Name:____

Solve the following problems in the space provided. Use the back of the page if needed. Each problem is worth 20 points. You must show your work in a logical fashion starting with the correctly applied physical principles which are on the last page. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. In the lab you conducted the e/m experiment by accelerating electrons with a potential difference of 3000V and sending them into a magnetic field which was adjusted so that the radius of curvature was 26.0cm. Find (a)the speed of the electrons and (b)the strength of the magnetic field.

(a)The initial potential energy of the electrons will be converted into potential energy according to the Law of Conservation of Energy. Using the definition of electric potential,

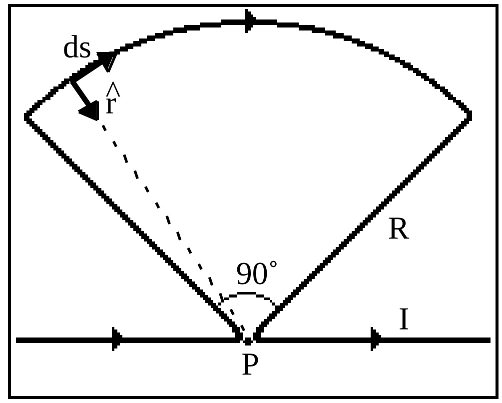
$$eV = \tfrac{1}{2}mv^2 \qquad v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2(1.6x10^{-19})(3000)}{9.11x10^{-31}}} = \underline{\underline{3.25x10^{7}\,m/s}}\ .$$

(b)The magnetic force on the moving electron causes circular motion according to Newton's Second Law,

$$\Sigma F = ma \qquad evB = m\frac{v^2}{r} \qquad B = \frac{mv}{er} = \frac{(9.11x10^{-31})(3.25x10^{7})}{(1.60x10^{-19})(0.26)} = \underline{\underline{7.11x10^{-4}T}}$$

where the expression for centripetal acceleration has been used.

2. Find the magnetic field at the point P caused by the current I in the 90˚ circular arc of radius R.



Use the Biot Savart Rule $\vec{B} = \frac{\mu_o}{4\pi}\int \frac{I d\vec{s} \times \hat{r}}{r^2}$.

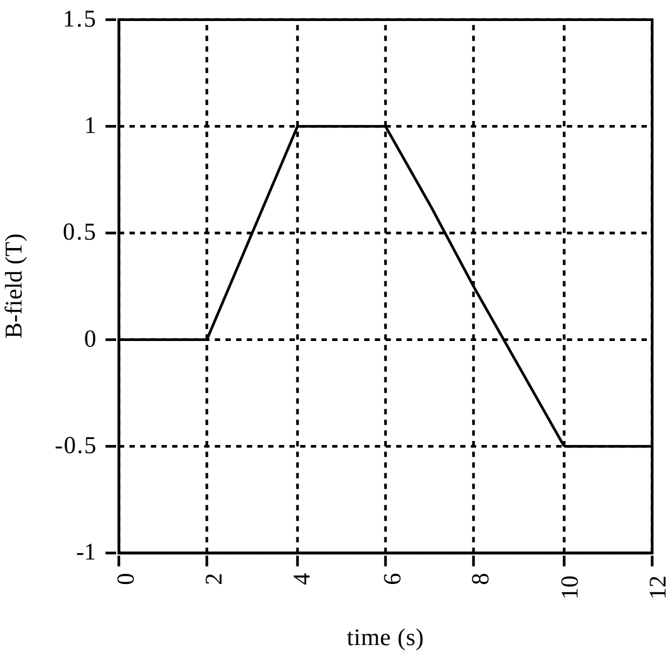
Since $d\vec{s}$ and $\hat{r}$ are parallel for all the straight sections of the wire, these sections create no magnetic field at the point P. The field at P is due only to the circular arc along which $d\vec{s}$ and $\hat{r}$ are perpendicular so $\vec{B}$ points into the page and

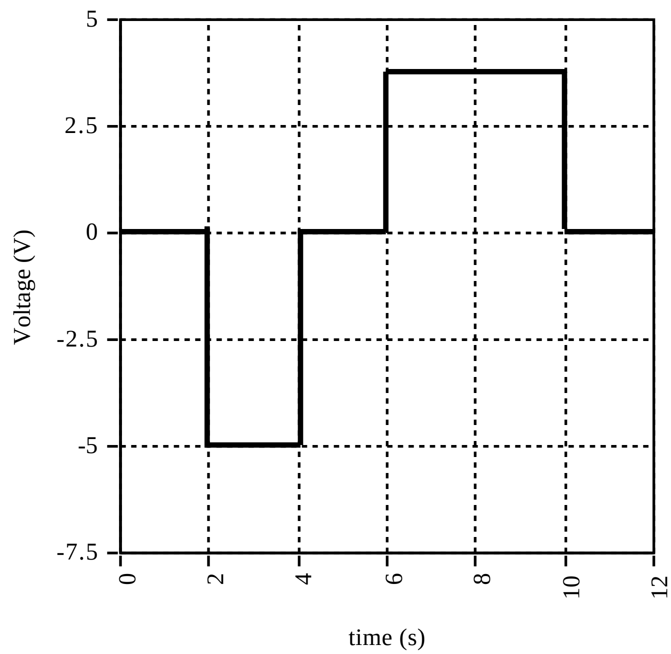
$$|d\vec{s} \times \hat{r}| = (ds)(1)\sin 90˚ = ds .$$

The magnitude of the field is,

$$B = \frac{\mu_o}{4\pi}\int \frac{I ds}{R^2} = \frac{\mu_o I}{4\pi R^2}\int ds = \frac{\mu_o I}{4\pi R^2} R\left(\frac{\pi}{2}\right) = \underline{\underline{\frac{\mu_o I}{8R}}} .$$

3. A square coil of 1000 turns has sides that are 10.0cm long. The coil is in a magnetic field that changes with time according to the graph below. Sketch the voltage induced in the coil as a function of time on the axes below.





(a)Using Faraday's Law the induced voltage is, $\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$ $\quad V = -N\frac{d\Phi_B}{dt}$.

Using the definition of flux and the fact that the B-field is constant in space and perpendicular to the plane of the coil, $V = -N\frac{d}{dt}BA = -NA\frac{dB}{dt} = -(1000)(0.10)^2(\text{slope}) = -10(\text{slope})$

4. An alternating current $I = I_o \sin 2\pi ft$ where $I_o = 2.00A$ and $f = 60.0Hz$ is supplied to a 10.0mH inductor. Find the peak induced voltage across the inductor and frequency of the voltage oscillations.

Use the definition of inductance is $\mathcal{E} \equiv -L\frac{dI}{dt}$ where $\frac{dI}{dt} = \frac{d}{dt} I_o \sin 2\pi ft = I_o 2\pi f \cos 2\pi ft$.

Substituting, $\mathcal{E} = -LI_o 2\pi f \cos 2\pi ft = -\mathcal{E}_o \cos 2\pi ft$

where $\mathcal{E}_o = LI_o 2\pi f = (0.010)(2.00)2\pi(60.0) = \underline{\underline{7.54V}}$

and the voltage oscillates at the same frequency as the current $\underline{\underline{f=60.0Hz}}$

5. In the lab, you studied the behavior of an electric motor and a generator. Explain how each device works and the distinction between them given that they are physically the same machine.

In an electric motor, current is sent through a coil that is placed in a magnetic field. The magnetic force on the current causes the coil to rotate. In a generator, a coil in a magnetic field is mechanically turned. As the field through the coil changes a voltage is induced in the coil according to Faraday's Law. The motor and the generator are both just a coil in a magnetic field. The distinction is that for a motor, electrical energy is converted into mechanical energy while for a generator, mechanical energy is converted into electrical energy.