第二十一章

必做题 ：

2,

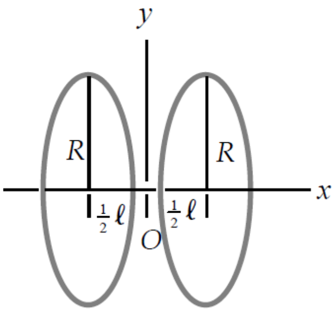
Choose the rightward direction to be positive. Then the field due to $+Q$ will be positive, and the field due to $-Q$ will be negative.

$$E = k\frac{Q}{(x+a)^2} - k\frac{Q}{(x-a)^2} = kQ\left(\frac{1}{(x+a)^2} - \frac{1}{(x-a)^2}\right) = \boxed{\frac{-4kQxa}{(x^2-a^2)^2}}$$

The negative sign means the field points to the $\boxed{\text{left}}$.

4,

Consider Example 21-9. We use the result from this example, but shift the center of the ring to be at $x = \frac{1}{2}\ell$ for the ring on the right, and at $x = -\frac{1}{2}\ell$ for the ring on the left. The fact that the original expression has a factor of x results in the interpretation that the sign of the field expression will give the direction of the field. No special consideration needs to be given to the location of the point at which the field is to be calculated.



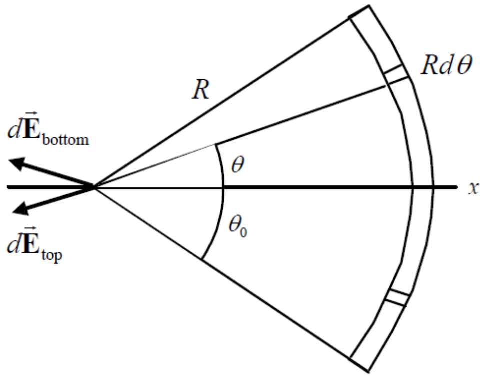
$$\vec{\mathbf{E}} = \vec{\mathbf{E}}_{\text{right}} + \vec{\mathbf{E}}_{\text{left}}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{Q\left(x-\frac{1}{2}\ell\right)}{\left[\left(x-\frac{1}{2}\ell\right)^2+R^2\right]^{3/2}}\hat{\mathbf{i}} + \frac{1}{4\pi\varepsilon_0}\frac{Q\left(x+\frac{1}{2}\ell\right)}{\left[\left(x+\frac{1}{2}\ell\right)^2+R^2\right]^{3/2}}\hat{\mathbf{i}}$$

$$= \hat{\mathbf{i}}\frac{Q}{4\pi\varepsilon_0}\left\{\frac{\left(x-\frac{1}{2}\ell\right)}{\left[\left(x-\frac{1}{2}\ell\right)^2+R^2\right]^{3/2}} + \frac{\left(x+\frac{1}{2}\ell\right)}{\left[\left(x+\frac{1}{2}\ell\right)^2+R^2\right]^{3/2}}\right\}$$

9,

Select a differential element of the arc which makes an angle of θ with the x axis. The length of this element is $Rd\theta$, and the charge on that element is $dq = \lambda R d\theta$. The magnitude of the field produced by that element is $dE = \frac{1}{4\pi\varepsilon_0}\frac{\lambda R d\theta}{R^2}$. From the diagram, considering pieces of the arc that are symmetric with respect to the x axis, we see that the total field will only have an x component. The vertical components of the field due to symmetric portions of the arc will cancel each other. So we have the following.



$$dE_{\text{horizontal}} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda R d\theta}{R^2}\cos\theta$$

$$E_{\text{horizontal}} = \int_{-\theta_0}^{\theta_0}\frac{1}{4\pi\varepsilon_0}\cos\theta\frac{\lambda R d\theta}{R^2} = \frac{\lambda}{4\pi\varepsilon_0 R}\int_{-\theta_0}^{\theta_0}\cos\theta d\theta = \frac{\lambda}{4\pi\varepsilon_0 R}\left[\sin\theta_0 - \sin\left(-\theta_0\right)\right] = \frac{2\lambda\sin\theta_0}{4\pi\varepsilon_0 R}$$

The field points in the negative x direction, so $E = \boxed{-\frac{2\lambda\sin\theta_0}{4\pi\varepsilon_0 R}\hat{\mathbf{i}}}$

10

(a) The field along the axis of the ring is given in Example 21-9, with the opposite sign because this ring is negatively charged. The force on the charge is the field times the charge q. Note that if x is positive, the force is to the left, and if x is negative, the force is to the right. Assume that $x \ll R$.

$$F = qE = \frac{q}{4\pi\varepsilon_0}\frac{(-Q)x}{\left(x^2+R^2\right)^{3/2}} = \frac{-qQx}{4\pi\varepsilon_0}\frac{1}{\left(x^2+R^2\right)^{3/2}} \approx \frac{-qQx}{4\pi\varepsilon_0 R^3}$$

This has the form of a simple harmonic oscillator, where the "spring constant" is $k_{\text{elastic}} = \frac{Qq}{4\pi\varepsilon_0 R^3}$.

(b) The spring constant can be used to find the period. See Eq. 14-7b.

$$T = 2\pi\sqrt{\frac{m}{k_{\text{elastic}}}} = 2\pi\sqrt{\frac{m}{\frac{Qq}{4\pi\varepsilon_0 R^3}}} = 2\pi\sqrt{\frac{m4\pi\varepsilon_0 R^3}{Qq}} = 4\pi\sqrt{\frac{m\pi\varepsilon_0 R^3}{Qq}}$$

第二十二章

必做题 ：1，3，6，8(e 不做)

1，

(*a*) From the diagram in the textbook, we see that the flux outward through the hemispherical surface is the same as the flux inward through the circular surface base of the hemisphere. On that surface all of the flux is perpendicular to the surface. Or, we say that on the circular base, $\vec{\mathbf{E}} \parallel \vec{\mathbf{A}}$. Thus $\Phi_E = \vec{\mathbf{E}} \bullet \vec{\mathbf{A}} = \boxed{\pi r^2 E}$.

(b) $\vec{\mathbf{E}}$ is perpendicular to the axis, then every field line would both enter through the hemispherical surface and leave through the hemispherical surface, and so $\Phi_E = \boxed{0}$.

3，

The only contributions to the flux are from the faces perpendicular to the electric field. Over each of these two surfaces, the magnitude of the field is constant, so the flux is just $\vec{\mathbf{E}} \bullet \vec{\mathbf{A}}$ on each of these two surfaces.

$$\Phi_E = \left(\vec{\mathbf{E}} \bullet \vec{\mathbf{A}}\right)_{\text{right}} + \left(\vec{\mathbf{E}} \bullet \vec{\mathbf{A}}\right)_{\text{left}} = E_{\text{right}}\ell^2 - E_{\text{left}}\ell^2 = \frac{Q_{\text{encl}}}{\varepsilon_0} \rightarrow$$

$$Q_{\text{encl}} = \left(E_{\text{right}} - E_{\text{left}}\right)\ell^2\varepsilon_0 = \left(410\,\text{N/C} - 560\,\text{N/C}\right)\left(25\,\text{m}\right)^2\left(8.85\times10^{-12}\,\text{C}^2/\text{N}\cdot\text{m}^2\right) = \boxed{-8.3\times10^{-7}\,\text{C}}$$

6，

(*a*) In the region $0 < r < r_1$, a gaussian surface would enclose no charge. Thus, due to the spherical symmetry, we have the following.

$$\oint \vec{\mathbf{E}} \bullet d\vec{\mathbf{A}} = E\left(4\pi r^2\right) = \frac{Q_{\text{encl}}}{\varepsilon_0} = 0 \quad \rightarrow \quad E = \boxed{0}$$

(*b*) In the region $r_1 < r < r_2$, only the charge on the inner shell will be enclosed.

$$\oint \vec{\mathbf{E}} \bullet d\vec{\mathbf{A}} = E\left(4\pi r^2\right) = \frac{Q_{\text{encl}}}{\varepsilon_0} = \frac{\sigma_1 4\pi r_1^2}{\varepsilon_0} \quad \rightarrow \quad E = \boxed{\frac{\sigma_1 r_1^2}{\varepsilon_0 r^2}}$$

(*c*) In the region $r_2 < r$, the charge on both shells will be enclosed.

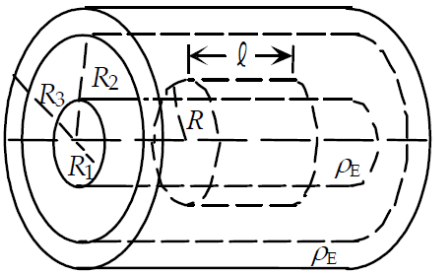
$$\oint \vec{\mathbf{E}} \bullet d\vec{\mathbf{A}} = E\left(4\pi r^2\right) = \frac{Q_{\text{encl}}}{\varepsilon_0} = \frac{\sigma_1 4\pi r_1^2 + \sigma_2 4\pi r_2^2}{\varepsilon_0} \quad \rightarrow \quad E = \boxed{\frac{\sigma_1 r_1^2 + \sigma_2 r_2^2}{\varepsilon_0 r^2}}$$

(*d*) To make $E = 0$ for $r_2 < r$, we must have $\boxed{\sigma_1 r_1^2 + \sigma_2 r_2^2 = 0}$. This implies that the shells are of opposite charge.

(*e*) To make $E = 0$ for $r_1 < r < r_2$, we must have $\boxed{\sigma_1 = 0}$. Or, if a charge $Q = -4\pi\sigma_1 r_1^2$ were placed at the center of the shells, that would also make $E = 0$.

8

The geometry of this problem is similar to Problem 33, and so we use the same development, following Example 22-6. See the solution of Problem 33 for details.



$$\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = E(2\pi R\ell) = \frac{Q_{\text{encl}}}{\varepsilon_0} \rightarrow E = \frac{Q_{\text{encl}}}{2\pi\varepsilon_0 R\ell}$$

(*a*) For $0 < R < R_1$, the enclosed charge is the volume of charge enclosed, times the charge density.

$$E = \frac{Q_{\text{encl}}}{2\pi\varepsilon_0 R\ell} = \frac{\rho_E \pi R^2 \ell}{2\pi\varepsilon_0 R\ell} = \boxed{\frac{\rho_E R}{2\varepsilon_0}}$$

(*b*) For $R_1 < R < R_2$, the enclosed charge is all of the charge on the inner cylinder.

$$E = \frac{Q_{\text{encl}}}{2\pi\varepsilon_0 R\ell} = \frac{\rho_E \pi R_1^2 \ell}{2\pi\varepsilon_0 R\ell} = \boxed{\frac{\rho_E R_1^2}{2\varepsilon_0 R}}$$

(*c*) For $R_2 < R < R_3$, the enclosed charge is all of the charge on the inner cylinder, and the part of the charge on the shell that is enclosed by the gaussian cylinder.

$$E = \frac{Q_{\text{encl}}}{2\pi\varepsilon_0 R\ell} = \frac{\rho_E \pi R_1^2 \ell + \rho_E\left(\pi R^2 \ell - \pi R_2^2 \ell\right)}{2\pi\varepsilon_0 R\ell} = \boxed{\frac{\rho_E\left(R_1^2 + R^2 - R_2^2\right)}{2\varepsilon_0 R}}$$

(*d*) For $R > R_3$, the enclosed charge is all of the charge on both the inner cylinder and the shell.

$$E = \frac{Q_{\text{encl}}}{2\pi\varepsilon_0 R\ell} = \frac{\rho_E \pi R_1^2 \ell + \rho_E\left(\pi R_3^2 \ell - \pi R_2^2 \ell\right)}{2\pi\varepsilon_0 R\ell} = \boxed{\frac{\rho_E\left(R_1^2 + R_3^2 - R_2^2\right)}{2\varepsilon_0 R}}$$

第二十三章

必做题 ： 4， 10， 12， 19， 22

4：

(*a*) The potential at the surface of a charged sphere is derived in Example 23-4.

$$V_0 = \frac{Q}{4\pi\varepsilon_0 r_0} \rightarrow Q = 4\pi\varepsilon_0 r_0 V_0 \rightarrow$$

$$\sigma = \frac{Q}{\text{Area}} = \frac{Q}{4\pi r_0^2} = \frac{4\pi\varepsilon_0 r_0 V_0}{4\pi r_0^2} = \frac{V_0\varepsilon_0}{r_0} = \frac{(680\,\text{V})(8.85\times10^{-12}\ \text{C}^2/\text{Nm}^2)}{(0.16\,\text{m})} = 3.761\times10^{-8}\,\text{C/m}^2$$

$$\approx \boxed{3.8\times10^{-8}\,\text{C/m}^2}$$

(*b*) The potential away from the surface of a charged sphere is also derived in Example 23-4.

$$V = \frac{Q}{4\pi\varepsilon_0 r} = \frac{4\pi\varepsilon_0 r_0 V_0}{4\pi\varepsilon_0 r} = \frac{r_0 V_0}{r} \rightarrow r = \frac{r_0 V_0}{V} = \frac{(0.16\,\text{m})(680\,\text{V})}{(25\,\text{V})} = 4.352\,\text{m} \approx \boxed{4.4\,\text{m}}$$

10：

The potential at the corner is the sum of the potentials due to each of the charges, using Eq. 23-5.

$$V = \frac{1}{4\pi\varepsilon_0}\frac{(3Q)}{\ell} + \frac{1}{4\pi\varepsilon_0}\frac{Q}{\sqrt{2}\ell} + \frac{1}{4\pi\varepsilon_0}\frac{(-2Q)}{\ell} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{\ell}\left(1+\frac{1}{\sqrt{2}}\right) = \boxed{\frac{1}{4\pi\varepsilon_0}\frac{\sqrt{2}Q}{2\ell}\left(\sqrt{2}+1\right)}$$

12：

We follow the development of Example 23-9, with Figure 23-15. The charge on a thin ring of radius R and thickness dR is $dq = \sigma dA = \sigma(2\pi R dR)$. Use Eq. 23-6b to find the potential of a continuous charge distribution.

$$V = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r} = \frac{1}{4\pi\varepsilon_0}\int_{R_1}^{R_2}\frac{\sigma(2\pi R dR)}{\sqrt{x^2+R^2}} = \frac{\sigma}{2\varepsilon_0}\int_{R_1}^{R_2}\frac{R}{\sqrt{x^2+R^2}}dR = \frac{\sigma}{2\varepsilon_0}\left(x^2+R^2\right)^{1/2}\Big|_{R_1}^{R_2}$$

$$= \boxed{\frac{\sigma}{2\varepsilon_0}\left(\sqrt{x^2+R_2^2}-\sqrt{x^2+R_1^2}\right)}$$

19：

(*a*) The electron was accelerated through a potential difference of 1.33 kV (moving from low potential to high potential) in gaining 1.33 keV of kinetic energy. The proton is accelerated through the opposite potential difference as the electron, and has the exact opposite charge. Thus the proton gains the same kinetic energy, $\boxed{1.33\text{ keV}}$.

(*b*) Both the proton and the electron have the same KE. Use that to find the ratio of the speeds.

$$\tfrac{1}{2}m_p v_p^2 = \tfrac{1}{2}m_e v_e^2 \rightarrow \frac{v_e}{v_p} = \sqrt{\frac{m_p}{m_e}} = \sqrt{\frac{1.67\times10^{-27}\text{kg}}{9.11\times10^{-31}\text{kg}}} = \boxed{42.8}$$

The lighter electron is moving about 43 times faster than the heavier proton.

22:

Let d_1 represent the distance from the left charge to point b, and let d_2 represent the distance from the right charge to point b. Let Q represent the positive charges, and let q represent the negative charge that moves. The change in potential energy is given by Eq. 23-2b.

$$d_1 = \sqrt{12^2+14^2}\text{cm} = 18.44\text{ cm} \qquad d_2 = \sqrt{14^2+24^2}\text{cm} = 27.78\text{ cm}$$

$$U_b - U_a = q(V_b - V_a) = q\frac{1}{4\pi\varepsilon_0}\left[\left(\frac{Q}{0.1844\,\text{m}}+\frac{Q}{0.2778\,\text{m}}\right)-\left(\frac{Q}{0.12\,\text{m}}+\frac{Q}{0.24\,\text{m}}\right)\right]$$

$$= \frac{1}{4\pi\varepsilon_0}Qq\left[\left(\frac{1}{0.1844\,\text{m}}+\frac{1}{0.2778\,\text{m}}\right)-\left(\frac{1}{0.12\,\text{m}}+\frac{1}{0.24\,\text{m}}\right)\right]$$

$$= \left(8.99\times10^9\,\text{N}\cdot\text{m}^2/\text{C}^2\right)\left(-1.5\times10^{-6}\text{C}\right)\left(33\times10^{-6}\text{C}\right)\left(-3.477\,\text{m}^{-1}\right) = 1.547\,\text{J} \approx \boxed{1.5\,\text{J}}$$

第二十四章

必做题 ： 5， 7， 9， 11， 18

5:

We apply Eq. 27-3 to each circumstance, and solve for the magnetic field. Let $\vec{\mathbf{B}} = B_x\hat{\mathbf{i}} + B_y\hat{\mathbf{j}} + B_z\hat{\mathbf{k}}$.

For the first circumstance, $\vec{\boldsymbol{\ell}} = \ell\hat{\mathbf{i}}$.

$$\vec{\mathbf{F}}_B = I\vec{\boldsymbol{\ell}}\times\vec{\mathbf{B}} = (8.2\,\text{A})\begin{vmatrix}\hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}}\\ 2.0\text{m} & 0 & 0\\ B_x & B_y & B_z\end{vmatrix} = (-16.4\text{A}\cdot\text{m})B_z\hat{\mathbf{j}} + (16.4\text{A}\cdot\text{m})B_y\hat{\mathbf{k}} = (-2.5\hat{\mathbf{j}})\text{N} \rightarrow$$

$$B_y = 0\,;\ (-16.4\text{A}\cdot\text{m})B_z = -2.5\,\text{N} \rightarrow B_z = \frac{2.5\,\text{N}}{16.4\text{A}\cdot\text{m}} = 0.1524\,\text{T}\,;\ B_x \text{ unknown}$$

For the second circumstance, $\vec{\boldsymbol{\ell}} = \ell\hat{\mathbf{j}}$.

$$\vec{\mathbf{F}}_B = I\vec{\boldsymbol{\ell}}\times\vec{\mathbf{B}} = (8.2\,\text{A})\begin{vmatrix}\hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}}\\ 0 & 2.0\,\text{m} & 0\\ B_x & 0 & 0.1524\,\text{T}\end{vmatrix} = (2.5\text{N})\hat{\mathbf{i}} + (-16.4\text{A}\cdot\text{m})B_x\hat{\mathbf{k}} = (2.5\hat{\mathbf{i}} - 5.0\hat{\mathbf{k}})\text{N} \rightarrow$$

$$(-16.4\text{A}\cdot\text{m})B_x = -5.0\,\text{N} \rightarrow B_x = \frac{5.0\,\text{N}}{16.4\text{A}\cdot\text{m}} = 0.3049\,\text{T}$$

Thus $\vec{\mathbf{B}} = \boxed{(0.30\hat{\mathbf{i}} + 0.15\hat{\mathbf{k}})\text{T}}$.

7：

(*a*) The velocity of the ion can be found using energy conservation. The electrical potential energy of the ion becomes kinetic energy as it is accelerated. Then, since the ion is moving perpendicular to the magnetic field, the magnetic force will be a maximum. That force will cause the ion to move in a circular path.

$$E_{\text{initial}} = E_{\text{final}} \rightarrow qV = \tfrac{1}{2}mv^2 \rightarrow v = \sqrt{\frac{2qV}{m}}$$

$$F_{\max} = qvB = m\frac{v^2}{r} \rightarrow$$

$$r = \frac{mv}{qB} = \frac{m\sqrt{\frac{2qV}{m}}}{qB} = \frac{1}{B}\sqrt{\frac{2mV}{q}} = \frac{1}{0.340\,\text{T}}\sqrt{\frac{2\left(6.6\times10^{-27}\,\text{kg}\right)\left(2700\,\text{V}\right)}{2\left(1.60\times10^{-19}\,\text{C}\right)}} = \boxed{3.1\times10^{-2}\,\text{m}}$$

(*b*) The period can be found from the speed and the radius. Use the expressions for the radius and the speed from above.

$$v = \frac{2\pi r}{T} \rightarrow T = \frac{2\pi r}{v} = \frac{2\pi\frac{1}{B}\sqrt{\frac{2mV}{q}}}{\sqrt{\frac{2qV}{m}}} = \frac{2\pi m}{qB} = \frac{2\pi\left(6.6\times10^{-27}\,\text{kg}\right)}{2\left(1.60\times10^{-19}\,\text{C}\right)\left(0.340\,\text{T}\right)} = \boxed{3.8\times10^{-7}\,\text{s}}$$

9：

The force on the electron is given by Eq. 27-5a.

$$\vec{\mathbf{F}}_{\text{B}} = q\vec{\mathbf{v}}\times\vec{\mathbf{B}} = -e\begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ 7.0\times10^4\,\text{m/s} & -6.0\times10^4\,\text{m/s} & 0 \\ -0.80\,\text{T} & 0.60\,\text{T} & 0 \end{vmatrix} = -e\left(4.2-4.8\right)\times10^4\,\text{T}\bullet\text{m/s}\,\hat{\mathbf{k}}$$

$$= -\left(1.60\times10^{-19}\,\text{C}\right)\left(-0.6\times10^4\,\text{T}\bullet\text{m/s}\,\hat{\mathbf{k}}\right) = 9.6\times10^{-16}\,\text{N}\,\hat{\mathbf{k}} \approx \boxed{1\times10^{-15}\,\text{N}\,\hat{\mathbf{k}}}$$

11：

The total force on the proton is given by the Lorentz equation, Eq. 27-7.

$$\vec{\mathbf{F}}_B = q\left(\vec{\mathbf{E}}+\vec{\mathbf{v}}\times\vec{\mathbf{B}}\right) = e\left[\left(3.0\hat{\mathbf{i}}-4.2\hat{\mathbf{j}}\right)\times10^3\ \mathrm{V/m}+\begin{vmatrix}\hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}}\\ 6.0\times10^3\ \mathrm{m/s} & 3.0\times10^3\ \mathrm{m/s} & -5.0\times10^3\ \mathrm{m/s}\\ 0.45\,\mathrm{T} & 0.38\,\mathrm{T} & 0\end{vmatrix}\right]$$

$$=\left(1.60\times10^{-19}\mathrm{C}\right)\left[\left(3.0\hat{\mathbf{i}}-4.2\hat{\mathbf{j}}\right)+\left(1.9\hat{\mathbf{i}}-2.25\hat{\mathbf{j}}+0.93\hat{\mathbf{k}}\right)\right]\times10^3\ \mathrm{N/C}$$

$$=\left(1.60\times10^{-19}\mathrm{C}\right)\left[\left(4.9\hat{\mathbf{i}}-6.45\hat{\mathbf{j}}+0.93\hat{\mathbf{k}}\right)\right]\times10^3\ \mathrm{N/C}$$

$$=\left(7.84\times10^{-16}\hat{\mathbf{i}}-1.03\times10^{-15}\hat{\mathbf{j}}+1.49\times10^{-16}\hat{\mathbf{k}}\right)\mathrm{N/C}$$

$$=\boxed{\left[\left(0.78\hat{\mathbf{i}}-1.0\hat{\mathbf{j}}+0.15\hat{\mathbf{k}}\right)\right]\times10^{-15}\mathrm{N}}$$

18:

(*a*) The magnetic moment of the coil is given by Eq. 27-10. Since the current flows in the clockwise direction, the right hand rule shows that the magnetic moment is down, or in the negative *z*-direction.

$$\vec{\boldsymbol{\mu}} = NI\vec{\mathbf{A}} = 15(7.6\,\mathrm{A})\pi\left(\frac{0.22\,\mathrm{m}}{2}\right)^2\left(-\hat{\mathbf{k}}\right) = -4.334\hat{\mathbf{k}}\,\mathrm{A{\bullet}m^2} \approx \boxed{-4.3\hat{\mathbf{k}}\,\mathrm{A{\bullet}m^2}}$$

(*b*) We use Eq. 27-11 to find the torque on the coil.

$$\vec{\tau} = \vec{\boldsymbol{\mu}}\times\vec{\mathbf{B}} = \left(-4.334\ \hat{\mathbf{k}}\ \mathrm{A{\bullet}m^2}\right)\times\left(0.55\hat{\mathbf{i}}+0.60\hat{\mathbf{j}}-0.65\hat{\mathbf{k}}\right)\mathrm{T} = \boxed{\left(2.6\hat{\mathbf{i}}-2.4\hat{\mathbf{j}}\right)\mathrm{m{\bullet}N}}$$

(*c*) We use Eq. 27-12 to find the potential energy of the coil.

$$U = -\vec{\boldsymbol{\mu}}{\bullet}\vec{\mathbf{B}} = -\left(-4.334\ \hat{\mathbf{k}}\ \mathrm{A{\bullet}m^2}\right)\left(0.55\hat{\mathbf{i}}+0.60\hat{\mathbf{j}}-0.65\hat{\mathbf{k}}\right)\mathrm{T} = -\left(4.334\mathrm{A{\bullet}m^2}\right)(0.65\ \mathrm{T})$$

$$=\boxed{-2.8\ \mathrm{J}}$$

第二十五章

必做题 ：6，12，13，15，16，24

6:

The magnetic field at the loop due to the long wire is into the page, and can be calculated by Eq. 28-1. The force on the segment of the loop closest to the wire is towards the wire, since the currents are in the same direction. The force on the segment of the loop farthest from the wire is away from the wire, since the currents are in the opposite direction.

Because the magnetic field varies with distance, it is more difficult to calculate the total force on the left and right segments of the loop. Using the right hand rule, the force on each small piece of the left segment of wire is to the left, and the force on each small piece of the right segment of wire is to the right. If left and right small pieces are chosen that are equidistant from the long wire, the net force on those two small pieces is zero. Thus the total force on the left and right segments of wire is zero, and so only the parallel segments need to be considered in the calculation. Use Eq. 28-2.

$$F_{\text{net}} = F_{\text{near}} - F_{\text{far}} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d_{\text{near}}}\ell_{\text{near}} - \frac{\mu_0}{2\pi}\frac{I_1 I_2}{d_{\text{far}}}\ell_{\text{far}} = \frac{\mu_0}{2\pi} I_1 I_2 \ell \left(\frac{1}{d_{\text{near}}} - \frac{1}{d_{\text{far}}}\right)$$

$$= \frac{4\pi\times10^{-7}\ \text{T}\cdot\text{m/A}}{2\pi}(3.5\,\text{A})^2(0.100\,\text{m})\left(\frac{1}{0.030\,\text{m}} - \frac{1}{0.080\,\text{m}}\right) = \boxed{5.1\times10^{-6}\,\text{N, towards wire}}$$

12：

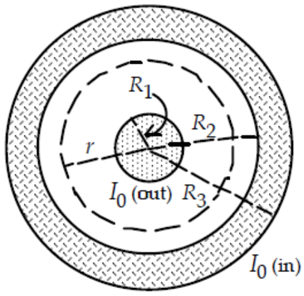
We use the results of Example 28-10 to find the maximum and minimum fields.

$$B_{\min} = \frac{\mu_0 NI}{2\pi r_{\max}} = \frac{(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})(687)(25.0\ \text{A})}{2\pi(0.270\ \text{m})} = 12.7\ \text{mT}$$

$$B_{\max} = \frac{\mu_0 NI}{2\pi r_{\min}} = \frac{(4\pi\times10^{-7}\ \text{T}\cdot\text{m/A})(687)(25.0\ \text{A})}{2\pi(0.250\ \text{m})} = 13.7\ \text{mT}$$

$$\boxed{12.7\ \text{mT} < B < 13.7\ \text{mT}}$$

13：



Because of the cylindrical symmetry, the magnetic fields will be circular. In each case, we can determine the magnetic field using Ampere's law with concentric loops. The current densities in the wires are given by the total current divided by the cross-sectional area.

$$J_{\text{inner}} = \frac{I_0}{\pi R_1^2} \qquad J_{\text{outer}} = -\frac{I_0}{\pi\left(R_3^2 - R_2^2\right)}$$

(*a*) Inside the inner wire the enclosed current is determined by the current density of the inner wire.

$$\oint \vec{\mathbf{B}} \cdot d\vec{s} = \mu_0 I_{\text{encl}} = \mu_0\left(J_{\text{inner}} \pi R^2\right)$$

$$B(2\pi R) = \mu_0 \frac{I_0 \pi R^2}{\pi R_1^2} \to \boxed{B = \frac{\mu_0 I_0 R}{2\pi R_1^2}}$$

(*b*) Between the wires the current enclosed is the current on the inner wire.

$$\oint \vec{\mathbf{B}} \cdot d\vec{s} = \mu_0 I_{\text{encl}} \;\to\; B(2\pi R) = \mu_0 I_0 \;\to\; \boxed{B = \frac{\mu_0 I_0}{2\pi R}}$$

(*c*) Inside the outer wire the current enclosed is the current from the inner wire and a portion of the current from the outer wire.

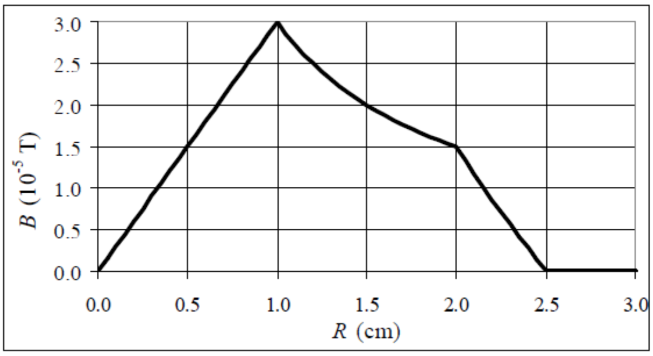
$$\oint \vec{\mathbf{B}} \cdot d\vec{s} = \mu_0 I_{\text{encl}} = \mu_0\left[I_0 + J_{\text{outer}} \pi\left(R^2 - R_2^2\right)\right]$$

$$B(2\pi r) = \mu_0\left[I_0 - I_0 \frac{\pi\left(R^2 - R_2^2\right)}{\pi\left(R_3^2 - R_2^2\right)}\right] \to \boxed{B = \frac{\mu_0 I_0}{2\pi R} \frac{\left(R_3^2 - R^2\right)}{\left(R_3^2 - R_2^2\right)}}$$

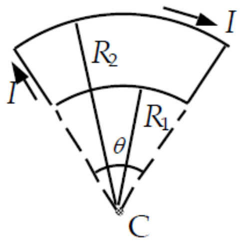
(*d*) Outside the outer wire the net current enclosed is zero.

$$\oint \vec{\mathbf{B}} \cdot d\vec{s} = \mu_0 I_{\text{encl}} = 0 \;\to\; B(2\pi R) = 0 \;\to\; \boxed{B = 0}$$

(*e*) See the adjacent graph. The spreadsheet used for this problem can be found on the Media Manager, with filename "PSE4_ISM_CH28.XLS," on tab "Problem 28.31e."



15：



Since the point C is along the line of the two straight segments of the current, these segments do not contribute to the magnetic field at C. We calculate the magnetic field by integrating Eq. 28-5 along the two curved segments. Along each integration the line segment is perpendicular to the radial vector and the radial distance is constant.

$$\vec{\mathbf{B}} = \frac{\mu_0 I}{4\pi}\int_0^{R_1\theta}\frac{d\vec{\ell}\times\hat{r}}{R_1^2} + \frac{\mu_0 I}{4\pi}\int_{R_2\theta}^{0}\frac{d\vec{\ell}\times\hat{r}}{R_2^2} = \frac{\mu_0 I}{4\pi R_1^2}\hat{\mathbf{k}}\int_0^{R_1\theta} ds + \frac{\mu_0 I}{4\pi R_2^2}\hat{\mathbf{k}}\int_{R_2\theta}^{0} ds$$

$$= \frac{\mu_0 I\theta}{4\pi R_1}\hat{\mathbf{k}} - \frac{\mu_0 I\theta}{4\pi R_2}\hat{\mathbf{k}} = \boxed{\frac{\mu_0 I\theta}{4\pi}\left(\frac{R_2 - R_1}{R_1 R_2}\right)\hat{\mathbf{k}}}$$

16:

Since the current in the two straight segments flows radially toward and away from the center of the loop, they do not contribute to the magnetic field at the center. We calculate the magnetic field by integrating Eq. 28-5 along the two curved segments. Along each integration segment, the current is perpendicular to the radial vector and the radial distance is constant. By the right-hand-rule the magnetic field from the upper portion will point into the page and the magnetic field from the lower portion will point out of the page.

$$\vec{\mathbf{B}} = \frac{\mu_0 I_1}{4\pi}\int_{\text{upper}}\frac{ds}{R^2}\hat{\mathbf{k}} + \frac{\mu_0 I_2}{4\pi}\int_{\text{lower}}\frac{ds}{R^2}\left(-\hat{\mathbf{k}}\right) = \frac{\mu_0(\pi R)}{4\pi R^2}\hat{\mathbf{k}}\left(I_1 - I_2\right) = \frac{\mu_0}{4R}\hat{\mathbf{k}}\left(0.35I - 0.65I\right) = \boxed{-\frac{3\mu_0 I}{40R}}$$

24:

(*a*) We set the magnetic force, using Eq. 28-2, equal to the weight of the wire and solve for the necessary current. The current must flow in the same direction as the upper current, for the magnetic force to be upward.

$$F_M = \frac{\mu_0 I_1 I_2}{2\pi r}\ell = \rho g\left(\frac{\pi d^2}{4}\ell\right) \rightarrow$$

$$I_2 = \frac{\rho g \pi^2 r d^2}{4\mu_0 I_1} = \frac{\left(8900\,\text{kg/m}^3\right)\left(9.80\,\text{m/s}^2\right)\pi^2\left(0.050\,\text{m}\right)\left(1.00\times10^{-3}\,\text{m}\right)^2}{2\left(4\pi\times10^{-7}\,\text{T}\cdot\text{m/A}\right)\left(48.0\,\text{A}\right)} = \boxed{360\,\text{A, right}}$$

(*b*) The lower wire is in $\boxed{\text{unstable equilibrium}}$, since if it is raised slightly from equilibrium, the magnetic force would be increased, causing the wire to move further from equilibrium.

(*c*) If the wire is suspended above the first wire at the same distance, the same current is needed, but in the opposite direction, as the wire must be repelled from the lower wire to remain in equilibrium. Therefore the current must be $\boxed{\text{360 A to the left}}$. This is a $\boxed{\text{stable equilibrium}}$ for vertical displacement since if the wire is moved slightly off the equilibrium point the magnetic force will increase or decrease to push the wire back to the equilibrium height.

第二十六章

必做题 ：2，3，15，16

2:

We choose up as the positive direction. The average induced emf is given by the "difference" version of Eq. 29-2a.

$$\mathscr{E} = -\frac{\Delta\Phi_B}{\Delta t} = -\frac{A\Delta B}{\Delta t} = -\frac{\pi(0.054\,\text{m})^2(-0.25\,\text{T} - 0.68\,\text{T})}{0.16\,\text{s}} = \boxed{5.3\times10^{-2}\,\text{V}}$$

3:

(*a*) When the plane of the loop is perpendicular to the field lines, the flux is given by the maximum of Eq. 29-1a.

$$\Phi_B = BA = B\pi r^2 = (0.50\,\text{T})\pi(0.080\,\text{m})^2 = \boxed{1.0\times10^{-2}\,\text{Wb}}$$

(*b*) The angle is $\theta = \boxed{55^\circ}$

(*c*) Use Eq. 29-1a.

$$\Phi_B = BA\cos\theta = B\pi r^2 = (0.50\,\text{T})\pi(0.080\,\text{m})^2\cos 55^\circ = \boxed{5.8\times10^{-3}\,\text{Wb}}$$

15:

The magnetic field inside the solenoid is given by Eq. 28-4, $B = \mu_0 nI$. Use Eq. 29-2a to calculate the induced emf. The flux causing the emf is the flux through the small loop.

$$\mathscr{E} = -\frac{d\Phi_B}{dt} = -A_1\frac{dB_{\text{solenoid}}}{dt} = -A_1\mu_0 n\frac{dI}{dt} = -A_1\mu_0 n(-\omega I_0\sin\omega t) = \boxed{A_1\mu_0 n\omega I_0\sin\omega t}$$

16:

(*a*) Because the velocity is perpendicular to the magnetic field and the rod, we find the induced emf from Eq. 29-3.

$$\mathscr{E} = B\ell v = (0.35\,\text{T})(0.250\,\text{m})(1.3\,\text{m/s}) = 0.1138\,\text{V} \approx \boxed{0.11\,\text{V}}$$

(*b*) Find the induced current from Ohm's law, using the **total** resistance.

$$I = \frac{\mathscr{E}}{R} = \frac{0.1138\,\text{V}}{25.0\,\Omega + 2.5\,\Omega} = 4.138\times10^{-3}\,\text{A} \approx \boxed{4.1\,\text{mA}}$$

(*c*) The induced current in the rod will be down. Because this current is in an upward magnetic field, there will be a magnetic force to the left. To keep the rod moving, there must be an equal external force to the right, given by Eq. 27-1.

$$F = I\ell B = (4.138\times10^{-3}\,\text{A})(0.250\,\text{m})(0.35\,\text{T}) = 3.621\times10^{-4}\,\text{N} \approx \boxed{0.36\,\text{mN}}$$

第二十七章

必做题 ：3，5，10， 15

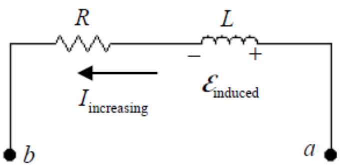
3：

We find the mutual inductance of the inner loop. If we assume the outer solenoid is carrying current I_1, then the magnetic field inside the outer solenoid is $B=\mu_0\frac{N_1}{\ell}I_1$. The magnetic flux through each loop of the small coil is the magnetic field times the area perpendicular to the field. The mutual inductance is given by Eq. 30-1.

$$\Phi_{21}=BA_2\sin\theta=\mu_0\frac{N_1I_1}{\ell}A_2\sin\theta \;;\; M=\frac{N_2\Phi_{21}}{I_1}=\frac{N_2\mu_0\frac{N_1I_1}{\ell}A_2\sin\theta}{I_1}=\boxed{\frac{\mu_0N_1N_2A_2\sin\theta}{\ell}}$$

5：

We draw the coil as two elements in series, and pure resistance and a pure inductance. There is a voltage drop due to the resistance of the coil, given by Ohm's law, and an induced emf due to the inductance of the coil, given by Eq. 30-5. Since the current is increasing, the inductance will create a potential difference to oppose the increasing current, and so there is a drop in the potential due to the inductance. The potential difference across the coil is the sum of the two potential drops.



$$V_{ab}=IR+L\frac{dI}{dt}=(3.00\,\text{A})(3.25\,\Omega)+(0.44\,\text{H})(3.60\,\text{A/s})=\boxed{11.3\,\text{V}}$$

10：

(*a*) When connected in series the voltage drops across each inductor will add, while the currents in each inductor are the same.

$$\mathcal{E}=\mathcal{E}_1+\mathcal{E}_2=-L_1\frac{dI}{dt}-L_2\frac{dI}{dt}=-(L_1+L_2)\frac{dI}{dt}=-L_{\text{eq}}\frac{dI}{dt} \to \boxed{L_{\text{eq}}=L_1+L_2}$$

(*b*) When connected in parallel the currents in each inductor add to the equivalent current, while the voltage drop across each inductor is the same as the equivalent voltage drop.

$$\frac{dI}{dt}=\frac{dI_1}{dt}+\frac{dI_2}{dt} \to \frac{\mathcal{E}}{L_{\text{eq}}}=\frac{\mathcal{E}}{L_1}+\frac{\mathcal{E}}{L_2} \to \boxed{\frac{1}{L_{\text{eq}}}=\frac{1}{L_1}+\frac{1}{L_2}}$$

Therefore, inductors in series and parallel add the same as resistors in series and parallel.

15：

We create an Amperean loop of radius r to calculate the magnetic field within the wire using Eq. 28-3. Since the resulting magnetic field only depends on radius, we use Eq. 30-7 for the energy density in the differential volume $dV = 2\pi r\ell dr$ and integrate from zero to the radius of the wire.

$$\oint \vec{\mathbf{B}} \cdot d\vec{\ell} = \mu_0 I_{enc} \to B(2\pi r) = \mu_0 \left(\frac{I}{\pi R^2}\right)(\pi r^2) \to B = \frac{\mu_0 I r}{2\pi R^2}$$

$$\frac{U}{\ell} = \frac{1}{\ell}\int u_B dV = \int_0^R \frac{1}{2\mu_0}\left(\frac{\mu_0 I r}{2\pi R^2}\right)^2 2\pi r dr = \frac{\mu_0 I^2}{4\pi R^4}\int_0^R r^3 dr = \boxed{\frac{\mu_0 I^2}{16\pi}}$$

第二十八章

必做题 ：1，5，8，10

1：

The current in the wires must also be the displacement current in the capacitor. Use the displacement current to find the rate at which the electric field is changing.

$$I_D = \varepsilon_0 A \frac{dE}{dt} \quad \to \quad \frac{dE}{dt} = \frac{I_D}{\varepsilon_0 A} = \frac{(2.8\,\mathrm{A})}{(8.85\times10^{-12}\,\mathrm{C^2/N\cdot m^2})(0.0160\,\mathrm{m})^2} = \boxed{1.2\times10^{15}\,\frac{\mathrm{V}}{\mathrm{m\bullet s}}}$$

5：

(*a*) If we write the argument of the cosine function as $kz + \omega t = k(z + ct)$, we see that the wave is traveling in the $\boxed{-z \text{ direction}}$, or $\boxed{-\hat{\mathbf{k}}}$.

(*b*) $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ are perpendicular to each other and to the direction of propagation. At the origin, the electric field is pointing in the positive x direction. Since $\vec{\mathbf{E}}\times\vec{\mathbf{B}}$ must point in the negative z direction, $\vec{\mathbf{B}}$ must point in the the $\boxed{-y \text{ direction}}$, or $\boxed{-\hat{\mathbf{j}}}$. The magnitude of the magnetic field is found from Eq. 31-11 as $B_0 = \boxed{E_0/c}$.

8：

(*a*) The general form of a plane wave is given in Eq. 31-7. For this wave, $E_x = E_0 \sin(kz - \omega t)$.

$$\lambda = \frac{2\pi}{k} = \frac{2\pi}{0.077\,\text{m}^{-1}} = 81.60\,\text{m} \approx \boxed{82\,\text{m}}$$

$$f = \frac{\omega}{2\pi} = \frac{2.3\times10^{7}\,\text{rad/s}}{2\pi} = 3.661\times10^{6}\,\text{Hz} \approx \boxed{3.7\,\text{MHz}}$$

Note that $\lambda f = (81.60\,\text{m})(3.661\times10^{6}\,\text{Hz}) = 2.987\times10^{8}\,\text{m/s} \approx c$.

(*b*) The magnitude of the magnetic field is given by $B_0 = E_0/c$. The wave is traveling in the $\hat{\mathbf{k}}$ direction, and so the magnetic field must be in the $\hat{\mathbf{j}}$ direction, since the direction of travel is given by the direction of $\vec{\mathbf{E}}\times\vec{\mathbf{B}}$.

$$B_0 = \frac{E_0}{c} = \frac{225\,\text{V/m}}{3.00\times10^{8}\,\text{m/s}} = 7.50\times10^{-7}\,\text{T} \quad \rightarrow$$

$$\vec{\mathbf{B}} = \boxed{\hat{\mathbf{j}}(7.50\times10^{-7}\,\text{T})\sin\left[(0.077\,\text{m}^{-1})z - (2.3\times10^{7}\,\text{rad/s})t\right]}$$

10：

The energy per unit area per unit time is given by the magnitude of the Poynting vector. Let ΔU represent the energy that crosses area A in a time ΔT.

$$S = \frac{cB_{\text{rms}}^2}{\mu_0} = \frac{\Delta U}{A\Delta t} \quad \rightarrow$$

$$\Delta t = \frac{\mu_0 \Delta U}{AcB_{\text{rms}}^2} = \frac{(4\pi\times10^{-7}\,\text{T}\cdot\text{m/A})(335\,\text{J})}{(1.00\times10^{-4}\,\text{m}^2)(3.00\times10^{8}\,\text{m/s})(22.5\times10^{-9}\,\text{T})^2} = 0.194\,\text{W/m}^2$$

$$= \boxed{2.77\times10^{7}\,\text{s}} \approx 321\ \text{days}$$

第二十九章

必做题 ：5，8，12，14，16，26，27，31，33，36

5：

For constructive interference, the path difference is a multiple of the wavelength, as given by Eq. 34-2a. The location on the screen is given by $x = \ell \tan\theta$, as seen in Fig. 34-7(c). For small angles, we have $\sin\theta \approx \tan\theta \approx x/\ell$. Second order means $m = 2$.

$$d\sin\theta = m\lambda \quad\rightarrow\quad d\frac{x}{\ell} = m\lambda \quad\rightarrow\quad x = \frac{\lambda m\ell}{d}\ ;\ x_1 = \frac{\lambda_1 m\ell}{d}\ ;\ x_2 = \frac{\lambda_2 m\ell}{d} \quad\rightarrow$$

$$\Delta x = x_2 - x_1 = \frac{(\lambda_2 - \lambda_1)m\ell}{d} = \frac{\left[(720-660)\times10^{-9}\,\mathrm{m}\right](2)(1.0\,\mathrm{m})}{(6.8\times10^{-4}\,\mathrm{m})} = 1.76\times10^{-4}\,\mathrm{m} \approx \boxed{0.2\,\mathrm{mm}}$$

This justifies using the small angle approximation, since $x \ll \ell$.

8:

For constructive interference, the path difference is a multiple of the wavelength, as given by Eq. 34-2a. The location on the screen is given by $x = \ell \tan\theta$, as seen in Fig. 34-7(c). For small angles, we have $\sin\theta \approx \tan\theta \approx x/\ell$.

$$d\sin\theta = m\lambda \quad\rightarrow\quad d\frac{x}{\ell} = m\lambda \quad\rightarrow\quad d = \frac{\lambda m\ell}{x} = \frac{(680\times10^{-9}\,\mathrm{m})(3)(2.6\,\mathrm{m})}{38\times10^{-3}\,\mathrm{m}} = \boxed{1.4\times10^{-4}\,\mathrm{m}}$$

12:

We equate the expression from Eq. 34-2a for the second order blue light to Eq. 34-2b, since the slit separation and angle must be the same for the two conditions to be met at the same location.

$$d\sin\theta = m\lambda_b = (2)(480\,\mathrm{nm}) = 960\,\mathrm{nm}\ ;\ d\sin\theta = (m' + \tfrac{1}{2})\lambda,\ m' = 0, 1, 2, \cdots$$

$$(m' + \tfrac{1}{2})\lambda = 960\,\mathrm{nm} \qquad m' = 0 \ \rightarrow\ \lambda = 1920\,\mathrm{nm}\ ;\ m' = 1 \ \rightarrow\ \lambda = 640\,\mathrm{nm}$$

$$m' = 2 \ \rightarrow\ \lambda = 384\,\mathrm{nm}$$

The only one visible is $\boxed{640\ \mathrm{nm}}$. 384 nm is near the low-wavelength limit for visible light.

14:

An expression is derived for the slit separation from the data for the 500 nm light. That expression is then used to find the location of the maxima for the 650 nm light. For constructive interference, the path difference is a multiple of the wavelength, as given by Eq. 34-2a. The location on the screen is given by $x = \ell \tan\theta$, as seen in Fig. 34-7(c). For small angles, we have $\sin\theta \approx \tan\theta \approx x/\ell$.

$$d\sin\theta = m\lambda \quad\rightarrow\quad d\frac{x}{\ell} = m\lambda \quad\rightarrow\quad d = \frac{\lambda m\ell}{x} = \frac{\lambda_1 m_1 \ell}{x_1} \quad\rightarrow\quad x = \frac{\lambda m\ell}{d} \quad\rightarrow$$

$$x_2 = \frac{\lambda_2 m_2 \ell}{\frac{\lambda_1 m_1 \ell}{x_1}} = x_1\frac{\lambda_2 m_2}{\lambda_1 m_1} = (12\,\mathrm{mm})\frac{(650\,\mathrm{nm})(2)}{(500\,\mathrm{nm})(3)} = 10.4\,\mathrm{mm} \approx \boxed{10\,\mathrm{mm}}\ \ (2\text{ sig. fig.})$$

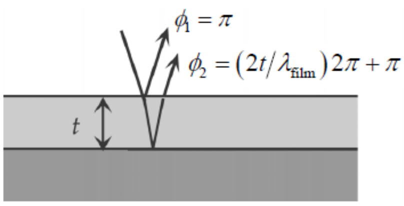
16:

To change the center point from constructive interference to destructive interference, the phase shift produced by the introduction of the plastic must be equivalent to half a wavelength. The wavelength of the light is shorter in the plastic than in the air, so the number of wavelengths in the plastic must be ½ greater than the number in the same thickness of air. The number of wavelengths in the distance equal to the thickness of the plate is the thickness of the plate divided by the appropriate wavelength.

$$N_{\text{plastic}} - N_{\text{air}} = \frac{t}{\lambda_{\text{plastic}}} - \frac{t}{\lambda} = \frac{tn_{\text{plastic}}}{\lambda} - \frac{t}{\lambda} = \frac{t}{\lambda}\left(n_{\text{plastic}} - 1\right) = \tfrac{1}{2} \quad \rightarrow$$

$$t = \frac{\lambda}{2\left(n_{\text{plastic}} - 1\right)} = \frac{680\,\text{nm}}{2\left(1.60 - 1\right)} = \boxed{570\,\text{nm}}$$

26:



An incident wave that reflects from the top surface of the coating has a phase change of $\phi_1 = \pi$. An incident wave that reflects from the glass $(n \approx 1.5)$ at the bottom surface of the coating has a phase change due to both the additional path length and a phase change of π on reflection, so $\phi_2 = \left(\frac{2t}{\lambda_{\text{film}}}\right)2\pi + \pi$. For constructive interference with a minimum non-zero thickness of coating, the net phase change must be 2π.

$$\phi_{\text{net}} = \phi_2 - \phi_1 = \left[\left(\frac{2t}{\lambda_{\text{film}}}\right)2\pi + \pi\right] - \pi = 2\pi \quad \rightarrow \quad t = \tfrac{1}{2}\lambda_{\text{film}} = \tfrac{1}{2}\left(\frac{\lambda}{n_{\text{film}}}\right).$$

The lens reflects the most for $\lambda = 570\,\text{nm}$. The minimum non-zero thickness occurs for $m = 1$:

$$t_{\min} = \frac{\lambda}{2n_{\text{film}}} = \frac{(570\,\text{nm})}{2(1.25)} = \boxed{228\,\text{nm}}$$

Since the middle of the spectrum is being selectively reflected, the transmitted light will be stronger in the red and blue portions of the visible spectrum.

27:

(a) When illuminated from above at A, a light ray reflected from the air-oil interface undergoes a phase shift of $\phi_1 = \pi$. A ray reflected at the oil-water interface undergoes no phase shift. If the oil thickness at A is negligible compared to the wavelength of the light, then there is no significant shift in phase due to a path distance traveled by a ray in the oil. Thus the light reflected from the two surfaces will destructively interfere for all visible wavelengths, and the oil will appear black when viewed from above.

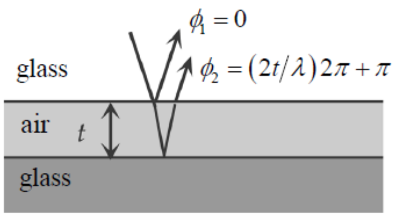
(b) From the discussion in part (a), the ray reflected from the air-oil interface undergoes a phase shift of $\phi_1 = \pi$. A ray that reflects from the oil-water interface has no phase change due to reflection, but has a phase change due to the additional path length of $\phi_2 = \left(\frac{2t}{\lambda_{\text{oil}}}\right)2\pi$. For constructive interference, the net phase change must be a multiple of 2π.

$$\phi_{\text{net}} = \phi_2 - \phi_1 = \left[\left(\frac{2t}{\lambda_{\text{oil}}}\right)2\pi\right] - \pi = m(2\pi) \quad \rightarrow \quad t = \tfrac{1}{2}\left(m+\tfrac{1}{2}\right)\lambda_{\text{oil}} = \tfrac{1}{2}\left(m+\tfrac{1}{2}\right)\frac{\lambda}{n_{\text{o}}}$$

From the diagram, we see that point B is the second thickness that yields constructive interference for 580 nm, and so we use $m = 1$. (The first location that yields constructive interference would be for $m = 0$.)

$$t = \tfrac{1}{2}\left(m+\tfrac{1}{2}\right)\frac{\lambda}{n_{\text{o}}} = \tfrac{1}{2}\left(1+\tfrac{1}{2}\right)\frac{580\,\text{nm}}{1.50} = \boxed{290\,\text{nm}}$$

31：



With respect to the incident wave, the wave that reflects from the air at the top surface of the air layer has a phase change of $\phi_1 = 0$. With respect to the incident wave, the wave that reflects from the glass at the bottom surface of the air layer has a phase change due to both the additional path length and reflection, so $\phi_2 = \left(\frac{2t}{\lambda}\right)2\pi + \pi$. For constructive interference, the net phase change must be an even non-zero integer multiple of π.

$$\phi_{\text{net}} = \phi_2 - \phi_1 = \left[\left(\frac{2t}{\lambda}\right)2\pi + \pi\right] - 0 = 2m\pi \quad \rightarrow \quad t = \tfrac{1}{2}\left(m-\tfrac{1}{2}\right)\lambda,\ m = 1, 2, \cdots.$$

The minimum thickness is with $m = 1$.

$$t_{\min} = \tfrac{1}{2}(450\,\text{nm})\left(1-\tfrac{1}{2}\right) = \boxed{113\,\text{nm}}$$

For destructive interference, the net phase change must be an odd-integer multiple of π.

$$\phi_{\text{net}} = \phi_2 - \phi_1 = \left[\left(\frac{2t}{\lambda}\right)2\pi + \pi\right] - 0 = (2m+1)\pi \quad \rightarrow \quad t = \tfrac{1}{2}m\lambda,\ \ = 0, 1, 2, \cdots$$

The minimum non-zero thickness is $t_{\min} = \tfrac{1}{2}(450\,\text{nm})(1) = \boxed{225\,\text{nm}}$.

33：参见课件相应内容

36:

We use the equation derived in Problem 33, where r is the radius of the lens (1.7 cm) to solve for the radius of curvature. Since the outer edge is the 44th bright ring, which would be halfway between the 44th and 45th dark fringes, we set m=44.5

$$r=\sqrt{m\lambda R} \quad \rightarrow \quad R=\frac{r^2}{m\lambda}=\frac{(0.017\,\mathrm{m})^2}{(44.5)(580\times10^{-9}\,\mathrm{m})}=11.20\,\mathrm{m}\approx\boxed{11\,\mathrm{m}}$$

We calculate the focal length of the lens using Eq. 33-4 (the lensmaker's equation) with the index of refraction of lucite taken from Table 32-1.

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)=(1.51-1)\left(\frac{1}{11.2\,\mathrm{m}}+\frac{1}{\infty}\right)=0.0455\,\mathrm{m}^{-1} \quad \rightarrow \quad f=\frac{1}{0.0455\,\mathrm{m}^{-1}}=\boxed{22\,\mathrm{m}}$$

第三十章

必做题 ：1，5，10，15，17，18，23

1：

The angle to the first maximum is about halfway between the angles to the first and second minima. We use Eq. 35-2 to calculate the angular distance to the first and second minima. Then we average these to values to determine the approximate location of the first maximum. Finally, using trigonometry, we set the linear distance equal to the distance to the screen multiplied by the tangent of the angle.

$$D\sin\theta_m=m\lambda \rightarrow \theta_m=\sin^{-1}\left(\frac{m\lambda}{D}\right)$$

$$\theta_1=\sin^{-1}\left(\frac{1\times580\times10^{-9}\ \mathrm{m}}{3.8\times10^{-6}\ \mathrm{m}}\right)=8.678^\circ \qquad \theta_2=\sin^{-1}\left(\frac{2\times580\times10^{-9}\ \mathrm{m}}{3.8\times10^{-6}\ \mathrm{m}}\right)=17.774^\circ$$

$$\theta=\frac{\theta_1+\theta_2}{2}=\frac{8.678^\circ+17.774^\circ}{2}=13.23^\circ$$

$$y=\ell\tan\theta_1=(10.0\ \mathrm{m})\tan(13.23^\circ)=\boxed{2.35\ \mathrm{m}}$$

5:

Given light with $\lambda = 605\ \text{nm}$ passing through double slits with separation $d = 0.120\ \text{mm}$, we use Eq. 34-2a to find the highest integer m value for the interference fringe that occurs before the angle $\theta = 90°$.

$$d\sin\theta = m\lambda \quad \rightarrow \quad m = \frac{\left(0.120\times10^{-3}\,\text{m}\right)\sin 90°°}{605\times10^{-9}\text{m}} = 198$$

So, including the $m = 0$ fringe, and the symmetric pattern of interference fringes on each side of $\theta = 0$, there are potentially a total of $198 + 198 + 1 = 397$ fringes. However, since slits have width $a = 0.040$ mm, the potential interference fringes that coincide with the slits' diffraction minima will be absent. Let the diffraction minima be indexed by $m' = 1, 2, 3$, etc. We then set the diffraction angles in Eq. 34-2a and Eq. 35-2 equal to solve for the m values of the absent fringes.

$$\sin\theta = \frac{m'\lambda}{D} = \frac{m\lambda}{d} \quad \rightarrow \quad \frac{m}{m'} = \frac{d}{D} = \frac{0.120\ \text{mm}}{0.040\ \text{mm}} = 3 \quad \rightarrow \quad m = 3m'$$

Using $m' = 1, 2, 3$, etc., the 66 interference fringes on each side of $\theta = 0$ with $m = 3, 6, 9, \ldots, 198$ will be absent. Thus the number of fringes on the screen is $397 - 2(66) = \boxed{265}$.

10:

We find the slit separation from Eq. 35-13. Then set the number of lines per centimeter equal to the inverse of the slit separation, $N=1/d$.

$$d\sin\theta = m\lambda \rightarrow N = \frac{1}{d} = \frac{\sin\theta}{m\lambda} = \frac{\sin 15.0°}{3\left(650\times10^{-7}\,\text{cm}\right)} = \boxed{1300\,\text{lines/cm}}$$

15:

We use Eq. 35-20, with $m = 1$.

$$m\lambda = 2d\sin\phi \quad \rightarrow \quad \phi = \sin^{-1}\frac{m\lambda}{2d} = \sin^{-1}\frac{(1)(0.138\,\text{nm})}{2(0.285\,\text{nm})} = \boxed{14.0°}$$

17:

The critical angle exists when light passes from a material with a higher index of refraction (n_1) into a material with a lower index of refraction (n_2). Use Eq. 32-7.

$$\frac{n_2}{n_1} = \sin\theta_C = \sin 55°$$

To find the Brewster angle, use Eq. 35-22a. If light is passing from high index to low index, we have the following.

$$\frac{n_2}{n_1} = \tan\theta_p = \sin 55° \rightarrow \theta_p = \tan^{-1}(\sin 55°) = \boxed{39°}$$

If light is passing from low index to high index, we have the following.

$$\frac{n_1}{n_2} = \tan\theta_p = \frac{1}{\sin 55°} \rightarrow \theta_p = \tan^{-1}\left(\frac{1}{\sin 55°}\right) = \boxed{51°}$$

18:

Let the initial intensity of the unpolarized light be I_0. The intensity after passing through the first Polaroid will be $I_1 = \frac{1}{2}I_0$. Then use Eq. 35-21.

$$I_2 = I_1\cos^2\theta = \tfrac{1}{2}I_0\cos^2\theta \rightarrow \theta = \cos^{-1}\sqrt{\frac{2I_2}{I_0}}$$

(a) $\theta = \cos^{-1}\sqrt{\frac{2I_2}{I_0}} = \cos^{-1}\sqrt{\frac{2}{3}} = \boxed{35.3°}$

(b) $\theta = \cos^{-1}\sqrt{\frac{2I_2}{I_0}} = \cos^{-1}\sqrt{\frac{2}{10}} = \boxed{63.4°}$

23:

We find the angles for the first order from Eq. 35-13.

$$\theta_1 = \sin^{-1}\frac{m\lambda}{d} = \sin^{-1}\frac{(1)(4.4\times10^{-7}\ \text{m})}{0.01\ \text{m}/7600} = 19.5°$$

$$\theta_2 = \sin^{-1}\frac{(1)(6.8\times10^{-7}\ \text{m})}{0.01\ \text{m}/7600} = 31.1°$$

The distances from the central white line on the screen are found using the tangent of the angle and the distance to the screen.

$$y_1 = L\tan\theta_1 = (2.5\,\text{m})\tan 19.5° = 0.89\,\text{m}$$

$$y_2 = L\tan\theta_2 = (2.5\,\text{m})\tan 31.1° = 1.51\,\text{m}$$

Subtracting these two distances gives the linear separation of the two lines.

$$y_2 - y_1 = 1.51\,\text{m} - 0.89\,\text{m} = \boxed{0.6\,\text{m}}$$

第三十一章

必做题 ： 2，3，8，14，19

2：

The speed is determined from the time dilation relationship, Eq. 36-1a.

$$\Delta t_0 = \Delta t\sqrt{1-v^2/c^2} \quad \rightarrow$$

$$v = c\sqrt{1-\left(\frac{\Delta t_0}{\Delta t}\right)^2} = c\sqrt{1-\left(\frac{2.60\times10^{-8}\,\mathrm{s}}{4.40\times10^{-8}\,\mathrm{s}}\right)^2} = \boxed{0.807c} = 2.42\times10^8\,\mathrm{m/s}$$

3：

The speed is determined from the length contraction relationship, Eq. 36-3a.

$$\ell = \ell_0\sqrt{1-v^2/c^2} \quad \rightarrow \quad v = c\sqrt{1-\left(\frac{\ell}{\ell_0}\right)^2} = c\sqrt{1-\left(\frac{35\,\mathrm{ly}}{56\,\mathrm{ly}}\right)^2} = \boxed{0.78c} = 2.3\times10^8\,\mathrm{m/s}$$

8：

The vertical dimensions of the ship will not change, but the horizontal dimensions will be contracted according to Eq. 36-3a. The base will be contracted as follows.

$$\ell_{\mathrm{base}} = \ell\sqrt{1-v^2/c^2} = \ell\sqrt{1-(0.95)^2} = \boxed{0.31\ell}$$

When at rest, the angle of the sides with respect to the base is given by $\theta = \cos^{-1}\dfrac{0.50\ell}{2.0\ell} = 75.52°$.

The vertical component of $\ell_{\mathrm{vert}} = 2\ell\sin\theta = 2\ell\sin 75.52° = 1.936\ell$ is unchanged. The horizontal component, which is $2\ell\cos\theta = 2\ell\left(\tfrac{1}{4}\right) = 0.50\ell$ at rest, will be contracted in the same way as the base.

$$\ell_{\mathrm{horizontal}} = 0.50\ell\sqrt{1-v^2/c^2} = 0.50\ell\sqrt{1-(0.95)^2} = 0.156\ell$$

Use the Pythagorean theorem to find the length of the leg.

$$\ell_{\mathrm{leg}} = \sqrt{\ell_{\mathrm{horizontal}}^2 + \ell_{\mathrm{vert}}^2} = \sqrt{(0.156\ell)^2 + (1.936\ell)^2} = 1.942\ell \approx \boxed{1.94\ell}$$

14：

We find the proton's momenta using Eq. 36-8.

$$p_{0.45}=\frac{m_p v_1}{\sqrt{1-\frac{v_1^2}{c^2}}}=\frac{m_p(0.45c)}{\sqrt{1-(0.45)^2}}=0.5039m_pc\ ;\ p_{0.80}=\frac{m_p v_2}{\sqrt{1-\frac{v_2^2}{c^2}}}=\frac{m_p(0.80c)}{\sqrt{1-(0.80)^2}}=1.3333m_pc$$

$$p_{0.98}=\frac{m_p v_2}{\sqrt{1-\frac{v_2^2}{c^2}}}=\frac{m_p(0.98c)}{\sqrt{1-(0.98)^2}}=4.9247m_pc$$

$$(a)\quad \left(\frac{p_2-p_1}{p_1}\right)100=\left(\frac{1.3333m_pc-0.5039m_pc}{0.5039m_pc}\right)100=164.6\approx\boxed{160\%}$$

$$(b)\quad \left(\frac{p_2-p_1}{p_1}\right)100=\left(\frac{4.9247m_pc-1.3333m_pc}{1.3333m_pc}\right)100=269.4\approx\boxed{270\%}$$

19：

The kinetic energy is given by Eq. 36-10.

$$K=(\gamma-1)mc^2=mc^2\ \rightarrow\ \gamma=2=\frac{1}{\sqrt{1-v^2/c^2}}\ \rightarrow\ v=\sqrt{\frac{3}{4}}c=\boxed{0.866c}$$

第三十二章

必做题 ： 7， 11， 13， 25

7：

We use Eq. 37-4b to calculate the work function.

$$W_0=hf-K_{\max}=\frac{hc}{\lambda}-K_{\max}=\frac{1240\ \text{eV}\bullet\text{nm}}{285\ \text{nm}}-1.70\ \text{eV}=\boxed{2.65\ \text{eV}}$$

11：

(*a*) In the Compton effect, the maximum change in the photon's wavelength is when scattering angle $\phi = 180^\circ$. We use Eq. 37-6b to determine the maximum change in wavelength. Dividing the maximum change by the initial wavelength gives the maximum fractional change.

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\theta) \quad \rightarrow$$

$$\frac{\Delta\lambda}{\lambda} = \frac{h}{m_e c\lambda}(1-\cos\theta) = \frac{\left(6.63\times10^{-34}\,\text{J}\bullet\text{s}\right)\left(1-\cos180^\circ\right)}{\left(9.11\times10^{-31}\,\text{kg}\right)\left(3.00\times10^{8}\,\text{m/s}\right)\left(550\times10^{-9}\,\text{m}\right)} = \boxed{8.8\times10^{-6}}$$

(*b*) We replace the initial wavelength with $\lambda = 0.10$ nm.

$$\frac{\Delta\lambda}{\lambda} = \frac{h}{m_e c\lambda}(1-\cos\theta) = \frac{\left(6.63\times10^{-34}\,\text{J}\bullet\text{s}\right)\left(1-\cos180^\circ\right)}{\left(9.11\times10^{-31}\,\text{kg}\right)\left(3.00\times10^{8}\,\text{m/s}\right)\left(0.10\times10^{-9}\,\text{m}\right)} = \boxed{0.049}$$

13：

We use the relativistic expression for momentum, Eq. 36-8.

$$p = \frac{mv}{\sqrt{1-v^2/c^2}} = \frac{mv}{\sqrt{1-v^2/c^2}} = \frac{h}{\lambda} \quad \rightarrow$$

$$\lambda = \frac{h\sqrt{1-v^2/c^2}}{mv} = \frac{\left(6.63\times10^{-34}\,\text{J}\bullet\text{s}\right)\sqrt{1-(0.98)^2}}{\left(9.11\times10^{-31}\,\text{kg}\right)(0.98)\left(3.00\times10^{8}\,\text{m/s}\right)} = \boxed{4.9\times10^{-13}\,\text{m}}$$

25：

The stopping potential is the voltage that gives a potential energy change equal to the maximum kinetic energy. We use Eq. 37-4b to first find the work function, and then find the stopping potential for the higher wavelength.

$$K_{\max} = eV_0 = \frac{hc}{\lambda} - W_0 \quad \rightarrow \quad W_0 = \frac{hc}{\lambda_0} - eV_0$$

$$eV_1 = \frac{hc}{\lambda_1} - W_0 = \frac{hc}{\lambda_1} - \left(\frac{hc}{\lambda_0} - eV_0\right) = hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_0}\right) + eV_0$$

$$= \frac{\left(6.63\times10^{-34}\,\text{J}\bullet\text{s}\right)\left(3.00\times10^{8}\,\text{m/s}\right)}{\left(1.60\times10^{-19}\,\text{J/eV}\right)}\left(\frac{1}{440\times10^{-9}\,\text{m}} - \frac{1}{380\times10^{-9}\,\text{m}}\right) + 2.70\,\text{eV} = 2.25\,\text{eV}$$

The potential difference needed to cancel an electron kinetic energy of 2.25 eV is $\boxed{2.25\text{ V}}$.

第三十三章

必做题 ： 4， 6

4:

The minimum uncertainty in the energy is found from Eq. 38-2.

$$\Delta E \geq \frac{\hbar}{\Delta t} = \frac{\left(1.055\times10^{-34}\,\mathrm{J\bullet s}\right)}{\left(1\times10^{-8}\,\mathrm{s}\right)} = 1.055\times10^{-26}\,\mathrm{J}\left(\frac{1\,\mathrm{eV}}{1.60\times10^{-19}\,\mathrm{J}}\right) = 6.59\times10^{-8}\,\mathrm{eV} \approx \boxed{10^{-7}\,\mathrm{eV}}$$

6:

The uncertainty in the energy is found from the lifetime and the uncertainty principle.

$$\Delta E = \frac{\hbar}{\Delta t} = \frac{h}{2\pi\Delta t}\ ;\ E = h\nu = \frac{hc}{\lambda}$$

$$\frac{\Delta E}{E} = \frac{\dfrac{h}{2\pi\Delta t}}{\dfrac{hc}{\lambda}} = \frac{\lambda}{2\pi c\Delta t} = \frac{500\times10^{-9}\,\mathrm{m}}{2\pi\left(3.00\times10^{8}\,\mathrm{m/s}\right)\left(10\times10^{-9}\,\mathrm{s}\right)} = 2.65\times10^{-8} \approx \boxed{3\times10^{-8}}$$

$$E = \frac{hc}{\lambda} \;\rightarrow\; dE = -\frac{hc}{\lambda^2}d\lambda \;\rightarrow\; \Delta E \approx -\frac{hc}{\lambda^2}\Delta\lambda = -\frac{E}{\lambda}\Delta\lambda \;\rightarrow\; \frac{\Delta E}{E} = -\frac{\Delta\lambda}{\lambda}$$

The wavelength uncertainty is the absolute value of this expression, and so $\frac{\Delta\lambda}{\lambda} = \boxed{3\times10^{-8}}$