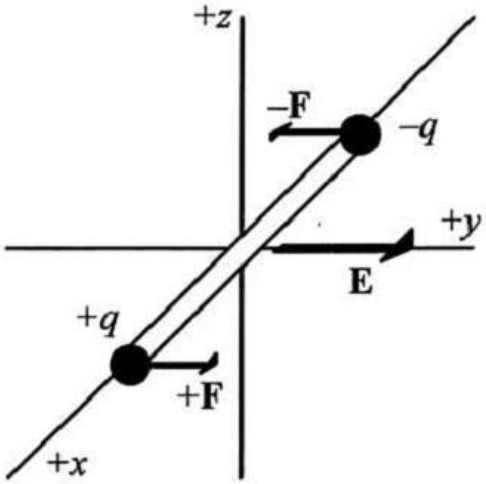
Answer on Question 62605, Physics, Electromagnetism

Question:

A long, thin rod (length = 4.0 m) lies along the x-axis, with its midpoint at the origin. In a vacuum, a $+8.0\ \mu C$ point charge is fixed to one end of the rod, and a $-8.0\ \mu C$ point charge is fixed to the other end. Everywhere in the x, y plane there is a constant external electric field (magnitude = $5.0 \cdot 10^3\ N/C$) that is perpendicular to the rod. With respect to the z axis, find the magnitude of the net torque applied to the rod.

Solution:

Here's the sketch of our task:



We have the long, thin rod of length $L = 4.0\ m$ that lies along the x-axis, with its midpoint at the origin as shown in the picture above. The $+8.0\ \mu C$ point charge is fixed to one end of the rod, and a $-8.0\ \mu C$ point charge is fixed to the other end. Also, everywhere in the x, y plane there is a constant external electric field of magnitude $5.0 \cdot 10^3\ N/C$ that is perpendicular to the rod. Our task is to find the magnitude of the net torque applied to the rod with respect to the z axis.

As we can see from the picture, the electrostatic forces acting on each charge are directed in opposite directions, but have the same magnitude:

$$F_e = |q|E,$$

here, q is the point charge and E is the electric field.

These forces will produce a torques and cause the rod to rotate about the z-axis. By the definition, the magnitude of the torque is equal to the magnitude of the force times the lever arm. The lever arm, l, is the perpendicular distance between the point where the electrostatic force applied and the axis of rotation. Since, the z-axis of rotation lies midway between the ends of the rod of length L, the lever arm will be $L/2$ and the torque:

$$\tau = F_e l = \frac{L}{2}|q|E.$$

Since both torques cause the rod to rotate about the z-axis in the same direction, they will add and we get:

$$\tau_{net} = \frac{L}{2}|q|E + \frac{L}{2}|q|E = |q|EL = 8.0 \cdot 10^{-6}\ C \cdot 5.0 \cdot 10^{3}\ \frac{N}{C} \cdot 4.0\ m = 0.16\ N \cdot m.$$

Answer:

$\tau_{net} = 0.16\ N \cdot m.$