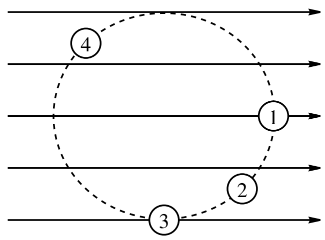
Part I

1. The diagram to the right shows four views of the end of a rod of length ℓ, moving clockwise at constant speed in a circular path, in a uniform magnetic field. The induced $\mathcal{E}$mf between the ends of the rod is maximum when the rod is at
(a) 1 (b) 2 (c) 3 (d) 4



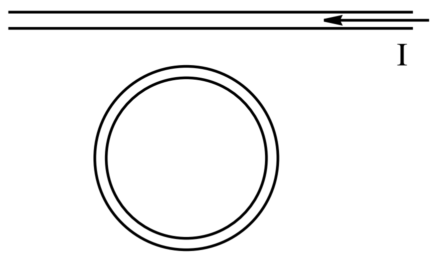
Answer (a). At (1) the conductor is moving perpendicular to the magnetic field so free electrons will feel maximum force.

2. When a wire loop is rotated in a uniform magnetic field the direction of the induced $\mathcal{E}$mf changes once every

   (a) quarter revolution.
   (b) half revolution.
   (c) revolution.
   (d) two revolutions.

   Answer (b).

3. The current in the long straight wire shown below is is increasing uniformly.
As a result a current is induced in the neighbouring loop. The current is



   (a) clockwise and constant.
   (b) clockwise and increasing uniformly.
   (c) counterclockwise and constant.
   (d) counterclockwise and increasing uniformly.

   Answer (a). It is clockwise since the flux is positive and increasing. It is constant because the flux is increasing at a constant rate.

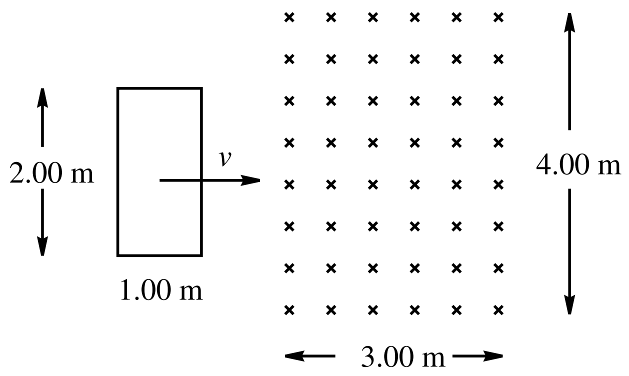
4. The force per unit length on two long parallel wires is measured to be 6.0×10^{-5} N/m when they are separated by 2.0 cm. When the two wires are moved to a distance of 1.0 cm and the current in each of the wires is doubled the new force is

   (a) 9.6×10^{-4} N/m
   (b) 4.8×10^{-4} N/m
   (c) 3.2×10^{-4} N/m
   (d) 1.2×10^{-4} N/m

   Answer (b). The force is 8 times as great: each current is doubled and the distance is halved.

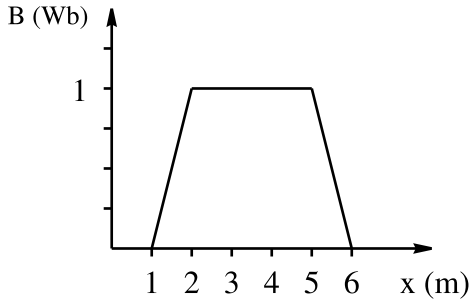
Part II

1. A rectangular loop 2.00 m long and 1.00 m wide and having a resistance of 10.0 Ω, is pushed at a constant speed of $v = 15.0$ m/s to the right as shown. It begins outside a uniform magnetic field of strength 0.500 T and width 3.00 m directed into the paper, and then moves through the field and beyond.



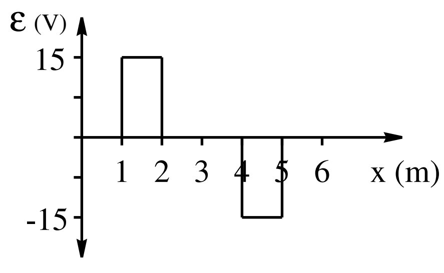
(a) Sketch a graph of the flux through the loop as a function of position as the loop passes from one side of the field to the other. Indicate on your graph the value of the maximum and minimum values of the flux. Explain the shape of your graph.

The maximum flux occurs when the loop is completely in the field $\Phi_{\text{max}} = BA = 0.50 \times 2.0 \times 1.0 = 1.0$ Wb. The minimum flux is zero when the loop is outside the field. While the loop enters the flux is increasing uniformly and as it leaves the flux is decreasing uniformly.



(b) Sketch a graph of the induced $\mathcal{E}$mf as a function of position as the loop passes from one side of the field to the other. Indicate on your graph the value of the maximum and minimum induced $\mathcal{E}$mf. Explain the shape of your graph.

$\mathcal{E} = BvL = 0.50 \times 15.0 \times 2.0 = 15$ Volts. As the loop enters the field the flux is increasing and $\mathcal{E} = 15.0$ V as the flux leaves the loop the flux is decreasing the $\mathcal{E}$mf will be in the opposite direction – ie $\mathcal{E} = -15.0$ V. When the loop is entirely inside the uniform field the there is no induced $\mathcal{E}$mf in the loop.



(c) Determine the direction of any induced current as the loop enters and leaves the region containing the field.

As the loop enters the field the current is counterclockwise as this provides an outward flux to oppose the increasing inward flux. As the loop leaves the field the current is clockwise as this provides an inward flux to oppose the decreasing inward flux.

(d) Explain why work must be done to move the loop into and out of the field. Calculate the total work done during the entire process.

When there is an induced $\mathcal{E}$mf current flows. Since current flows energy is lost through Joule heating. Therefore work must be done to provide energy to the circuit. Another way of looking at it is that when the current flows in a wire the wire feels a force opposing the motion that caused the current. An external force must then be applied to keep the loop moving and hence work must be done.

$$F = ILB = \frac{\mathcal{E}}{R}LB = \frac{BvL}{R}BL = \frac{B^2vL^2}{R} = 1.5\ \mathrm{N}$$

The force must be applied to push the coil into the field and out of the field (the same direction in both cases). So the total work done is $W =$(1.5 N)(2.0 m)= 3.0 J.