P24.1 We use the extended form of Ampère's law, Equation 24.7. Since no moving charges are present, $I = 0$ and we have

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 \in_0 \frac{d\Phi_E}{dt}.$$

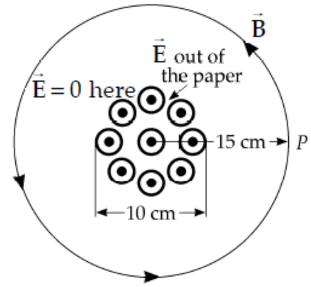

FIG. P24.1

In order to evaluate the integral, we make use of the symmetry of the situation. Symmetry requires that no particular direction from the center can be any different from any other direction. Therefore, there must be *circular symmetry* about the central axis. We know the magnetic field lines are circles about the axis. Therefore, as we travel around such a magnetic field circle, the magnetic field remains constant in magnitude. Setting aside until later the determination of the *direction* of $\vec{B}$, we integrate $\oint \vec{B} \cdot d\vec{\ell}$ around the circle

at $R = 0.15$ m

to obtain $2\pi RB$.

Differentiating the expression $\Phi_E = AE$

we have $\frac{d\Phi_E}{dt} = \left(\frac{\pi d^2}{4}\right)\frac{dE}{dt}.$

Thus, $\oint \vec{B} \cdot d\vec{\ell} = 2\pi RB = \mu_0 \in_0 \left(\frac{\pi d^2}{4}\right)\frac{dE}{dt}.$

Solving for B gives $B = \frac{\mu_0 \in_0}{2\pi R}\left(\frac{\pi d^2}{4}\right)\frac{dE}{dt}.$

Substituting numerical values, $B = \frac{(4\pi \times 10^{-7}\ \text{H/m})(8.85 \times 10^{-12}\ \text{F/m})\left[\pi(0.10\ \text{m})^2\right](20\ \text{V/m}\cdot\text{s})}{2\pi(0.15\ \text{m})(4)}$

$$B = \boxed{1.85 \times 10^{-18}\ \text{T}}.$$

In Figure 24.1, the direction of the *increase* of the electric field is out the plane of the paper. By the right-hand rule, this implies that the direction of $\vec{B}$ is *counterclockwise*. Thus, the direction of $\vec{B}$ at P is upwards.

***P24.3** $\vec{F} = m\vec{a} = q\vec{E} + q\vec{v} \times \vec{B}$

$$\vec{a} = \frac{e}{m}\left[\vec{E} + \vec{v} \times \vec{B}\right] \text{ where } \vec{v} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 200 & 0 & 0 \\ 0.200 & 0.300 & 0.400 \end{vmatrix} = -200(0.400)\hat{j} + 200(0.300)\hat{k}$$

$$\vec{a} = \frac{1.60 \times 10^{-19}}{1.67 \times 10^{-27}}\left[50.0\hat{j} - 80.0\hat{j} + 60.0\hat{k}\right] = 9.58 \times 10^7\left[-30.0\hat{j} + 60.0\hat{k}\right]$$

$$\vec{a} = 2.87 \times 10^9\left[-\hat{j} + 2\hat{k}\right]\ \text{m/s}^2 = \boxed{\left(-2.87 \times 10^9\,\hat{j} + 5.75 \times 10^9\,\hat{k}\right)\ \text{m/s}^2}$$

P24.4 (a) Since the light from this star travels at 3.00×10^{8} m/s

the last bit of light will hit the Earth in $\dfrac{6.44\times10^{18}\text{ m}}{3.00\times10^{8}\text{ m/s}}=2.15\times10^{10}\text{ s}=680\text{ years}$.

Therefore, it will disappear from the sky in the year $2\,004+680=\boxed{2.68\times10^{3}\text{ C.E.}}$.

The star is 680 light-years away.

(b) $$\Delta t=\frac{\Delta x}{v}=\frac{1.496\times10^{11}\text{ m}}{3\times10^{8}\text{ m/s}}=\boxed{499\text{ s}}=8.31\text{ min}$$

(c) $$\Delta t=\frac{\Delta x}{v}=\frac{2\left(3.84\times10^{8}\text{ m}\right)}{3\times10^{8}\text{ m/s}}=\boxed{2.56\text{ s}}$$

(d) $$\Delta t=\frac{\Delta x}{v}=\frac{2\pi\left(6.37\times10^{6}\text{ m}\right)}{3\times10^{8}\text{ m/s}}=\boxed{0.133\text{ s}}$$

(e) $$\Delta t=\frac{\Delta x}{v}=\frac{10\times10^{3}\text{ m}}{3\times10^{8}\text{ m/s}}=\boxed{3.33\times10^{-5}\text{ s}}$$

P24.5 $$v=\frac{1}{\sqrt{\kappa\mu_0\epsilon_0}}=\frac{1}{\sqrt{1.78}}c=0.750c=\boxed{2.25\times10^{8}\text{ m/s}}$$

P24.6 $$\frac{E}{B}=c$$

or $\dfrac{220}{B}=3.00\times10^{8}$

so $B=7.33\times10^{-7}\text{ T}=\boxed{733\text{ nT}}$.

P24.7 (a) $f\lambda = c$

or $f(50.0 \text{ m}) = 3.00 \times 10^8 \text{ m/s}$

so $\boxed{f = 6.00 \times 10^6 \text{ Hz} = 6.00 \text{ MHz}}$.

(b) $\dfrac{E}{B} = c$

or $\dfrac{22.0}{B_{\text{max}}} = 3.00 \times 10^8$

so $\vec{\mathbf{B}}_{\text{max}} = \boxed{-73.3\hat{\mathbf{k}} \text{ nT}}$.

(c) $k = \dfrac{2\pi}{\lambda} = \dfrac{2\pi}{50.0} = 0.126 \text{ m}^{-1}$

and $\omega = 2\pi f = 2\pi\left(6.00 \times 10^6 \text{ s}^{-1}\right) = 3.77 \times 10^7 \text{ rad/s}$

$$\vec{\mathbf{B}} = \vec{\mathbf{B}}_{\text{max}} \cos(kx - \omega t) = \boxed{-73.3\cos\left(0.126x - 3.77 \times 10^7 t\right)\hat{\mathbf{k}} \text{ nT}}.$$

P24.8 (a) $$B = \frac{E}{c} = \frac{100 \text{ V/m}}{3.00 \times 10^8 \text{ m/s}} = 3.33 \times 10^{-7} \text{ T} = \boxed{0.333\ \mu\text{T}}$$

(b) $$\lambda = \frac{2\pi}{k} = \frac{2\pi}{1.00 \times 10^7 \text{ m}^{-1}} = \boxed{0.628\ \mu\text{m}}$$

(c) $$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{6.28 \times 10^{-7} \text{ m}} = \boxed{4.77 \times 10^{14} \text{ Hz}}$$