1. Find the torque around the $x-$axis, $\vec{\tau}$, that the blue wire carrying a current I (see Fig. 1) experiences in the presence of a uniform magnetic field, $\vec{B} = B_o\hat{\boldsymbol{\jmath}}$.

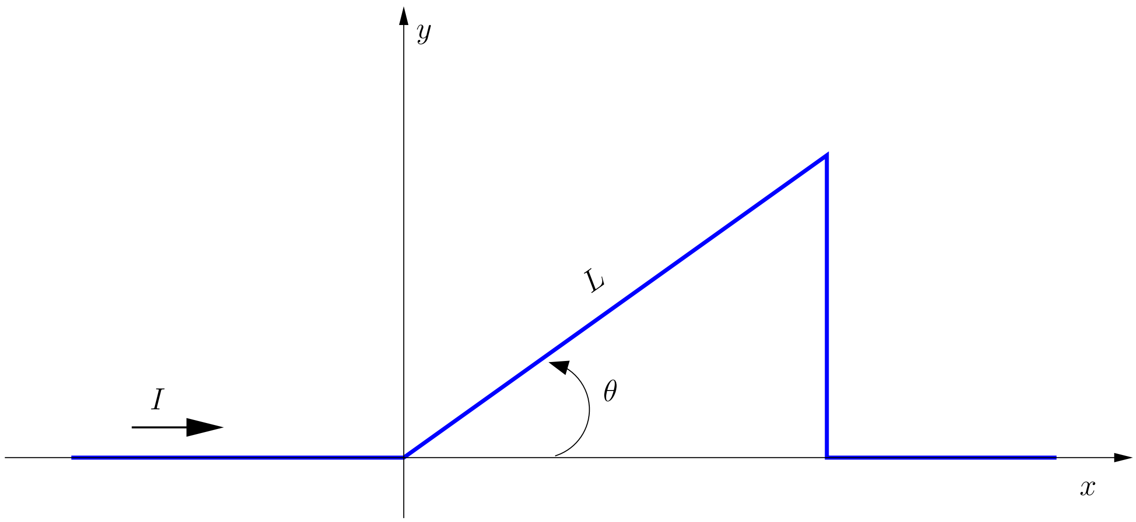

Figure 1: A wire carrying current I is shown in blue. L is the length of the "diagonal" part of the wire.

Ans: $\vec{\tau} = \frac{IB_oL^2\sin(\theta)\cos(\theta)}{2}\hat{\boldsymbol{\imath}}$

2. Find the net force on a wire bent into a semi-circle shape with radius R and carrying a current I (see Fig. 2) in the presence of a non-uniform magnetic field, $\vec{B} = \arctan(\theta)z\hat{\boldsymbol{k}}$. Make sure you evaluate any integrals that may arise!

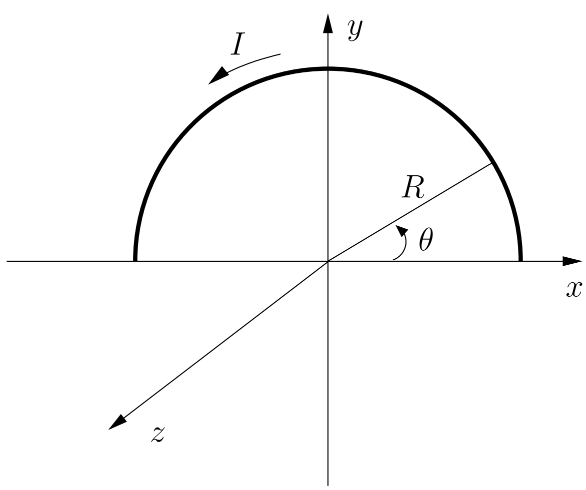

Figure 2: A semi-circular wire with radius R and current I lies in the $z = 0$ plane.

Ans: $\vec{F} = 0\hat{\boldsymbol{\imath}} + 0\hat{\boldsymbol{\jmath}} + 0\hat{\boldsymbol{k}}$

3. Set up an expression for the net force on the wire (curve) $y = f(x)$, where $x_1 \leq x \leq x_2$ lies in the $z = 0$ plane and carries a current I (see Fig. 3). Assume that there is a non-uniform magnetic field $\vec{B} = \vec{B}(x, y, z)$ in the region of space where the wire lies.

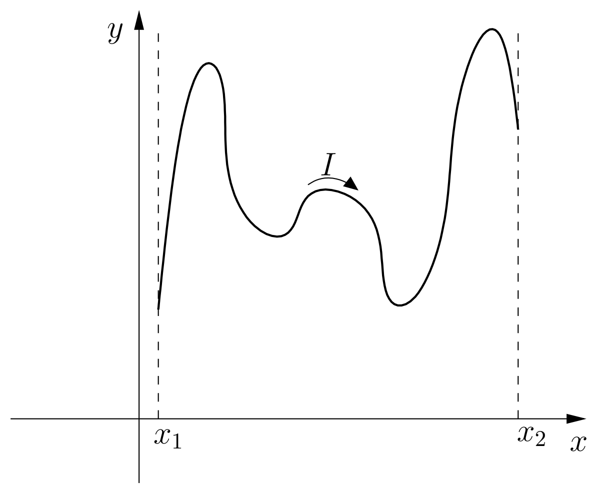

Figure 3: An arbitrary wire (curve), $y = f(x)$, carrying a current I (as indicated on the diagram) is shown.

Ans: $\vec{F} = \int_{x_1}^{x_2} I \left[\mathrm{d}x\, \hat{\boldsymbol{\imath}} + f'(x)\, \mathrm{d}x\, \hat{\boldsymbol{\jmath}} \right] \times \vec{B}(x, y = f(x), z = 0)$

4. A particle with charge q is traveling with constant velocity $\vec{v}$, where $v \ll c$ and $c = \frac{1}{\sqrt{\epsilon_o \mu_o}}$ is the speed of light (we will learn this later in the course). Write an expression for the magnetic field, $\vec{B}$, that the particle generates, in terms of the electric field $\vec{E}$ and speed of light c.

Ans: $\vec{B} = \frac{\vec{v} \times \vec{E}}{c^2}$

5. Helmholtz coil. This problem is NOT on the quiz.

(a) **Without using any symmetry arguments**, find the magnetic field anywhere on the $z-$axis.

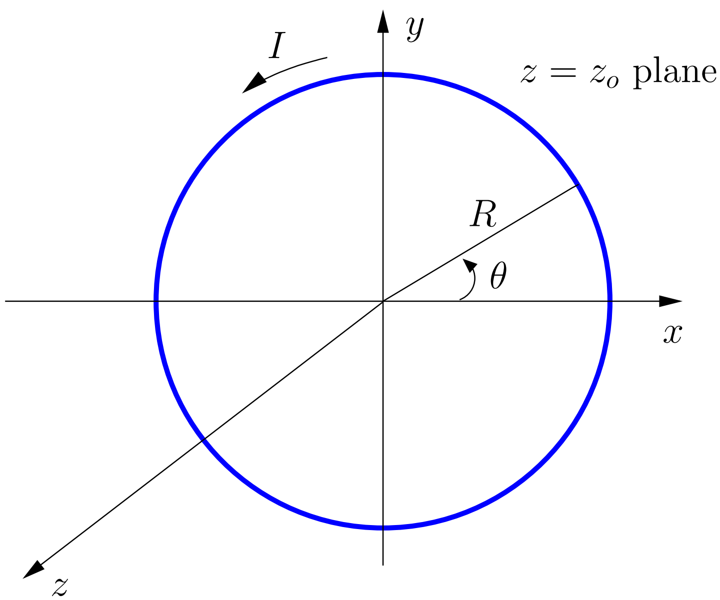

Figure 4: A circular wire with radius R and current I lies in the $z = z_o$ plane.

Ans: $\vec{B} = \frac{\mu_o I R^2}{2\left[R^2 + (z - z_o)^2\right]^{3/2}}\hat{\boldsymbol{k}}$

(b) Find the magnetic field due to two circular coils, each having a radius R and carrying current I in the same direction. Assume the center of the first circular coil is at $(0, 0, 0)$ and the center of the second circular coil is at $(0, 0, R)$. Furthermore, assume that N_1 is the number of wire loops in the first coil and N_2 is the number of wire loops in the second coil.

Ans: $\vec{B} = \frac{N_1 \mu_o I R^2}{2\left[R^2 + z^2\right]^{3/2}}\hat{\boldsymbol{k}} + \frac{N_2 \mu_o I R^2}{2\left[R^2 + (z - R)^2\right]^{3/2}}\hat{\boldsymbol{k}}$