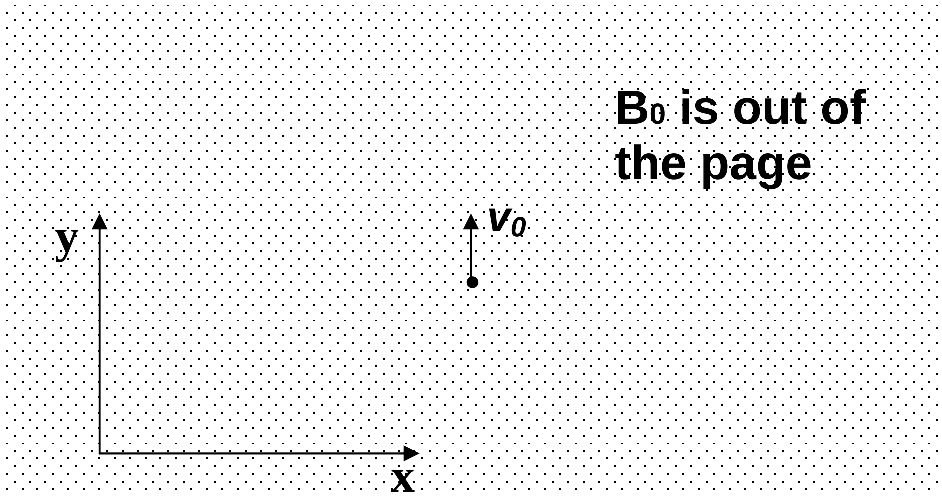
# Physics 270 Exam

**You may use a one-page (both sides) formula sheet for this exam.  You may use a calculator---but it should not be necessary.  No other written or electronic aids are allowed.  The exam ends promptly at 1:50.**

**In problems calling for expressions as answers, give your expressions in terms of the parameters of the problem.**

**Show your work.  To get full credit you must indicate how you obtained your answers from the physical principles studied in the course.  Moreover, to receive partial credit it is essential that you make your reasoning clear.  For some questions I will provide the answer (which may be useful in later sections) and ask you to explain how the answer is obtained.  To get any credit for these you MUST show your reasoning---after all, you already have the correct answer.**

1. A magnetic field of magnitude $B_0$ is constant in space and time and is oriented in the positive z direction (which is out of the page in the figure below). A negatively charged particle with a charge $-Q$ and a mass $M$ is moving with a speed of $V_0$ in the positive y direction.

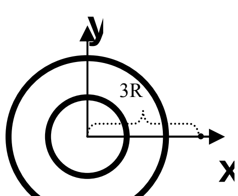



a. What is the direction of the force on the particle?

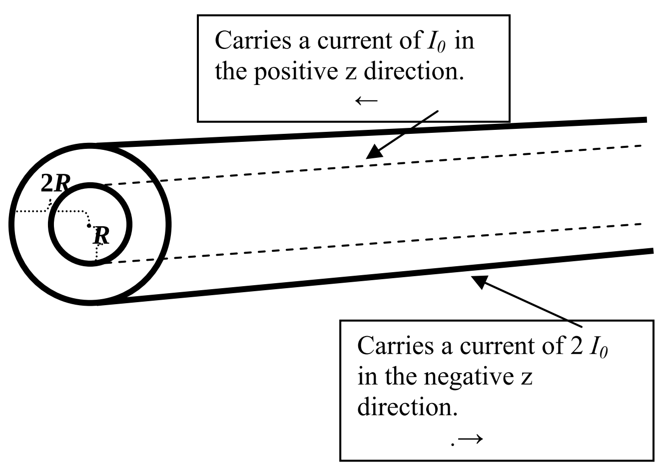
b. Find an expression for the magnitude of the force on the particle. As with all problems on the exam, express your answers in terms of the parameters of the problem such as $Q$ and $B_0$.

c. The magnetic force acting on the charge will cause the particle to make a circular orbit. Find an expression for the radius of the circle.

**2.** Consider two long coaxial conducting cylinders of radius $R$ and $2R$, respectively, aligned along the z-axis. The inner cylinder carries a current of magnitude $I_0$ in the positive z direction (*out* of the page in the cross-sectional view below). The outer cylinder carries a current of magnitude $2I_0$ in the negative z direction (*into* the page in the cross-sectional view below).



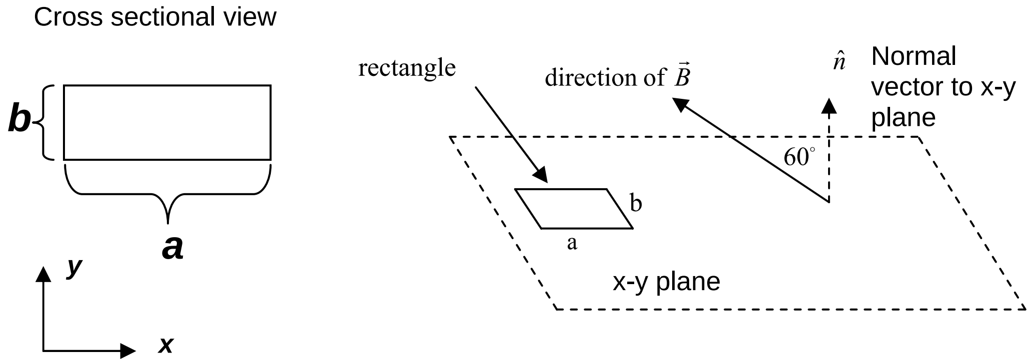

Cross-sectional view




a. What is the direction of a magnetic field at a point on the x axis a distance $3R$ from the origin?

b. Use Ampere's law and symmetry to find an expression for the magnitude of the magnetic field at the point on the x axis a distance $3R$ from the origin.

3. A magnetic field is constant in space and is given by $\vec{B} = \left(\frac{\sqrt{3}}{2}\hat{i} + \frac{1}{2}\hat{k}\right)B_0\, e^{-\lambda t}$ where λ and $B_0$ are positive constant. That is, the field is oriented $60^\circ$ relative to the normal of the x-y plane (see diagram below). The magnitude of the field is $B = B_0\, e^{-\lambda t}$ and thus is decreasing with time. Consider a rectangle in the magnetic field; it has sides of $a$ and $b$ and lies in the x-y plane.




a. The magnetic flux through the rectangle is given by $\Phi_m = \dfrac{a\,b\,B_0\,e^{-\lambda t}}{2}$. Explain how this result is obtained.

b. Find an expression for $\mathcal{E}$, the EMF around the rectangle.

c. If a wire loop were placed on the rectangle, which way would the current flow---clockwise or counterclockwise? Briefly explain the reason for your answer.

4. A beam of laser light is directed in the positive z direction. It is described by a running electromagnetic wave moving in the z direction. (*Note, this is not exactly like the case in the book where the wave travels in the x direction.)* The magnetic field is polarized in the x direction; it is given by $\vec{B} = \hat{i}B_0 \sin\left(k(z - ct)\right)$.

a. Write an expression for the electric field. (Hint: What is its magnitude? In what direction is it pointing? In figuring out the direction, it may help to recall that the Poynting vector $\vec{S}$ points in the direction of propagation.)

b. What is the magnitude and direction of the Poynting vector, $\vec{S}$, for this wave? Give this as an expression in terms of the parameters for this problem. Note that since $B_0$ is specified, and not $E_0$, one should express $\vec{S}$ in terms of $B_0$ rather than $E_0$.

c. A black material is defined as one which absorbs all of the energy of light hitting it. Suppose one has a square of black material. The sides are of length *d.* Suppose this square is placed in the x-y plane at the position z=0 in the region where the light is present (and described by the wave given above). Find expressions for:

i. The power absorbed by the material at any time.
ii. The average power absorbed by the material.
iii. The total energy absorbed by the material in a time $T$.