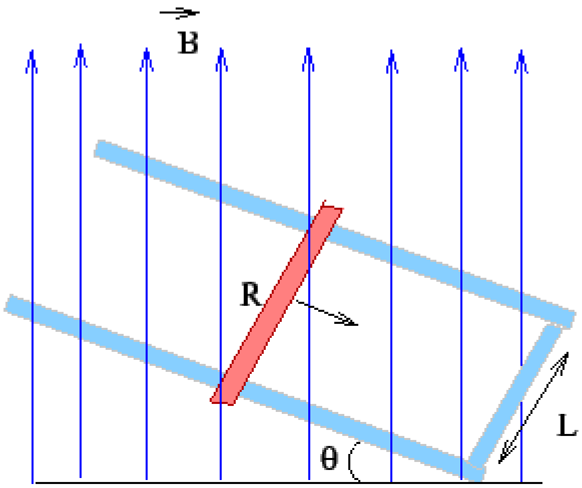
Exercise 1

A pair of parallel conducting rails are inclined at an angle θ to the horizontal. The rails are connected to each other at the ground by a conducting strip. A conductor of resistance R, oriented parallel to the strip can slide down the incline along the rails. The resistances of the rails and the strip are negligible.

A uniform magnetic field $\vec{B}$ exists in the vertical direction. The slider is released at some height. Show that the slider attains a terminal speed given by

$$v = \frac{mgR\sin\theta}{B^2L^2\cos^2\theta}$$

where L is the distance between the rails.



Exercise 2

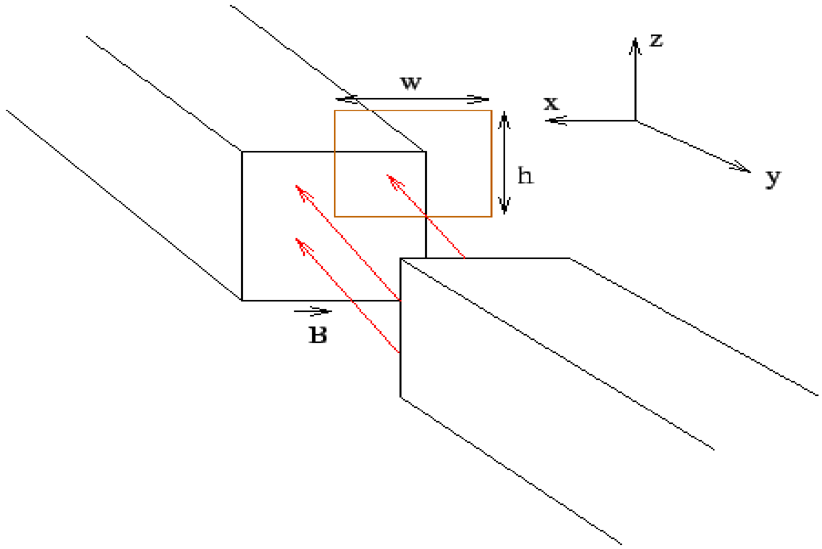
In the above problem, show that after attaining the terminal velocity, the change in the potential energy of the slider is equal to the Joule heat produced in the slider.

Hint for Solution :

In the preceding exercise, show that the current is given by $BLv\cos\theta/R$. The rate of Joule heat is I^2R. The amount of heat produced in time t is I^2Rt. In time t, the slider moves through a distance vt. The change in the potential energy is $mgvt\sin\theta$.

Exercise 3

A rectangular loop of width w and height h falls under gravity into a region of constant magnetic field B. The loop has a mass m and resistance R. The magnetic field, which remains perpendicular to the plane of the loop, is constant within the pole pieces and is zero outside.



(a) Find the current in the loop when the speed of the loop is v and (i) it is partly inside and partly outside the field region (ii) it is wholely inside the filed.

(b) Find the force acting on the loop in both the cases above.

(c) Determine the terminal velocity of the loop.

Assume that the pole pieces are much deeper than the height h.

(**Answer** : (a) (i) Bwv/R counter-clockwise (ii) zero. (b) B^2w^2v/R acts only on the lower edge. (c) terminal speed in case (i) is $v_0 = mgR/B^2w^2$. Once wholely inside, the speed increases with time as $v = v_0 + gt$.)

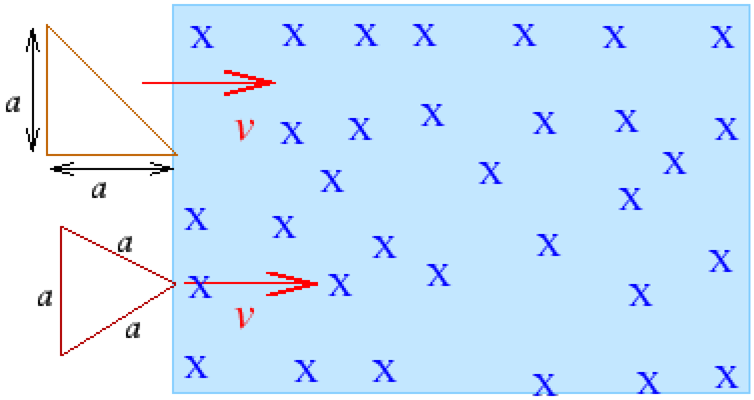
Exercise 4

A triangular current loop in the shape of an right isoceles triangle of base $a = 1$ m enters a region of constant magnetic field with a uniform speed $v = 2$ m/s. At $t = 0$ a corner of the base is at the edge of the field region (top of the figure). Find the emf at time (i) $t = 0.3$ s and (ii) $t = 1$ s.

(Ans. (i) 0.6 volts (ii) zero.)

Exercise 5

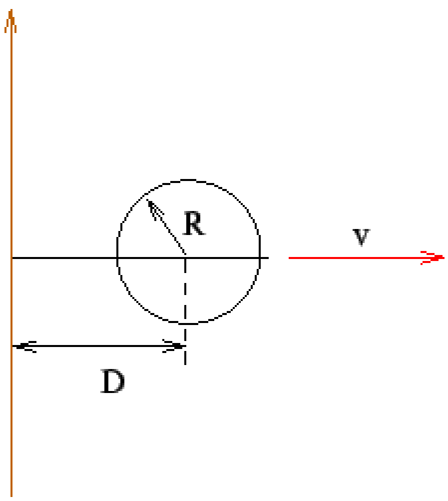
Repeat the above exercise for an equilateral triangle with side $a = 1$ m.



(Answer : 0.7 volts)

Exercise 6

(Mathematically difficult problem) : A circular loop of radius R lies in the same plane as a long straight conductor carrying a current I. The centre of the loop is at a distance D from the wire ($D > R$). The loop moves perpendicular to the wire with a uniform speed v. Calculate the motional emf developed.



(Hint : Consider the field at an element of area $r dr d\theta$. The distance of the element from the wire is $D + r\cos\theta$. Calculate the flux by integrating from $r = 0$ to R and from $\theta = 0$ to 2π. Use : $\int_0^{2\pi} \frac{d\theta}{D + r\cos\theta} = \frac{2\pi}{\sqrt{D^2 - r^2}}$

(Answer $\mu_0 I v(D/\sqrt{D^2 - R^2} - 1)$)