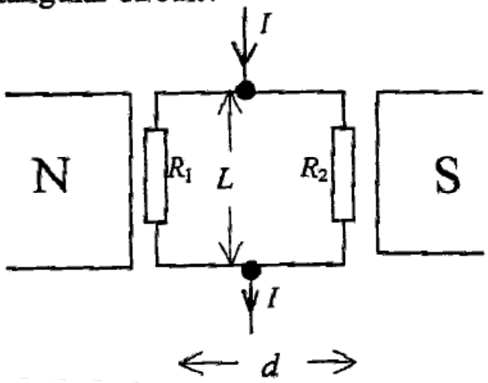
R1-2005 Q1(m)

m) Figure 1.m shows a current-carrying circuit in which the current I splits to pass through two parallel resistors of resistance R_1 and R_2. The resistors form the vertical arms of the rectangular part of the circuit of length L and width d. The rectangular arrangement is in the plane of a uniform horizontal magnetic field of flux density B produced by two pole pieces. What is the torque on the rectangular circuit?

Figure 1.m



[6]

R1-2008 Q1(l)

(l) An inverted U-shaped metal rod, with negligible electrical resistance, is erected in a vertical plane on a bench, Figure 1.l. A horizontal rod XY, length L, equal to the distance between the arms of the U, mass m and electrical resistance R, can slide freely down the arms of the U. A homogeneous magnetic field of flux density B is perpendicular to the plane of the U.

(i) If the horizontal rod falls from rest, under gravity, it will reach a terminal velocity. Explain why this occurs.

(ii) Calculate the magnitude and direction of the current, I, produced after the terminal velocity, v, of the rod is attained.

(iii) By considering the terminal motion during a small time interval, Δt, show that the loss in gravitational potential energy is equal to the heat dissipated.

[10]

R1-2009 Q1(q)

(q) What is a magnetic field line ?
Draw the magnetic field lines in a plane perpendicular to: (i) a current I in an infinite straight wire and (ii) the axis of a bar magnet at one end.

[6]

R1-2010 Q1(p)

(p) Electrons with speed v, much less than c, are injected into a uniform magnetic field of flux density B at an angle θ to the field.

(i) Show the motion is periodic.

(ii) Determine the time for one period, T.

(iii) Determine the distance travelled, L, along the direction of the field in time T.

Hint: Consider the motion along and perpendicular too the field .

[8]

R1-2002 Q4

Q4 Figure 4.1

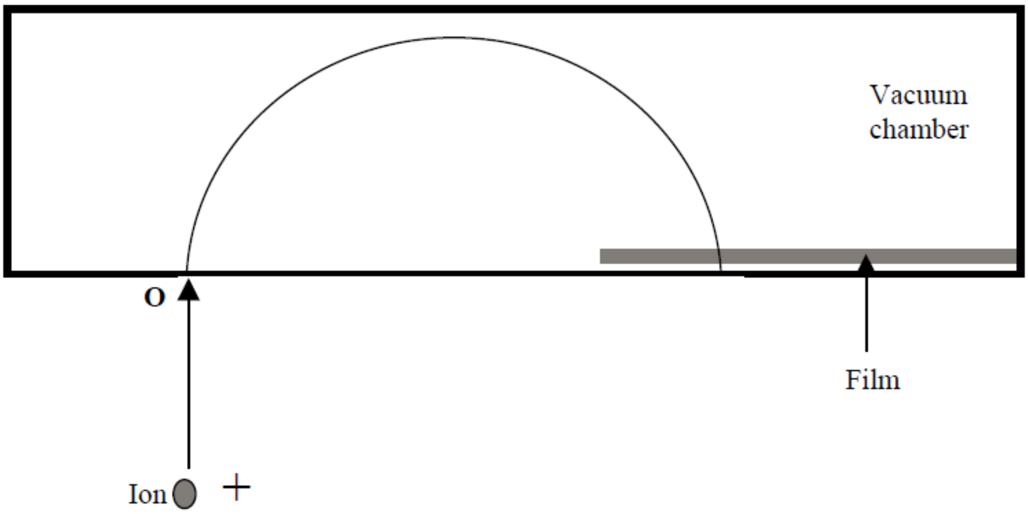


Figure 4.1

A mass spectrometer measures the mass m of ions. An ion, charge Q, is accelerated to a high speed v. It is injected at right angles to OP at O, Figure 4.1, into a region with a uniform magnetic field B which is perpendicular to the initial velocity of the ion. The ion will impact on the photographic film at P. By measuring the distance OP the mass of the ion can be determined. The spectrometer is contained in a vacuum chamber.

a) Show that:

(i) the path of an ion is circular and state the direction of the magnetic field
(ii) the radius R of the circle is given by

$$R = mv/(BQ).$$

[4]

b) Singly charged ions of K^{39}_{19} and K^{41}_{19} are accelerated through a p.d. of 500V and injected into the mass spectrometer with a magnetic flux density $B = 0.70$ T.

(i) What is the speed v_i of the ions injected into the spectrometer?
(ii) Determine the speed at which the ions hit the film, v_f.
(iii) Calculate the distance OP for each ion.

[7]

c) (i) If the accelerating voltage fluctuates within a range (500 ± 5) V, obtain the spread in OP for each ion.
Determine if the spectrometer can distinguish between the two ions.
(ii) How will a small variation in the incident direction of the ions, for constant v_i, affect their trajectories?

[9]

R1-2002 Q5(b)

b) A metal ring of mass m, radius r with a small radius of the cross sectional area, and resistance R falls, symmetrically, from rest, at time $t = 0$, in a horizontal radial magnetic field of magnitude B, Figure 5.2. At time t it has a vertical velocity v, an acceleration a and a current I.

Plan view

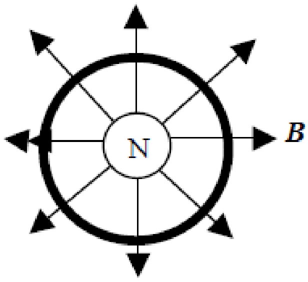


Figure 5.2

(i) Show that, due to the rate at which the magnetic flux is cut,

$$I = 2\pi rBv/R.$$

(ii) Deduce that

$$ma = mg - (2\pi rB)^2 v/R.$$

(iii) Derive the initial variation of v with t.
Deduce the terminal velocity of the ring.

(iv) Sketch graphically the variation of a and v with t. [10]

R1-2003 Q5

a) The magnitude of the magnetic flux density **B** at a distance r from an infinite straight wire carrying a current I is given by

$$B = \frac{\mu_o I}{2\pi r} \quad , \qquad \text{where } \mu_o \text{ is the permeability of free space.}$$

Show that the force per unit length, F, between two infinite parallel wires carrying currents I_1 and I_2, a distance r apart, is given by

$$F = \frac{\mu_o I_1 I_2}{2\pi r} \; .$$

Indicate the direction of F in a diagram. [2]

b) Sketch the field lines due to two parallel wires, each with current I (i) in the same direction and (ii) in opposite directions.
Draw a graph of the resultant magnetic flux density, B, against distance, x, along the infinite line through the two wires, in a plane perpendicular to the wires, for cases (i) and (ii). [9]

c) Power line conductors are arranged as a set of three parallel wires, each carrying a current of 200 A in the same direction, and separated from each other by 0.50 m, Figure 5.1.
Determine the force per metre on each wire. Draw a force diagram. [5]

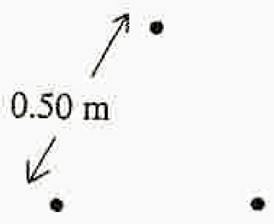


Figure 5.1

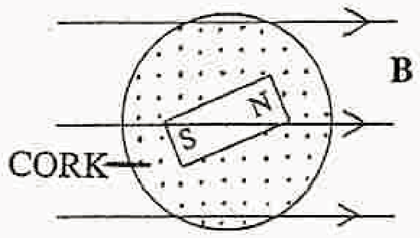


Figure 5.2

d) Figures 5.2 shows a cork, with a magnet resting on it, which is floating on water in a constant horizontal magnetic field of flux density B. When perturbed from equilibrium it oscillates with angular frequency f given by

$$f^2 \doteq \alpha B \; , \qquad \text{where } \alpha \text{ is a constant.}$$

When the magnet is suspended by a thread in the magnetic field

$$f^2 = \gamma B + \lambda \; , \qquad \text{where } \gamma \text{ and } \lambda \text{ are constants.}$$

On what physical property does λ depend ?
Describe how to use the latter arrangement to (i) verify that B, due to an infinite straight wire, falls off with distance r as $(1/r)$ and (ii) determine λ. [4]

R1-2004 Q4(c)

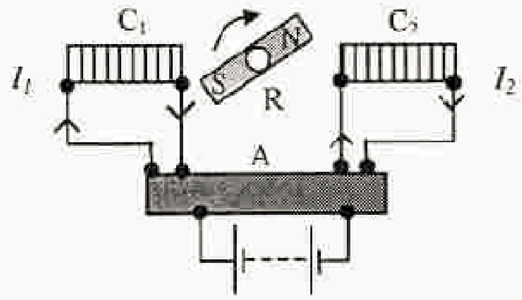


Figure 4.2

Figure 4.2 is a diagram of a brushless d c motor used to propel the solar car. The electrical cells are connected to a "black box" A, which supplies currents I_1 and I_2 to the coils. The rotor R is a magnet connected to the wheels.

(i) What is the purpose of A?

(ii) Sketch, on the same graph, the currents in the coils C_1 and C_2 as a function of time t.

[4]

R1-2004 Q6(b)

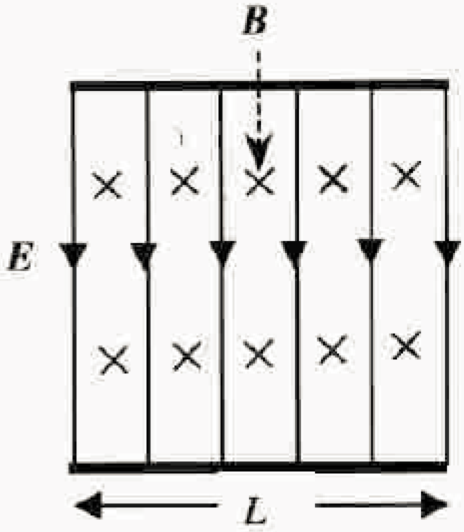


Figure 6.2

Figure 6.2 shows the plates, length L, of a CRO with a constant electric field $\boldsymbol{E}$ and a constant magnetic field of flux density $\boldsymbol{B}$ parallel to the plates and perpendicular to $\boldsymbol{E}$. A charge q, mass m, travelling horizontally with velocity v enters the region between the plates.

(i) If $\mathbf{B} = 0$, show that on emerging it will be deflected vertically by a distance y_1 given by

$$y_1 = \frac{qEL^2}{2mv^2} .$$

(ii) If $\boldsymbol{E} = 0$ and $\boldsymbol{B}$ is finite, show that the charge will emerge with a vertical deflection, y_2, in the opposite direction to y_1, given by

$$y_2 = R - \sqrt{R^2 - L^2} , \qquad \text{where } R = \frac{mv}{Bq} .$$

(iii) Show that if, during the motion through the plates, the fields are adjusted so that the forces on q balance,

$$\frac{q}{m} = \frac{2y_1 E}{B^2 L^2} .$$

[10]

R1-2005 Q4

a) A particle, mass m, rotates in a circle of radius r with constant speed s.

(i) Determine the work done by the particle in one revolution.

(ii) State the force acting on the particle.
How does it vary during the motion? [4]

b) A particle, mass m and charge Q, enters a constant magnetic field, B. The field is directed in the z – direction. It initially has velocity components along the Cartesian x-, y-, and z- axes of u, v, and w respectively, and is located at the origin.

(i) What is the magnitude of its initial velocity component, v_{xy}, in the $x - y$ plane?

Write down:

(ii) its position along the z – axis at time t

(iii) the radius of curvature, r, in any $x - y$ plane [5]

c) (i) What is the period, T, of the motion ?

(ii) Explain how the motion alters if B is increased in magnitude. [4]

d) Sketch graphs giving the variation with time, t, of the following:

(i) x and z displacements

(ii) v_x and v_z, the Cartesian velocity components

(iii) a_x and a_z, the Cartesian acceleration components [5]

e) How will reversing the direction of B affect the motion? [2]

R1-2007 Q6

(a) Faraday's law of electromagnetic induction can be expressed as

$$E = \text{ - RATE OF INCREASE OF } (\Phi).$$

Explain the symbols and the significance of the negative sign. [3]

(b) The wing span of a jumbo jet is 80m, its length is 60m and its depth is 8.0m. Estimate the magnitude of the electric potential differences that exist over the surface of the jet when it flies horizontally at 720 kmh^{-1}:

(i) over the North Pole
(ii) northwards over the equator
(iii) eastwards along the equator
(iv) northwards over London

The Earth's magnetic field density is 3×10^{-5} T at the equator, 5×10^{-5} T over London and 6×10^{-5} T at the North Pole. The angle between the horizontal and the Earth's magnetic field at London, the angle of dip, is 66°.

[11]

(c) A copper rod of length L is pivoted at its mid point and rotates about a horizontal axis perpendicular to its length, in a vertical plane, with a constant angular frequency ω . A uniform magnetic field flux density B exists parallel to the axis.

What is the magnitude of the emf developed between:

(i) the centre and one end of the rod ?
(ii) the ends of the rod ?
(iii) the ends of the rod when the pivot is moved to a point a distance x from one end ?

[6]