446.

Problem 34.43 (RHK)

Consider the possibility of a new design for an electric train. The engine is driven by the force due to the vertical component of the Earth's magnetic field on a conducting axle. Current is passed down one rail, into a conducting wheel, through the axle, through another conducting wheel, and then back to the source via the other rail (*see the previous problem #* ***445***). *We can take the vertical component of the Earth's field to be* 10 μT. (a) *We have to calculate the current required to provide a modest* 10-kN *force*. (b) *We have to find the power loss for each ohm of resistance in the rails*. (c) *We have to decide whether such a train is totally unrealistic or just marginally unrealistic.*

Solution:

We will use the results of the previous problem, i.e. problem # 445, in answering this problem.

The role of the sliding wire that moves on the rails will be played by the axle of the engine of the train. The driving magnetic field is the vertical component of the Earth's magnetic field, which is assumed to be $10\ \mu\text{T}$. The length of the axle of the engine is 3.0 m. We will calculate the current, $i\ (\text{A})$, that is needed for providing a force of 10 kN.

(a)

Force on a wire of length *d*, placed in magnetic field B, which is perpendicular to the current *i* flowing through it, will be

$F = idB.$

In our problem

$B = 10\ \mu\text{T} = 10^{-5}\ \text{T},$

$d = 3.0\ \text{m},$

and

$F = 10^{4}\ \text{N}.$

Therefore,

$$i = \frac{10^{4}}{3.0 \times 10^{-5}}\ \text{A} = 333 \times 10^{6}\ \text{A}.$$

(b)

Power loss for each ohm of resistance in the rails will be

$$P = i^2 R = \left(333 \times 10^6\right)^2 \times 1\ \text{W} = 1.11 \times 10^{17}\ \text{W}.$$

Therefore, such a train is totally unrealistic.