50 m long with an internal diameter of 8.0 mm and the average excess pressure of the gas in the barrel is 5.0×10^3 atmospheres. Assuming that the recoil velocity of the rifle is negligible, and neglecting friction and any rotational energy acquired by the bullet,
(i) show that the average force on the bullet is 3.5×10^4 N.
(ii) calculate the acceleration of the bullet.
(iii) calculate the muzzle velocity of the bullet.
(Assume 1 atmosphere = 1.4×10^5 Pa.)

(**AEB** Nov 80: *all other Boards*)

1.21S A cable-operated lift of total mass 500 kg moves upwards from rest in a vertical shaft. The graph shows how its velocity varies with time.



(a) For the period of time indicated by DE, determine (i) the distance travelled, (ii) the acceleration of the lift.
(b) Calculate the tension in the cable during the interval (i) OA, (ii) BC. Assume that the cable has negligible mass compared with that of the lift, and that friction between the lift and the shaft can be ignored.

(**JMB**: *all other Boards*)

1.33L

(a) A steady stream of balls each of mass 0.2 kg hits a vertical wall at right angles. If the speed of the balls is $15\,m\,s^{-1}$ and 600 hit the wall in 12 s and rebound at the same speed, what is the average force acting on the wall? Sketch a graph to show how the actual force on the wall varies with time over a period of 0.10 s.

Explain how the average force on the wall could be obtained from this graph. Explain briefly how the above problem can lead to an understanding of how a gas exerts a pressure on the walls of its container.

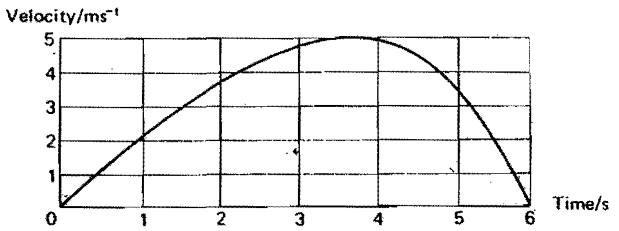
(b) A car travelling along a level road at a speed of $10\,m\,s^{-1}$ crashes head-on into a wall. If the mass of the car is 1000 kg, calculate the kinetic energy and momentum of the car just before the collision.

If the impact time (the time taken for the car to come to rest) is 0.2 s, calculate the average force acting on the wall and explain why it is an average. Why is it advantageous for a passenger if the impact time is increased? Make a calculation to support your point. How in practice could car design be improved to achieve an increase of impact time?

(London: *all other Boards*)

1.34L State Newton's laws of motion and outline an experimental method of verifying the second law.

A bead of mass 5 kg is free to slide along a perfectly smooth rigid wire which lies in a vertical plane. The wire is curved, and when the bead is released from rest under the influence of gravity, its speed (v) varies with time (t) as shown in the graph.



(a) What physical quantities are represented by (i) the total area under the graph, (ii) the slope of the graph at a given point?

(b) At what approximate angles to the vertical is the bead moving at times $t = 0$, $t = 3.75$ s and $t = 6$ s?

(c) What is the difference between the potential energy of the bead at its highest and lowest points?

(d) Give a rough sketch of the shape of the wire, indicating the oint from which the bead is released, and its position at times $t = 3.75$ s and $t = 6$ s.

(O and C: *all other Boards*)

1.35L This question is about the ideas and the evidence in the wave theory of atoms. The passage below consists of numbered statements (i) to (v). For each of these you are asked to give arguments that 'explain' and 'support' them. The arguments that you use may be of many kinds and you should indicate what kind they are – eg, theories, models, calculations, evidence.

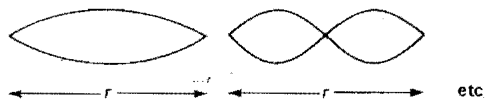
Passage (i) It can be shown that electrons have wave properties, having a wavelength related to their momentum by $mv = h/\lambda$.

(ii) If a wavelike electron is confined in a 'box' of size 10^{-10} m, its momentum can't be less than a certain size, and so its kinetic energy has a lower limit, too. The smaller the box, the bigger the ke of the electrons.

(iii) If the atom is to be stable, the sum of the pe and ke of the electron must be negative. We know that the electrical potential energy of an electron is −10eV when it is about 10^{-10} m from a proton. All this leads to an explanation of why atoms cannot be much smaller than about 10^{-10} m.

(iv) Consideration of its spectrum shows that a hydrogen atom has a whole series of energy levels with energies given by c/n^2, where c is a constant and n has values 0, 1, 2, 3, ... etc.

(v) The simplest idea is that electrons in hydrogen behave like standing waves on a string of length r as in the diagram. This would explain why there are discrete values of kinetic energy associated with integers n, but it would give the wrong rule for the way energy depends upon n.



(O and C Nuffield *only*)

1.36L

(a) (i) Define the 'moment of inertia' of a rigid body about a fixed axis. (ii) A body has mass M and moment of inertia I about an axis through its centre of gravity. The centre of gravity of the body moves with linear velocity v and the body rotates with angular velocity ω about the axis through the centre of gravity. Give an expression for the total kinetic energy of the body.

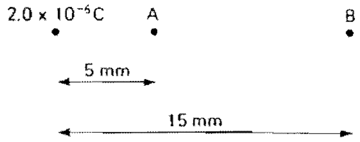
(b) A solid cylinder of radius 0.12 m and mass 3.0 kg starts from rest and rolls without slipping through a distance of 0.70 m down a slope inclined at an angle of 30° to the horizontal. Neglecting rolling friction, calculate (i) the total kinetic energy of the cylinder, (ii) the linear velocity of the centre of gravity of the system, (iii) the angular velocity of the cylinder about its axis.

The moment of inertia of a solid cylinder of mass M and radius a about its axis is $\frac{1}{2}Ma^2$.

(c) (i) Calculate the linear acceleration of the cylinder down the slope. (ii) If there were no friction and the cylinder slid without rolling what would then be the acceleration down the slope?

(JMB*: *AEB, Cambridge, WJEC, O and C*, SEB SYS*)

2.25S (i) The magnitude of the force on an electron when it is at a point A, 5.0 mm from a point charge of 2.0×10^{-6} C, is 1.2×10^{-10} N.



What is the magnitude of the force on an electron when it is at point *B*, a distance of 15 mm from the same point charge?
(ii) Calculate the electric field strength due to the 2.0×10^{-6}C charge at point *A*.

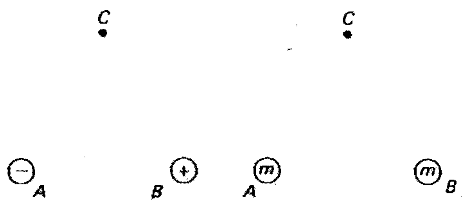
(**SEB H**: *all other Boards*)

2.26S

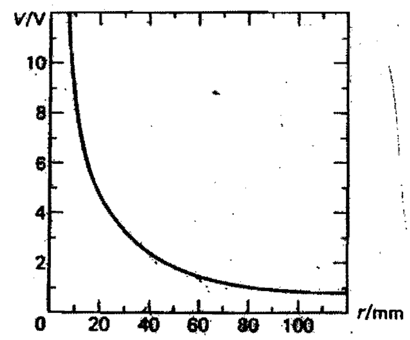
(a) (i) An *electric field of force* exists around an isolated point charge. Explain briefly the meaning of the term in italics. (ii) The units for electric field intensity may be stated as volts per metre or newtons per coulomb. Show that these are equivalent.

(b) Sketch the pattern of electric lines of force for the following: (i) an isolated negative charge; (ii) an isolated positive charge.

(c) (i) Two equal charges of opposite sign are placed at *A* and *B*, two of the vertices of an equilateral triangle *ABC*. The field due to each charge may be considered separately, and the results combined to give the resultant field. Using this idea, indicate the direction of the electric field at C.



(ii) Gravitational fields may be combined in the same way as electric fields. If the charges at *A* and *B* were replaced by equal point masses *m*, indicate on the diagram the direction of the gravitational field at *C* due to the masses at *A* and *B*.



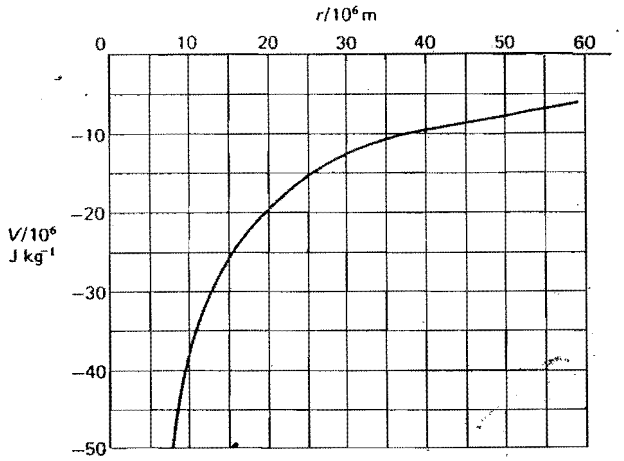
(d) The graph shows the variation of electric potential *V* with distance *r* from an isolated positive point charge. (i) Making use of the graph, calculate the force on a point charge of + 2 C placed 30 mm from the isolated point charge. (ii) The + 2 C charge is moved from the point 30 mm from the positive charge to a point 10 mm from the positive charge. How much energy is required to do this?

(**NISEC**: ***all other Boards except SEB H***)

2.27S Define electric field strength and electric potential at a point. Derive the relationship between the electric field strength and the electric potential gradient at a given point.

(**AEB** June 81: *all other Boards except SEB H*)

2.28S The diagram shows the variation of the Earth's gravitational potential *V* with distance *r* from the centre of the Earth.



(a) (i) What is the potential at an infinite distance from the Earth? (ii) Why is the potential on the graph negative?

(b) What is the value of the gravitational field at 25×10^6m from the centre of the Earth? Show how you arrive at your answer.

(c) How much energy is required to raise a mass of 70 kg from 10×10^6 m to 50×10^6 m above the Earth's centre? Show how you arrive at your answer.

(**O and C Nuffield**: *all other Boards except SEB H*)

2.29S A closed wire loop in the form of a square of side 4.0 cm is mounted with its plane horizontal. The loop has a resistance of $2.0 \times 10^{-3}\Omega$, and negligible self-inductance. The loop is situated in a magnetic field of strength 0.70 T directed vertically downwards. When the field is switched off, it decreases to zero at a uniform rate in 0.80 s. What is (a) the current induced in the loop, (b) the energy dissipated in the loop during the change in the magnetic field? Show on a diagram, justifying your statement, the direction of the induced current.

(**SUJB**: *all other Boards except SEB H*)

2.39L This question asks you to say more about **four** brief statements about magnetic flux.

(a) The passage below consists of **four** main statements, numbered (i), (ii), (iii) and (iv). For each of these statements you are asked to give arguments which explain and support the statement; these might refer to theoretical principles, or to experimental evidence, or both. Your arguments should include explanation of the principles and description of the evidence.

(b) Statement (iii) could be described in general terms as a statement about practical applications based on an experimental result (the value of μ_r). For each of statements (i), (ii) and (iv) give a similar description to say what sort of ideas are in the statement, eg, it is a definition based on previous ideas or it is a summary of experimental results or some other description you think appropriate; give a **brief** justification for each description.

Passage

(i) We can show from experiments with solenoids in air that magnetic flux φ is related to the current I and number of turns N by an equation of the form

$$NI = \frac{\varphi L}{\mu_0 A}$$

where L is the length and A the cross-section area; however, it takes a whole set of careful experiments to sort out the various factors correctly.

(ii) The equation is very like the equation which relates the flow of electric current in a circuit to the various factors which determine it: we can compare the two equations term by term, so that it seems reasonable to say that magnetic flux is like the flow of something.

(iii) Useful practical applications nearly always use solenoids filled with iron because when iron is used, μ_0 is replaced by $\mu_0\mu_r$ and the value of μ_r can be as much as 1000.

(iv) The idea of flux as a flow around a magnetic circuit is often helpful. For example, it can easily be shown that if an iron ring electromagnet has a small air gapcut in it there is a large reduction in φ – just like the effects on the current when a large resistor is inserted in series in an electrical circuit.

(**O and C Nuffield**: *all other Boards except SEB H*)

2.40L A straight solenoid of length L and circular cross-section of radius r is uniformly wound with a single layer of N turns and carries a current I. The solenoid is so long that end-effects may be neglected. Write down expressions for the flux density B inside the solenoid and the total flux through the solenoid.

(a) The current in the solenoid is increased at a uniform rate from zero to I in time t. Find an expression for the back-emf induced in the solenoid during the change.

(b) Find the electrical work done against this back-emf in establishing the current.

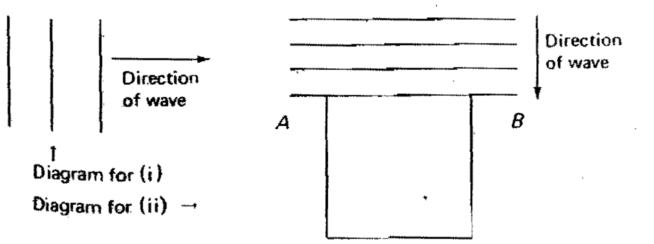
(c) The work found in (b) is the energy stored in the magnetic field of the solenoid. Show that this energy is $B^2/2\mu_0$ per unit volume.

(d) What becomes of this energy when the circuit is broken?

(**O and C**: *all other Boards except SEB H*)

4.17S

(a) The wave theory of light provides an explanation of many aspects of reflection, refraction and interference. (i) The three parallel lines in the sketch represent sections of a wave front of a parallel beam of light at times $t = 0$, $t = t_1$ and $t = 2t_1$. Using the principle of secondary wavelets, show how to construct one further wave front, for $t = 3t_1$. (A written explanation is *not* required). (ii) The sketch shows a plane light wave encountering a glass block of refractive index 1.5. The four parallel lines represent the position of a single wave front at a series of equal time intervals. Draw six further wave fronts at the same equal time intervals showing how the light wave continues beyond *AB*. (Your drawing should be to scale.)

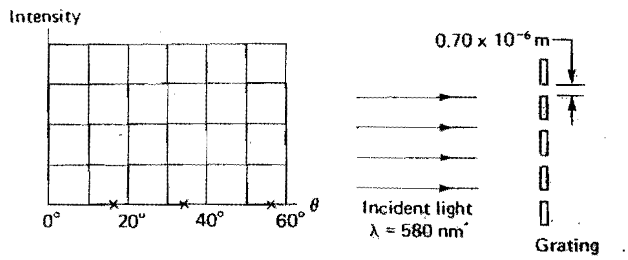


(b) Three parallel narrow slits *P*, P_1 and P_2 are illuminated by the source *S* of monochromatic light of wavelength λ as shown in the diagram (which is not to scale). The distances of P_1 and P_2 from *O* are equal. A series of bright and dark fringes are formed on the

screen at *T*, with a **bright** fringe at *O'*, on the axis of the system, and a **dark** fringe at *R*. (i) The beams emerging from P_1 and P_2 are 'coherent'. What does this mean? (ii) What relationship must exist between the lengths P_1R and P_2R? (iii) When the wavelength of the source is 500 nm, the centre of the 120th **dark** fringe, counting from *O'*, lies at *R*. Upon replacement of the source by one of unknown wavelength, *R* is found to be the location of the 90th **bright** fringe (counting from *O'* as zero). Find the wavelength of the unknown source.

(NISEC: *all other Boards except O and C Nuffield, SEB H, SEB SYS*)

4.19S A parallel beam of monochromatic light of wavelength 580 nm is incident normally on a diffraction grating having a large number of regular slits, each of width 0.70×10^{-6}m, as shown in the diagram. After passing through the grating the light will have, as a result of interference, intensity maxima in certain directions. Calculations predict that for the first, second, and third order interference maxima, the values of the angle θ between the direction of the incident light and the directions of these maxima should be approximately 16°, 34° and 56°, respectively.



(a) At what value of θ would the light diffracted by a SINGLE slit of width 0.70×10^{-6}m have its first intensity MINIMUM? Show the steps in your calculation.

(b) Produce a sketch graph showing how the intensity of light varies when plotted against θ. Make the range of θ vary from 0° to 60° and mark the 16°, 34° and 54° points on the axis. Plot the intensity on the vertical axis.

(**O and C Nuffield**: *JMB* and all other Boards except SEB H and WJEC*)

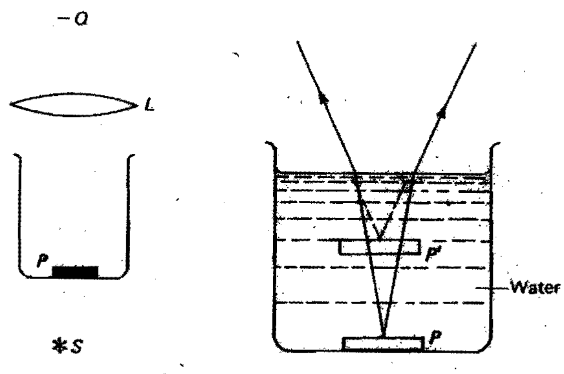
4.20S* The phenomenon of Fraunhofer diffraction may be demonstrated by illuminating a wide slit by a parallel beam of monochromatic light and focusing the light that passes through the slit on to a white screen. A diffraction pattern may then be observed on the screen.

(a) Sketch the intensity variation in the diffraction pattern as a function of distance across it.

(b) What would happen to the intensity variation if the width of the slit were halved?

(**Cambridge**: *all other boards except WJEC and SEB SYS*)

4.21S An opaque disc *P*, 3 mm diameter, lies at the bottom of a glass beaker, and is illuminated from below by a source *S*. A converging lens *L* of focal length 10 cm, situated 15 cm above the disc, forms an image of this at Q. Where is Q situated, and what is the size of the image? Explain qualitatively how the position and size of the image of the disc is changed when the beaker is filled with water.



(**SUJB**: *London, AEB, O and C, Oxford, NISEC*, Cambridge*)

4.26L This question is about diffraction.

The passage below presents three sets of ideas about diffraction. For each of the sections (i) to (iii) you are asked to write a more complete explanation of the ideas. Your explanation may include:

fuller explanations of the theory;
quantitative calculations to illustrate the ideas;
discussion of possible experiments.

Passage

(i) Light from a point source appears to cast sharp shadows and this leads to the familiar idea that it travels in straight lines. However, this is not exactly true: the shadows are not perfectly sharp, although special experiments are needed to show the effect because it is so small. This unfamiliar property is called diffraction and is explained by a wave model of light.

(ii) The consequence is that the eye, or a camera, or even the best possible telescope, doesn't produce a perfect image. Instead it gives an image which is slightly blurred. When we try to make a telescope magnify more to show finer details of the stars this blurring effect can become an obstacle.

(iii) But diffraction can also be put to good effect. Diffraction gratings are made to enhance the effect and make use of it to give a powerful method of investigating spectra.

(O and C Nuffield: *all except SEB H*)

4.27L Describe the steps in outline you would take in setting up a diffraction grating in combination with a spectrometer to examine the spectrum of visible light. Explain the function of each part of the system and show on a clear diagram the passage of light rays from the source, through the system, to the observer's eye.

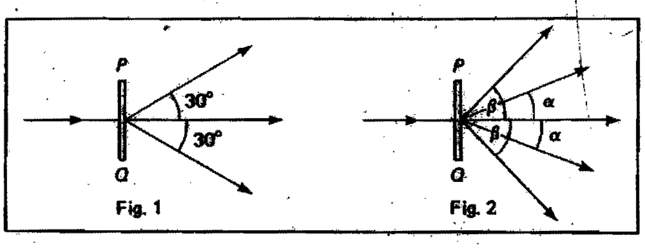
When the spectrum of light containing violet and red components only is examined with a diffraction grating, it is found that the fourth line from the centre (not counting the zero-order line) is a mixture of red and violet. Explain this. If the grating has 500 lines per mm, and the diffraction angle for the composite line is 43.6°, find the wavelengths of the violet and red components.

What will be the fifth line in the spectrum and at what diffraction angle will it occur?

(WJEC: *all other Boards except SEB H*)

4.28L

(a) A narrow parallel-sided beam of white light is dispersed by a diffraction grating which is placed perpendicular to the beam, ie, parallel to the incident wavefronts. Explain this effect in detail.

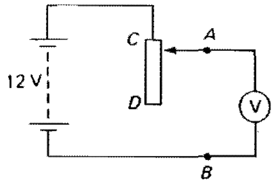


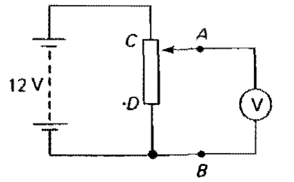
(b) Figure 1 shows the action, in air, of a plane diffraction grating *PQ* on a monochromatic beam of light which falls normally on the grating. Figure 2 shows the whole arrangement immersed in water, of refractive index 1.33. The beam is now diffracted as shown, making angles α ($< 30°$) and β ($> 30°$) with the normal. Explain these changes produced by the water.

Given that the grating has 8.0×10^5 lines per metre, calculate (i) the wavelength of the light in air, (ii) the wavelength of the light in water, (iii) the angle α, and (iv) the angle β.

(London: *all other Boards*)

7.27S A student wanted to light a lamp labelled 3 V 0.2 A but only had available a 12 V battery of negligible internal resistance. In order to reduce the battery voltage he connected up the circuit shown in Fig. 1. He included the voltmeter – using it rather stupidly – so that he could check the voltage before connecting the lamp between A and B. The maximum value of the resistance of the rheostat CD was 1000 Ω.





(a) He found that, when the sliding contact of the rheostat was moved down from C to D, the voltmeter reading dropped from 12 V to 11 V. What was the resistance of the voltmeter?

(b) He modified his circuit as shown in Fig. 2, using the rheostat as a potentiometer, and was now able to adjust the rheostat to give a meter reading of 3 V. What current would now flow through the voltmeter?

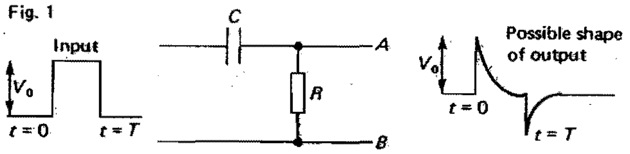
(c) Assuming that this current is negligible compared with the current through the rheostat, how far down from C would the sliding contact have been moved?

(d) The student then removed the voltmeter and connected the lamp in its place, but it did not light. How would you explain this? (The lamp itself was not defective.)

(**O and C Nuffield**: *and all other Boards*)

7.39L This question is about the properties of RC circuits fed with square pulses.

Fig. 1

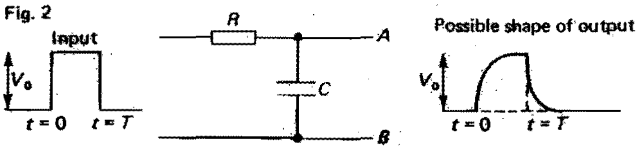


Below are four sets of ideas (a) to (d) about the effects of RC circuits on square pulses. (i) Explain fully why each statement (a) to (d) is correct. (ii) Say briefly how you would demonstrate each statement experimentally, giving typical magnitudes of components you would need to use. (iii) Describe one practical application of each of the two circuits shown.

(a) When a square pulse is first applied (at $t=0$) to the circuit in Fig. 1, the potential difference first appears in full across AB, and then decays exponentially. An inverse effect is found when the pulse is switched off at $t=T$.

(b) The variation with time of the potential difference observed across AB depends on how RC compares with the length of the pulse T. Very different effects are seen for $T \gg RC$, and $T \ll RC$.

Fig. 2



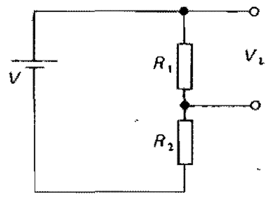
(c) A re-arrangement of the circuit (Fig. 2) leads to quite different effects across AB. These effects again depend on whether $T \gg RC$, or $T \ll RC$. This new type of circuit is called an integrating circuit.

(d) The results in (c) can be related to those for the circuit of (a), by remembering that $V_{input} = V_R + V_C$ at all times.

(**O and C Nuffield**: *and Oxford*, O and C*, and all other Boards except SEB SYS*)

7.34L State Ohm's law.

For the circuit shown in the diagram, derive an expression for the potential difference V_1 in terms of R_1, R_2 and V, where the symbols have their customary meanings and the cell has negligible internal resistance.



Deduce expressions for the potential differences indicated by a moving-coil voltmeter of resistance R when it is connected (a) across R_1, (b) across R_2.

Calculate the readings on the meter if

$V = 2$ V, $R_1 = R_2 = 1 \times 10^3$ Ω and $R = 500$ Ω.

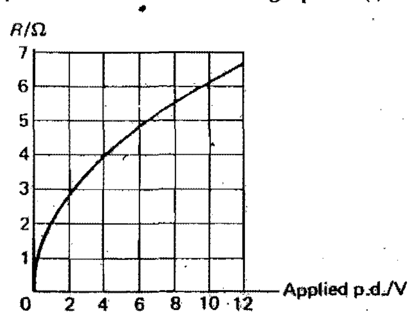
Comment on the fact that your calculated values do not add to 2 V. Hence, discuss the factors that affect the choice of voltmeters for practical purposes.

(**Cambridge**: *and all other Boards*)

7.36L

(a) Describe an experiment to determine how (i) the electrical resistance of a lamp filament, and (ii) the power converted by the filament, vary with the potential difference applied to it. Indicate with a clearly labelled circuit diagram.

(b) In such an experiment on a 12 V, 24 W lamp, the graph showing how the resistance R of the lamp filament varied with the applied pd was obtained. Use the graph to (i) calculate the



power of the lamp under normal working conditions, ie, when the applied pd is 12 V, (ii) estimate the temperature of the lamp filament under normal working conditions, assuming that the resistance of the filament is proportional to its temperature in Kelvin and that room temperature is 300 K, (iii) calculate the resistance of a fixed resistor which, when placed in series with the lamp and a 20 V dc supply, allows the lamp to work normally.

(c) When such a lamp is switched on, it may take about 0.5 s to achieve full brightness, at which time the current through the lamp is about 2 A. Explain why the current is initially greater than this and calculate its maximum value.

(**London**: *and all other Boards*)

8.23S The plates of a horizontal parallel-plate capacitor are 1 cm apart and the potential difference is 10 kV. It is found that an oil drop of mass 1.96×10^{-13} kg remains stationary between the plates. How many electronic charges does the oil drop carry? Indicate briefly how the mass of the drop could be determined experimentally assuming its charge is not known. (Electronic charge $= 1.6 \times 10^{-19}$ C).

(**WJEC**: *JMB* and all other Boards except SEB H*)

8.24S When a beam of electrons moving with speed 8.8×10^5 m s^{-1} was subjected to a uniform magnetic field of flux density 5 mT directed at right angles to the original beam, it was found that the electrons described a circular path of radius 1 mm. Find the charge-to-mass ratio for the electron.

(**WJEC**: *all other Boards except SEB H*)

8.25S When a light of frequency 5.4×10^{14} Hz is shone on to a metal surface the maximum energy of the electrons emitted is 1.2×10^{-19} J. If the same surface is illuminated with light of frequency 6.6×10^{14} Hz the maximum energy of the electrons emitted is 2.0×10^{-19} J. Use this data to calculate a value for the Planck constant.

(**London**: *and all other Boards except SEB SYS*)

8.26S Draw a sketch showing the energy levels of the electron in a hydrogen atom. Indicate on your diagram (a) the ground state of the atom, (b) the first excited state, (c) the ionization energy. How may information about the energy levels of atoms be obtained?

(**Cambridge**: *and all other Boards except SEB SYS*)

8.27S The accelerating voltage across an X-ray tube is 33.0 kV. Explain why the frequency of the X-radiation cannot exceed a certain value and calculate this maximum frequency. (The Planck constant $= 6.6 \times 10^{-34}$ J s; the charge on an electron $= 1.6 \times 10^{-19}$ C.)

(**AEB**: *JMB, WJEC and NISEC*)

8.30S A scientist wished to find the age of a sample of rock in which he knew that radioactive potassium ($^{40}_{19}$K) decays to give the stable isotope argon ($^{40}_{18}$A). He started by making the following measurements:

Decay rate of the potassium in the sample = 0.16 disintegrations/second
Mass of the potassium in the sample = 0.6×10^{-6}g
Mass of the argon in the sample = 4.2×10^{-6}g

(a) Show how he could then calculate that for the potassium (i) the decay constant (λ) was 1.8×10^{-17} s^{-1}, (ii) the half-life was 1.2×10^9y.

(b) Calculate the age of the rock, assuming that originally there would have been no argon in the sample. Show the steps in your calculation.

(c) Identify and explain a difficulty involved in measuring the decay rate of 0.16 s^{-1} given earlier in the question.

(**O and C Nuffield**: *NISEC and all other Boards except SEB H and SEB SYS*)

8.32L

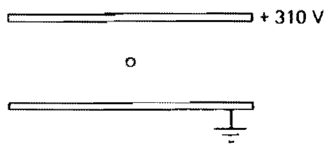
(a) Define the quantity **electrical potential difference**. What is the relationship between this quantity and electrical field strength?

(b) A small drop of oil of mass m which carries a charge Q may be held stationary in a vertical electric field of intensity E. Write down the expressions for the forces on the drop which are then in balance. Describe how this idea can be used to measure Q. Explain how the results of such an experiment indicate that all charges consist of an integral number of basic units of charge, e. In such an experiment an average of 20 doubly charged drops are produced per second. If this charge is provided by the current from the supply, what is the value of this current? Why does measuring this current not provide the basis of a practical method of estimating the value of e?
(The value of e is -1.6×10^{-19} C.)

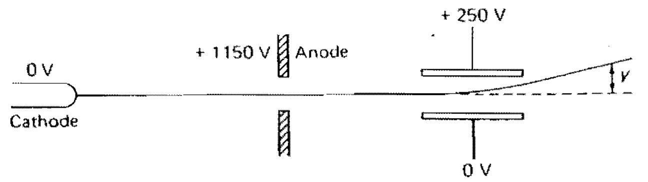
(**London**: *JMB* and all other Boards except SEB H*)

8.33L

(a) (i) Electric field strength can be expressed in V m^{-1} or N C^{-1}. Show that these are equivalent. (ii) A charged plastic sphere of mass 3.0×10^{-15} kg is held at rest between two horizontal parallel metal plates as shown in the diagram. The distance between the plates is 5.0×10^{-3} m and a potential difference of 310 V is applied across them. Calculate the charge carried by the sphere and indicate any assumptions made in the calculation of this charge. (iii) If the polarity of the plates is suddenly reversed, calculate the initial acceleration of the sphere.



(b) Electrons are emitted from the cathode in an evacuated tube. The electrons start from rest and are accelerated through a potential difference of 1150 V. Some of the electrons pass through



the anode into a region where the electric field may be assumed to be zero. Calculate (i) the speed of the electrons when they reach the anode; (ii) the deflection y that they undergo after passing between two parallel plates which are 2.0×10^{-2} m long and 1.0×10^{-2} m apart, and between which a potential difference of 250 V is maintained.

(**SEB SYS**: *all other Boards except SEB H*)

8.34L

(a) Describe and explain how to obtain a stream of fast-moving electrons. (Such a stream of electrons must also be focused if a beam is required, but you are not asked to describe the focusing system). Briefly describe one method of detecting or tracking the path of an electron beam.

(b) Describe an experiment which can be used to measure the specific charge of the electron (e/m_e) and explain how the result is obtained from the observations.

(c) An electron beam, in which the electrons are travelling at 1.0×10^7 m s^{-1}, enters a magnetic field in a direction perpendicular to the field direction. It is found that the beam can pass through without change of speed or direction if an electric field of strength 1.1×10^4 V m^{-1} is applied in the same region at a suitable orientation. (i) Calculate the strength of the magnetic field. (ii) If the electric field were switched off, what would be the radius of curvature of the electron path?

(Electron charge $e = -1.6 \times 10^{-19}$C; electron mass $m_e = 9.1 \times 10^{-31}$ kg.)

(**NISEC**: *and Oxford* and all other Boards except SEB H*)

8.36L

(a) What is meant by the photoelectric effect? Describe a practical application of this effect.

(b) A freshly cleaned zinc plate is connected to a gold-leaf electroscope. The plate is negatively charged and the leaves of the electroscope diverge. The plate is now irradiated with a mixture of ultraviolet and visible radiation and the leaves collapse. If a sheet of glass is held between the ultraviolet lamp and the plate, the collapse of the leaves is halted. If the plate is positively charged the leaves do not collapse when the ultraviolet radiation falls on the plate. Explain these observations.

(c) Explain what is meant by the work function of a metal. Discuss how the value of the work function influences the kinetic energy of the electrons liberated by photoelectric emission.

(d) A photoemissive metal will only emit electrons if the frequency of the incident radiation exceeds 5.0×10^{14} Hz. What is the value of the work function of the metal? What would be the maximum kinetic energy of the emitted electrons if the incident radiation were of wavelength 330 nm?

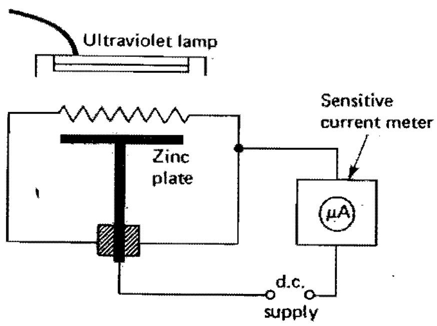
(The Planck constant = 6.6×10^{-34} J s; velocity of electromagnetic radiation = 3.0×10^8 m s^{-1}.)

(**AEB** June 81: *all other Boards except SEB SYS*)

8.37L

(a) Explain what is meant by the photoelectric effect. Indicate how it depends on (i) the frequency of the light, (ii) the intensity of the light. Explain how your answers to (i) and (ii) are related to a theory of the nature of light.

(b) A clean zinc plate is mounted in an ionization chamber, just below a wire mesh, as shown. The chamber is connected in series with a dc supply and a sensitive current meter. The current meter amplifies any small current in the circuit by a factor of 10^4 and displays the amplified current on a microammeter. The zinc plate is illuminated by an ultraviolet lamp. Describe how you would use the apparatus to show that any small current in the circuit was due to the photoelectric effect.



(c) The ultraviolet lamp above is replaced by a radioactive source. The distance of the source from the wire mesh is altered and for a number of source positions the amplified current indicated by the microammeter is recorded. The following results are obtained:

Height of source above wire mesh (cm)	5	4	3	2	1
Current (μA)	0.0	0.0	0.5	15	20

(i) What type of radiation is being detected? Give a reason for your answer. (ii) What would be the effect, if any, of reversing the polarity of the dc supply?

(**SEB H**: *all other Boards except SEB SYS*)

8.35L

(a) When atoms absorb energy by colliding with moving electrons, light or X-radiation may subsequently be emitted. For each type of radiation, state typical values of the energy per atom which must be absorbed and explain in atomic terms how each type of radiation is emitted

(b) State **one** similarity and **two** differences between optical atomic emission spectra and X-ray emission spectra produced in this way.

(c) Electrons are accelerated from rest through a potential difference of 10 000 V in an X-ray tube. Calculate (i) the resultant energy of the electrons in eV, (ii) the wavelength of the associated electron waves and (iii) the maximum energy and the minimum wavelength of the X-radiation generated.

(Charge of electron = 1.6×10^{-19}C, mass of electron = 9.11×10^{-31} kg, Planck's constant = 6.62×10^{-34} J s, speed of electromagnetic radiation *in vacuo* = 3.00×10^{8} m s^{-1}.)

(JMB: *and WJEC, NISEC*)

8.38L When the stable isotope of manganese $^{55}_{25}$Mn is irradiated in a nuclear reactor the radioactive isotope $^{56}_{25}$Mn is produced. $^{56}_{25}$Mn decays to a stable isotope $^{56}_{26}$Fe. Write equations for these nuclear transformations.

$^{56}_{25}$Mn has a half-life of a few hours. Give a full account of an experiment to measure the half-life of an isotope such as $^{56}_{25}$Mn. What factors affect the precision of the value you obtain?

Calculate the difference in mass between the particles present before and after the decay of $^{56}_{25}$Mn, given that the total energy liberated in the decay of a $^{56}_{25}$Mn nucleus is 5.9×10^{-13} J.

When $^{56}_{25}$Mn decays to $^{56}_{26}$Fe the iron nucleus is left in an excited state. The iron nucleus radiates this excitation energy as a single γ-ray of wavelength 1.47×10^{-12} m. Calculate the energy carried by the γ-ray photon, and hence the maximum kinetic energy carried by the other decay products.

($h = 6.6 \times 10^{-34}$ J s, $m_e = 9.1 \times 10^{-31}$ kg.)

(O and C: *JMB*, and all other Boards except SEB SYS and AEB*)

8.39L

(a) Describe in terms of nuclear structure the three different stable forms of the element neon, which have nucleon numbers 20, 21 and 22. Why is it impossible to distinguish between these forms chemically? A beam of single ionized atoms is passed through a region in which there are an electric field of strength E and a magnetic field of flux density B at right angles to each other and to the path of the atoms. Ions moving at a certain speed v are found to be undeflected in traversing the field region. Show (i) that $v = E/B$, and (ii) that these ions have any mass. If the emerging beam contained ions of neon, suggest how it might be possible to show that all three forms of the element were present.

(b) Explain what is meant by the binding energy of the nucleus. Calculate the binding energy per nucleon for $^{4}_{2}$He and $^{3}_{2}$He. Comment on the difference in these binding energies and explain its significance in relation to the radioactive decay of heavy nuclei.

(Mass of $^{1}_{1}$H = 1.007 83 u, mass of $^{1}_{0}n$ = 1.008 67 u, mass of $^{3}_{2}$He = 3.016 64 u, mass of $^{4}_{2}$He = 4.003 87 u, 1 u = 931 MeV.)

(London: *JMB*, and all other Boards*)

8.40L

(a) (i) Sketch a graph showing how the number of neutrons N varies with the number of protons Z for stable nuclei. Draw the line $N = Z$ and indicate approximate numerical values of N and Z on the axes. (ii) What can be deduced from the graph concerning the numbers of neutrons and protons in stable nuclei?

(b) Describe briefly the process of α-emission and β-emission by which unstable nuclei may spontaneously decay. For each process state the relation between the masses of the initial and final atoms and the emitted particle, for the decay to be possible.

(c) (i) Calculate the energy released when $^{64}_{29}$Cu nucleus decays into $^{64}_{30}$Zn.

Atomic mass of $^{64}_{29}$Cu = 63.929 76 u

Atomic mass of $^{64}_{30}$Zn = 63.929 14 u

1 atomic mass unit, u = 931.5 MeV

(ii) If the $^{64}_{29}$Cu nucleus is at rest, will the resulting $^{64}_{30}$Zn nucleus also be at rest? Give a reason for your answer.

(JMB*: *(b), (c) all Boards except SEB SYS and AEB*)