Exam 2 Solutions

Honors Physics

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Problem 1

(a) The current generator supplies a *constant* current. The force on the current rod is:

$$F = ma = m\frac{dv}{dt} = iBL \tag{1}$$

Integrating yields:

$$v(t) = \frac{iBL}{m}t \tag{2}$$

The direction of v is away from the generator.

(b and c) Now consider the case when the constant current generator is replaced by a constant voltage source. Initially the current in the rod is V/R where R is the resistance of the circuit and the V is the voltage of the source. Because of the current there is a force on the rod. The rod moves away from the voltage source. As it does, there is an induced emf, ε, given by:

$$\varepsilon = \frac{d(BA)}{dt} = B\frac{d(A)}{dt} = BLv \tag{3}$$

where A is the area of the circuit which changes with time as the rod moves. But ε acts opposite to the applied V so that the current is now $(V - \varepsilon)/R$ – the current decreases and the velocity increases and eventually the velocity reaches a terminal velocity when the current is zero when $V = \varepsilon$. So the terminal velocity is given by:

$$v = \frac{V}{BL} \tag{4}$$

Problem 2

In this problem we can ignore the straight sections of current that are radially directed from the point at the center of the arc (upper segment) and semi-circle (lower segment). They contribute zero magnetic field.

For an arc length of s centered at point P where the radius of curvature is R, the field at point P is perpendicular to the plane in which the arc lies and is given by the right-hand-rule where the magnitude is:

$$B = \frac{\mu_0 i s}{4\pi R^2} \tag{5}$$

The arc length of the lower segment is πR_l and the arc length of the upper segment is $2\pi R_u/3$. The net magnetic field at the center is perpendicular to the page and inward and of magnitude:

$$\left|\frac{\mu_0 i}{4}\left[\frac{1}{R_l} - \frac{4}{3R_u}\right]\right| = 1.68 \times 10^{-6}\ T \tag{6}$$

Problem 3

On either side of a magnetic dipole the magnetic field is anti-parallel to the direction of the dipole. So in arrangement (a) the orientation of the two dipoles about the center dipole is energetically favored (lower potential energy).

That is not the case for arrangement (b) which therefore has a larger potential energy.