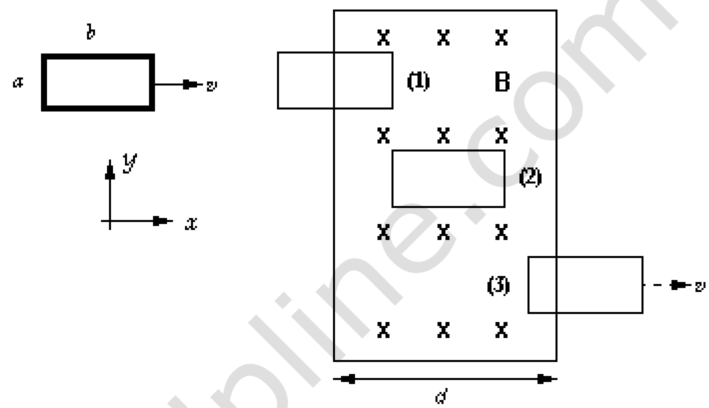
Q- A one-turn rectangular loop oriented parallel to the *x*-*y* plane and having dimensions *a* = 2 cm, *b* = 11 cm moves with a constant velocity *v* = 20 m/s in the +*x* direction. An external agent (force) ensures that this velocity remains constant throughout the motion. The wire of which the loop is made has negligible resistance. A resistor *R* = 26 Ω (not shown) is connected in the upper side of the loop. At some point, the loop enters a region of constant, spatially uniform magnetic field *B* = 1.7 T pointing in to the page. The magnetic field covers a region of "thickness" *d* = 26 cm in the *x*-direction. Calculate the induced current in the loop for each configuration.



The figure above shows the three configurations: (a) loop entering the field region; (b) loop entirely within the field region; and (c) loop emerging from the field region.

(a) Let at t = 0 the loop enters the field then at time t the length of the loop inside the field will be

x = v*t

Hence the area of the loop within the field at time t is given by

A = x*a

And the magnetic flux through it as a function of time t is given by

$$\phi_B = \vec{B} \bullet \vec{A} = BA\cos\theta = Bxa = Bavt \qquad [\theta = 0]$$

As the magnetic field strength B is constant and the area in the field is varying with time, according to the Faraday's law we have

$$\varepsilon = -\frac{d\phi_B}{dt} = -\frac{d\left(Bavt\right)}{dt} = -Bav \qquad \text{------------------------ (1)}$$

Thus the ***magnitude*** of current in the loop when it is entering in the field is given by

$$I = \frac{\varepsilon}{R} = \frac{Bav}{R} = \frac{1.7*0.02*20}{26} = 0.026\text{ A}$$

The direction of the induced current is given by the Lenz law. According to this law the direction of the induced current is such that it opposes the cause due to which it is produced. Here the current is induced due to increase in the flux in -Z direction hence the direction of the current will be such a direction that it will produce the flux in + z direction. And according to right hand rule the current in counterclockwise direction will produce the field in +z direction, hence the current in the loop will be in CCW direction.

(b) When the whole loop is with in the field the net flux through the loop remains unchanged and hence the induced EMF and the current in the loop will be zero.

(c) When the loop is coming out of the field again the flux through the loop will decrease at the same rate and the EMF induced and the current is the same in magnitude as in configuration (1) which is 0.026 A.

Here the current is induced due to decrease in the flux in -Z direction hence the direction of the current will be such a direction that it will produce the flux in - z direction. And according to right hand rule the current in clockwise direction will produce the field in - z direction, hence the current in the loop will be in CW direction.