A conducting rod of length $\ell = 35.0$ cm is free to slide on two parallel conducting bars as shown. Two resistors, $R_1 = 2.00 \, \Omega$ and $R_2 = 5.00 \, \Omega$ are connected across the ends of the bars to form a loop. A constant magnetic field $B = 2.50 \, T$ is directed perpendicularly into the page. An external agent pulls the rod to the left with a constant speed of $v = 8.00 \, m/s$.

(a) [8 pts.] Find the currents in both resistors.
(b) [6 pts.] Calculate the total power delivered to the resistance of the circuit.
(c) [6 pts.] Find the magnitude of the applied force that is needed to move the rod with this constant velocity.

\[ I_1 = \frac{E}{R_1} = \frac{B\ell v}{R_1} = \frac{(2.5)(0.35)(8)}{2} = 3.50 \, A \]
\[ I_2 = \frac{E}{R_2} = \frac{B\ell v}{R_2} = \frac{(2.5)(0.35)(8)}{5} = 1.40 \, A \]

\[ P = P_1 + P_2 = I_1^2 R_1 + I_2^2 R_2 = (3.5)^2 (2) + (1.4)^2 (5) = 34.30 \, W \]

\[ F = \frac{P}{v} = \frac{34.30}{8} = 4.29 \, N \]
A piece of copper wire with thin insulation, 200 m long and 1.00 mm in diameter, is wound onto a plastic tube to form a long solenoid. This coil has a circular cross section and consists of tightly wound turns in one layer. If the current in the solenoid drops linearly from 1.80 A to zero in 0.120 seconds, an emf of 80.0 mV is induced in the coil. What is the length of the solenoid, measured along its axis? Assume the radius of solenoid is much greater than 1.00 mm.

\[ \varepsilon = -L \frac{dI}{dt}, \quad L = \frac{N^2 A \mu_0}{\varepsilon} \]

\[ \frac{\varepsilon \Delta t}{\Delta I} = L = \frac{N^2 A \mu_0}{\varepsilon \Delta t} \]

\[ l = \frac{N^2 A \mu_0 \Delta I}{\varepsilon \Delta t} \]

\[ = \frac{200^2}{2\pi^2 \mu_0} \cdot \pi r^2 \left( \frac{1.80}{80 \times 10^{-3}} \right) \left( \frac{1.80}{0.120} \right) \]

\[ = 0.75 \text{ m} \quad \text{or} \quad 75 \text{ cm} \]
Consider a series RLC circuit having the following circuit parameters: \( R = 200 \, \Omega \), \( L = 663 \, \text{mH} \), and \( C = 26.5 \, \mu\text{F} \). The applied voltage has an amplitude of 50.0 V and a frequency of 60.0 Hz.

(a) \[ 5 \text{ pts.} \] Find the current \( I_{\text{max}} \), including its phase constant \( \phi \) relative to the applied voltage \( \Delta V \).

(b) \[ 5 \text{ pts.} \] Find the voltage \( \Delta V_R \) across the resistor and its phase relative to the current.

(c) \[ 5 \text{ pts.} \] Find the voltage \( \Delta V_C \) across the capacitor and its phase relative to the current.

(d) \[ 5 \text{ pts.} \] Find the voltage \( \Delta V_L \) across the inductor and its phase relative to the current.

\[ \omega = 2\pi f = 2\pi 60 = 376.99 \, \text{rad/s} \]

\[ X_L = \omega L = (376.99)(663 \times 10^{-3}) = 247.95 \, \Omega \]

\[ X_C = \frac{1}{\omega C} = \frac{1}{376.99 \times 26.5 \times 10^{-6}} = 100.12 \, \Omega \]

Impedance of the circuit:

\[ Z = \sqrt{R^2 + (X_L - X_C)^2} \]

\[ Z = \sqrt{200^2 + (249.95 - 100.12)^2} = 249.91 \, \Omega \]

(a) \[ I_{\text{max}} = \frac{\Delta V_{\text{max}}}{Z} = \frac{50}{249.91} = 0.20 \, \text{mA} \]

(b) \[ \Delta V_R = I_{\text{max}} R = (0.2)(200) = 40 \, \text{V} \] in phase with \( I \).

(c) \[ \Delta V_C = I_{\text{max}} X_C = (0.2)(100.12) = 20 \, \text{V} \] lead by 90°.

(d) \[ \Delta V_L = I_{\text{max}} X_L = (0.2)(249.91) = 50 \, \text{V} \] lag by 90°.
An 80.0 Ω resistor, a 200 mH inductor, and a 0.1500 μF capacitor are connected in parallel across a 120 V (rms) source operating at 374 rad/s.

(a) [5 pts.] What is the resonant frequency of the circuit?
(b) [6 pts.] Calculate the rms current in the resistor, inductor and capacitor.
(c) [5 pts.] What is the rms current delivered by the source?
(d) [4 pts.] Is the current leading or lagging behind the voltage? By what angle?

\[ X_L = \omega L = 374 \text{(200x10}^3) = 74.80 \Omega \]
\[ X_C = \frac{1}{\omega C} = \frac{1}{374 \text{(0.15x10}^{-6})} = 17.825 \text{.31} \Omega \]

a) \[ \omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(200\times10^3)(0.15\times10^{-6})}} = 5,773.50 \text{ rad/s} \]

b) \[ I_R = \frac{E}{R} = \frac{120}{80} = 1.50 \text{ A} \]
[1.50 A]

\[ I_L = \frac{E}{X_L} = \frac{120}{74.80} = 1.60 \text{ A} \]

\[ I_C = \frac{E}{X_C} = \frac{120}{17.825} = 0.007 \text{ A} \]

\[ I_C \]

\[ I_5 = \left[ I_R^2 + (I_L - I_c)^2 \right]^{1/2} \]
\[ = \left[ 1.5^2 + (1.6 - 0.007)^2 \right]^{1/2} \]
\[ = 2.19 \text{ A} \]

\[ \Theta = \tan^{-1}\left( \frac{I_L - I_c}{I_R} \right) \]
\[ = \tan^{-1}\left( \frac{1.6 - 0.007}{1.5} \right) = 46.7^\circ \text{ Lagging} \]
A microwave source produces pulses of 20.0 GHz radiation, with each pulse lasting 1.00 ns. A parabolic reflector with a face area of radius $6.00 \text{ cm}$ is used to focus the microwaves into a parallel beam of radiation, as shown in the drawing. The average power during each pulse is 25.0 kW.

(a) What is the wavelength of these microwaves?

(b) What is the total energy contained in each pulse?

(c) Calculate the average energy density inside each pulse.

(d) Determine the amplitude of the electric and magnetic fields in these microwaves.

(e) Assuming this pulsed beam strikes an absorbing surface, calculate the force exerted on the surface during the 1.00 ns duration of each pulse.

\[
\lambda = \frac{c}{f} = \frac{3 \times 10^8}{20 \times 10^9} = 0.015 \text{ m}
\]

\[
\text{Total energy} = (2.5 \times 10^5 \text{ J}) (10^{-9} \text{ s}) = 2.5 \times 10^{-5} \text{ J}
\]

\[
\text{Energy density} = \frac{E}{\nu \rho} = \frac{2.5 \times 10^5}{\pi (0.06)^2 (3 \times 10^8)(10^{-9})} = 0.007 \text{ J/m}^3
\]

\[
S = \rho \cdot c = \frac{E^2}{c \mu_0}
\]

\[
S_{av} = \frac{E_{av}^2}{c \mu_0} = \frac{E^2}{2c \mu_0}
\]

\[
E = 2c \mu_0 \rho \cdot c
\]

\[
E = c (2 \mu_0 \rho)^{1/2}
\]

\[
E = (3 \times 10^8) (2 \pi \times 10^7 \text{ m/s})^{1/2}
\]

\[
E = 4.08 \times 10^4 \text{ V/m}
\]

\[
B = \frac{E}{c} = \frac{4.08 \times 10^4}{3 \times 10^8} = 1.36 \times 10^{-4} \text{ T}
\]

\[
F = \frac{S_{av}}{c} \pi d^2 = \frac{E^2}{2c^2 \mu_0} \pi d^2
\]

\[
= \frac{(4.08 \times 10^4)^2 \pi (0.06)^2}{2 (9 \times 10^{-6}) 4\pi \times 10^{-7}}
\]

\[
= 8.32 \times 10^{-5} \text{ N}
\]