A conducting rod of mass 1.75 kg slides without friction on two horizontal conducting rails that are 10.0 cm apart. It starts from rest at t = 0. At t = 0 a steady current I = 25.0 A, is turned on. The rod travels 2.09 m to the right in the first 3.00 seconds.

(a) Find the magnitude and direction of the magnetic field (assumed uniform and vertical).
(b) Calculate the Emf generated in the rod as a function of time.

a) Force on current carrying conductor
\[ \vec{F} = I \vec{d} \times \vec{B} \]
\( l, B = \text{const} \Rightarrow \vec{F} = \text{const} \) and \( m = \text{const} \) \( \Rightarrow \) \( a = \text{const} \)

So we can use kinematic equations
\[ \Delta x = \frac{1}{2} a t^2 + v_0 t \]
\( \Rightarrow \) \( a = \frac{2\Delta x}{t^2} = 0.4644 \text{ m/s}^2 \)

To find direction of \( \vec{B} \), note that we want \( \vec{F} = F \hat{i} \), we know \( \vec{d} = dl \hat{j} \Rightarrow \vec{B} = B \hat{z} \), up out of the paper, as \( \hat{j} \times \hat{z} = \hat{x} \)

To find magnitude of \( \vec{B} \)
\[ |\vec{F}| = I l B (\sin 90^\circ) = ma \]
\( \Rightarrow \) \( B = \frac{ma}{l I} = 0.3251 \text{ T} \)

\[ B = 0.325 \text{ T up out of paper} \]
b) The \( I \) is held constant, we can ignore it while we calculate the force on the charges in the bar that are due to the bars velocity & the \( \overline{B} \) field

\[
d\overline{F}_{\text{on charges}} = d\overline{g} \times \overline{B}
\]

\[
d\overline{w} = l \, d\overline{F} = l \, d\overline{g} \times (\overline{v} \times \overline{B})
\]

\[
E = \frac{d\overline{w}}{d\overline{g}} = l \, v \, B \sin(90^\circ) = l \, B \, v(t)
\]

Now, we need \( I \) to calculate \( v(t) \)

\[
v(t) = at = I \frac{eb^2}{m} \, t \quad \text{part a)}
\]

\[
\Rightarrow \quad E = l \, B \, \frac{Ieb^2}{m} \, t = \boxed{I \frac{eb^2}{m} \, t = \varepsilon}
\]

OR, if you chose to think of a generator connecting the 2 wires a far but finite distance away, then,

\[
|E| = \frac{d\Phi_b}{dt} = B \frac{d(\text{area})}{dt} = B \, l \, \frac{dx}{dt}
\]

\[
\frac{dx}{dt} = v = at
\]

\[
E = Blv = Bl(\frac{Ieb^2}{m})t = \boxed{I \frac{eb^2}{m} \, t = \varepsilon}
\]

Numerically,

\[
E = (0.0151 \, \varepsilon) t
\]

\( \leftarrow 10 \text{ pts}, \text{ either answer} \)

Common Errors —

Forgetting Kinematics
(e.g. \( v_x = \frac{dx}{dt} \)) -5 pts

No function for part b)

\( E(t) = Blv(t) \) -5 pts

Calculating \( \overline{B} \) due to wires —
This is not what the problem was asking. - No credit