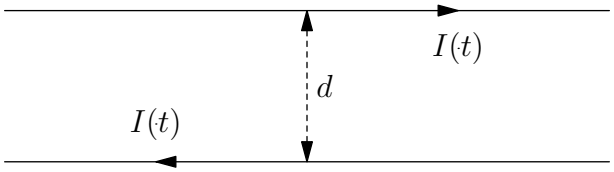
M03E.1—Force Between Current Carrying Wires

Problem

Two infinitely long parallel wires, a distance d apart, carry time-dependent currents $I(t)$ of the same magnitude but opposite direction, as shown in the figure:



We will consider two possible time histories of the current:

a) Suppose that the current switches on suddenly at time $t = 0$ and remains constant thereafter (i.e. that $I(t) = I_0\theta(t)$). Calculate, as a function of time, the force per unit length $F(t)$ on the wires and sketch your result. It is not really possible to instantaneously turn on a current in a circuit: explain how your answer reflects this fact.

b) Now let's do it in a more realistic fashion by turning on a linearly increasing current at time $t = 0$ which continues to increase until I_0 is reached (i.e. $I(t) = bt$ for $t < 0 < I_0/b$ and $I = I_0$ for later times). As in the previous item, calculate the force per unit length $F(t)$ between the wires and plot your result.

Note the possibly useful indefinite integral:

$$\int \frac{dy}{\sqrt{y^2 - a^2}} = \log(\sqrt{y^2 - a^2} + y)$$