1. [4 marks] The magnetic field at the centre of a 1.0-cm-diameter loop is 2.5 mT.

(a) Determine the current in the loop.

(b) A long straight wire carries the same current as in Part (a). Determine the distance from the wire at which the magnetic field is 2.5 mT.

Solution: (a) The magnetic field $B$ at the centre of the loop is

$$B = \frac{\mu_0 I}{2R}$$

and therefore

$$I = \frac{2RB}{\mu_0}$$

$$I = \frac{2(5 \times 10^{-3})(2.5 \times 10^{-3})}{4\pi \times 10^{-7}}$$

$$I = 19.9 \text{ A}$$

(b) The magnetic field for the long straight wire is

$$B = \frac{\mu_0 I}{2\pi r}$$

and therefore, using the result of Part (a), we obtain

$$r = \frac{\mu_0 I}{2\pi B}$$

$$r = \frac{\mu_0}{2\pi} \cdot \frac{I}{B}$$

$$r = \frac{\mu_0}{2\pi} \cdot \frac{2R}{\mu_0}$$

$$r = \frac{R}{\pi}$$

$$r = \frac{5 \times 10^{-3}}{\pi}$$

$$r = 1.59 \times 10^{-3} \text{ m}$$

$$r = 1.59 \text{ mm}$$
2. [4 marks] At $t = 0$ s, a proton is moving with a speed of $5.5 \times 10^5$ m/s in the direction shown in the figure. A uniform magnetic field of magnitude 1.50 T points in the positive-$y$ direction. Determine the $y$-coordinate of the proton's position 10 $\mu$s later.

![Diagram of proton motion with magnetic field](image)

**Solution:** Using the right hand rule, the force on the proton is straight out of the page. Thus, the component of force in the $y$-direction is zero. Thus, the $y$-component of acceleration is zero; in other words, the $y$-component of velocity is constant.

Thus, the $y$-component of displacement is

$$y = v_y \Delta t = v \sin 30^\circ \Delta t = (5.5 \times 10^5) \left( \frac{1}{2} \right) (10 \times 10^{-6}) = 2.75 \text{ m}$$

3. [4 marks] A 1000-turn coil of wire 2.0 cm in diameter is in a magnetic field that drops from 0.10 T to 0 T in 10 ms. The axis of the coil is parallel to the field. Determine the emf of the coil.

**Solution:**

$$\mathcal{E} = N \frac{\Delta \Phi}{\Delta t} = NA \frac{\Delta B}{\Delta t} = (1000) \left( \pi \left[10^{-2}\right]^2 \right) \left( \frac{0.1}{10 \times 10^{-3}} \right) = \pi = 3.1 \text{ V}$$

4. [4 marks] A mass spectrometer is designed to separate protein fragments. Each fragment is ionized by the removal of a single electron, then enters a region in which there is a uniform, 0.80 T magnetic field at a speed of $2.3 \times 10^5$ m/s. If a protein fragment has a mass 85 times the mass of a proton, determine the distance between the points where the fragment enters and exits the magnetic field.

**Solution:** The distance between the points where the fragment enters and exits the magnetic field is the diameter of the circular orbit of the fragment, $2r$. Applying Newton's second law of motion to the circular orbit of the fragment, and then solving
for the diameter, we obtain

\[
ma = F \\
\frac{mv^2}{r} = qvB \\
r = \frac{mv^2}{qvB} \\
r = \frac{mv}{qB} \\
2r = \frac{2mv}{qB} \\
2r = \frac{2 (85 \times 1.67 \times 10^{-27}) (2.3 \times 10^5)}{(1.60 \times 10^{-19}) (0.80)} \\
2r = 0.51 \text{ m}
\]

5. **[4 marks]** While using a dimmer switch to investigate a new type of incandescent light bulb, you notice that the light changes both its spectral characteristics and its brightness as the voltage is increased. If the wavelength of maximum intensity decreases from 1800 nm to 1600 nm as the bulb’s voltage is increased, by how many degrees Celsius does the filament temperature increase?

**Solution:**

\[
\lambda_{\text{peak}} = \frac{2.9 \times 10^6}{T} \quad \implies \quad T = \frac{2.9 \times 10^6}{\lambda_{\text{peak}}}
\]

Thus,

\[
\Delta T = \frac{2.9 \times 10^6}{\lambda_{\text{peak},2}} - \frac{2.9 \times 10^6}{\lambda_{\text{peak},1}}
\]

\[
\Delta T = 2.9 \times 10^6 \left[ \frac{1}{\lambda_{\text{peak},2}} - \frac{1}{\lambda_{\text{peak},1}} \right]
\]

\[
\Delta T = 2.9 \times 10^6 \left[ \frac{1}{1600} - \frac{1}{1800} \right]
\]

\[
\Delta T = 201.4 \text{ K}
\]

\[
\Delta T = 200 \degree \text{C}
\]

6. **[5 marks]** Choose the best response from the alternatives.

(a) Two long straight wires carry equal and opposite currents, as shown in the figure below. At a point directly between the two wires, the magnetic field is

i. directed up, towards the top of the page.
ii. directed down, towards the bottom of the page.
iii. directed straight out of the page.
iv. directed straight into the page.
v. zero.
(b) The figure below shows four particles moving to the right as they enter a region of uniform magnetic field, directed into the paper as shown. All particles have the same speed and the same charge. Which particle has the largest mass?

i. A
ii. B
iii. C
iv. D
v. [They all have the same mass.]

Answer: (iv)

(c) A current-carrying wire produces a magnetic field. When the current in the wire doubles, the magnetic field

i. increases by a factor of two.
ii. decreases by a factor of two.
iii. does not change.
iv. increases by a factor of four.
v. decreases by a factor of four.

Answer: (i)

(d) One coil is placed on top of another, with their axes parallel, and without the two coils being electrically connected. The bottom coil is connected in series to a battery and a switch. With the switch closed, there is a clockwise current in the bottom coil. When the switch is opened, the current in the bottom coil decreases abruptly to zero. What is the direction of the induced current in the top coil?
i. clockwise
ii. counter-clockwise
iii. zero, because there is an induced current only when the coils move relative to each other
iv. zero, because there is no change in magnetic flux through the top coil
v. [It depends on the magnitude of the current.]

**Answer:** (i)

(e) Two identical bar magnets are dropped vertically from the same height. One magnet passes through a closed metal ring and the other magnet passes through a metal ring that has a gap in it. Which magnet reaches the ground first?

   i. the magnet passing through the closed ring
   ii. the magnet passing through the ring with the gap
   iii. the magnets reach the ground at the same time
   iv. [It depends on the initial height.]
   v. [It depends on the strength of the magnet.]

**Answer:** (ii)