1. Serway, Problem 35.28 (5 points)

   Solution

   Light incident on the left side of the prism is initially refracted, propagates through the prism, and is refracted again when it reemerges. We want to express the first angle of incidence θ_1 exclusively in terms of n and Φ. The second angle of refraction is given as $\frac{\pi}{2}$, that is, light does not emerge from the other side, but rather propagates along it. We assume the prism is in a vacuum so that the index of refraction outside the prism is unity. There are then two unknowns: the first angle of refraction θ_2 and the critical angle θ_c for the prism medium. Using Snell's Law, we can relate θ_1 and θ_2 as

$$\sin\theta_1 = n\sin\theta_2.$$

   Meanwhile

$$\sin\theta_c = \frac{1}{n}$$

   and

$$\Phi = \theta_2 + \theta_c,$$

   so we may rewrite our initial equation as

$$\begin{aligned}
\sin\theta_1 &= n\sin(\Phi - \theta_c) \\
&= n\sin\left[\Phi - \sin^{-1}\left(\frac{1}{n}\right)\right] \\
&= n\left\{\sin\Phi\cos\left[\sin^{-1}\left(\frac{1}{n}\right)\right] - \cos\Phi\sin\left[\sin^{-1}\left(\frac{1}{n}\right)\right]\right\} \\
&= \cancel{n}\left(\sin\Phi\frac{\sqrt{n^2-1}}{\cancel{n}} - \cos\Phi\frac{1}{\cancel{n}}\right) \\
&= \sqrt{n^2-1}\sin\Phi - \cos\Phi.
\end{aligned}$$

   The minimum angle of incidence is therefore

$$\theta_1 = \boxed{\sin^{-1}\left[\sqrt{n^2-1}\sin\Phi - \cos\Phi\right]}.$$

2. Serway, Problem 35.52 (5 points)

   Solution

   (a) The speed of the laser spot along the circular wall of the silo is simply

$$\begin{aligned}
v &= r\omega \\
&= (3)(35) \\
&= \boxed{105\,\mathrm{m/s}}.
\end{aligned}$$

(b) For the progress of the laser spot along a long flat wall, we analyze a right triangle whose legs are given by the perpendicular distance r of the laser source from the wall, and the distance x of the spot from the perpendicular. The hypotenuse is then the laser beam itself which makes an angle θ with r, thus

$$\tan\theta = \frac{x}{r}.$$

To find the speed $v = dx/dt$ of the spot, we differentiate with respect to time:

$$\begin{aligned}
\frac{d}{dt}\tan\theta &= \frac{d}{dt}\frac{x}{r} \\
\left(1+\tan^2\theta\right)\frac{d\theta}{dt} &= \frac{1}{r}\frac{dx}{dt} \\
\omega(1+\tan^2\theta) &= \frac{v}{r}
\end{aligned}$$

and solve for v:

$$\begin{aligned}
v &= r\omega(1+\tan^2\theta) \\
&= \boxed{r\omega\left(1+\frac{x^2}{r^2}\right)}.
\end{aligned}$$

(c) The minimum speed is $\boxed{\omega r}$ at $\boxed{x=0}$.

(d) As the angle $\theta \to \frac{\pi}{2}$, the distance $x \to \infty$, and the speed $v \to \infty$. However, the maximum speed of the light placing the spot on the wall is the speed of light $\boxed{c}$.

(e) For speed $v \to c$, angle $\theta \to \frac{\pi}{2}$, which is a quarter turn of the laser source, thus

$$\begin{aligned}
t &= \frac{T}{4} \\
&= \frac{\pi}{2\omega} \\
&= \frac{\pi}{(2)(35)} \\
&= \boxed{45\,\text{ms}}.
\end{aligned}$$

3. Serway, Problem 35.58 (5 points)

<u>Solution</u>

Serway gives a recipe for the solution. Following it explicitly we have

(a) Finding the transit time of the light:

$$\begin{aligned}
t &= \frac{r_1}{v_1} + \frac{r_2}{v_2} \\
&= \frac{\sqrt{a^2+x^2}}{v_1} + \frac{\sqrt{b^2+(d-x)^2}}{v_2} \\
&= \frac{n_1\sqrt{a^2+x^2}}{c} + \frac{n_2\sqrt{b^2+(d-x)^2}}{c}.
\end{aligned}$$

(b) Setting $dt/dx = 0$:

$$\frac{d}{dx}\left[\frac{n_1\sqrt{a^2+x^2}}{c} + \frac{n_2\sqrt{b^2+(d-x)^2}}{c}\right] = 0$$

$$\frac{\cancel{2}xn_1}{\sqrt{a^2+x^2}\cancel{c}} - \frac{\cancel{2}x(d-x)n_2}{\sqrt{b^2+(d-x)^2}\cancel{c}} = 0$$

$$\frac{n_1 x}{\sqrt{a^2+x^2}} = \frac{n_2(d-x)}{\sqrt{b^2+(d-x)^2}}.$$

(c) Analyzing the triangles in the figure, we see that this leads to

$$n_1 \sin\theta_1 = n_2 \sin\theta_2.$$

4. Serway, Problem 35.64 (5 points)

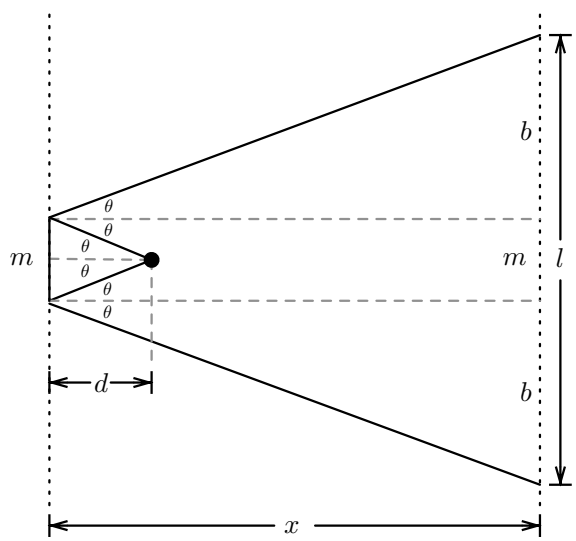
Solution

The slope of the line is

$$n \approx 1.33$$

which is the index of refraction of water.

5. Serway, Problem 36.2 (2 points)



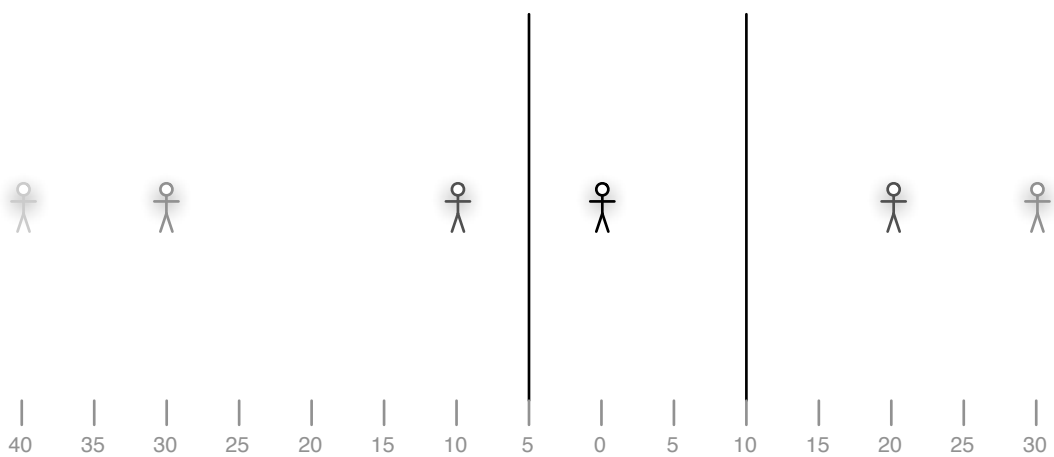
Solution

We construct a top-down view of the setup, as Serway suggests. The mirror is length m, and the organist sits a distance d away. There is a distance x between the walls, and a length l of the opposite wall viewed by the organist. In constructing the figure, we note that the angle of incidence θ is the same as the angle of reflection for a flat mirror, and that the line of sight from the organist to the edge

of the mirror defines the limits of her view, and indeed defines the only angle we need consider in this problem. We write

$$\begin{aligned} l &= m + 2b \\ &= m + 2x\tan\theta \\ &= m + 2x\left(\frac{m}{2d}\right) \\ &= m + \frac{mx}{d} \\ &= m\left(1 + \frac{x}{d}\right) \\ &= (0.6)\left(1 + \frac{5.3}{0.8}\right) \\ &= \boxed{4.6\,\mathrm{m}}. \end{aligned}$$

6. Serway, Problem 36.4 (2 points)



Solution

As per the figure, the first image in the left hand mirror is a reflection of the person. The second image in the left hand mirror is a reflection of the reflection in the right hand mirror of the person. The third image in the left hand mirror is a reflection of the reflection in the right hand mirror of the first reflection in the left hand mirror of the person. The distances are indicated on the scale.

7. Serway, Problem 36.8 (2 points)

Solution

Remember that for a convex mirror, the radius of curvature R is negative, as is the location of the

virtual image q. Solving the mirror equation for the image distance q we have

$$\begin{aligned} q &= \left(\frac{2}{R} - \frac{1}{p}\right)^{-1} \\ &= \left(-\frac{2}{0.55} - \frac{1}{10}\right)^{-1} \\ &= \boxed{-0.27}, \end{aligned}$$

indicating that the $\boxed{\text{virtual}}$ image is 27 cm behind the mirror. The magnification is given by

$$\begin{aligned} M &= -\frac{q}{p} \\ &= \frac{0.27}{10} \\ &= \boxed{0.027}, \end{aligned}$$

which indicates that the image is $\boxed{\text{upright}}$ and $\boxed{\text{diminished}}$.

8. Serway, Problem 36.14 (2 points)

   Solution

   We are given $p = 30$ cm and $M = 0.013$. We write

$$\begin{aligned} q &= -pM \\ &= -(0.30)(0.013) \\ &= -0.0039. \end{aligned}$$

   Plugging into the mirror equation and solving for R, we have

$$\begin{aligned} R &= 2\left(\frac{1}{p} + \frac{1}{q}\right)^{-1} \\ &= 2\left(\frac{1}{0.30} - \frac{1}{0.0039}\right)^{-1} \\ &= \boxed{-0.79\,\text{cm}}. \end{aligned}$$

9. Serway, Problem 36.18 (3 points)

   Solution

   We are given $p = 24$ m, $h = 1.5$ m, $R = \infty$, and the distance $l = 1.55$ m from our eye to the mirror. We write

$$\begin{aligned} q &= \left(\frac{2}{R} - \frac{1}{p}\right)^{-1} \\ &= \left(\frac{2}{\infty} - \frac{1}{24}\right)^{-1} \\ &= \boxed{-24\,\text{m}}. \end{aligned}$$

The distance from the virtual image to our eye is

$$\begin{aligned} d &= l + |q| \\ &= 1.55 + 24 \\ &= \boxed{25.55\,\mathrm{m}}. \end{aligned}$$

The magnification is 1 (flat mirror), and so the height of the image $h' = \boxed{1.5\,\mathrm{m}}$. The angle subtended by the image at that distance is then

$$\begin{aligned} \theta &= \frac{h'}{d} \\ &= \frac{1.5}{25.55} \\ &= 0.0587 = \boxed{3.36^\circ}. \end{aligned}$$

For a convex mirror of radius -2, we find:

$$q = \left(\frac{2}{R} - \frac{1}{p}\right)^{-1} = \left(-\frac{2}{2} - \frac{1}{24}\right)^{-1} = \boxed{-0.96\,\mathrm{m}};$$

$$d = l + |q| = 1.55 + 0.96 = \boxed{2.51\,\mathrm{m}};$$

$$M = -\frac{q}{p} = \frac{0.96}{24} = 0.04;$$

$$h' = Mh = (0.04)(1.5) = \boxed{6\,\mathrm{cm}};$$

and

$$\theta = \frac{h'}{d} = \frac{0.06}{2.51} = 0.0239 = \boxed{1.37^\circ}.$$

An actual object of height $h = 1.5$ m subtending an angle of 1.37° would be located at a distance

$$\begin{aligned} d_{\mathsf{apparent}} &= \frac{h}{\theta} \\ &= \frac{1.5}{0.0239} \\ &= \boxed{63\,\mathrm{m}}. \end{aligned}$$

10. Serway, Problem 36.20 (3 points)

Solution

The apparent depth of the bottom of the flint glass from within the water is

$$q_{\mathsf{b}} = -\frac{n_{\mathsf{w}}}{n_{\mathsf{g}}} p_{\mathsf{b}}.$$

The apparent depth of *that* apparent depth from above the water (depth h) is

$$\begin{aligned} q'_{\mathsf{b}} &= -\frac{n_{\mathsf{a}}}{n_{\mathsf{w}}}(h - q_{\mathsf{b}}) \\ &= -\frac{n_{\mathsf{a}}}{\cancel{p_{\mathsf{w}}}}\left(h + \frac{\cancel{p_{\mathsf{w}}}}{n_{\mathsf{g}}}p_{\mathsf{b}}\right) \\ &= -n_{\mathsf{a}}\left(\frac{h}{n_{\mathsf{w}}} + \frac{p_{\mathsf{b}}}{n_{\mathsf{g}}}\right) \\ &= -1.00\left(\frac{0.12}{1.33} + \frac{0.08}{1.66}\right) \\ &= -0.138. \end{aligned}$$

Meanwhile the apparent depth of the top of the flint glass is

$$\begin{aligned} q_{\mathsf{t}} &= -\frac{n_{\mathsf{a}}}{n_{\mathsf{w}}}p_{\mathsf{t}} \\ &= -\frac{1.00}{1.33}(0.12) \\ &= -0.090, \end{aligned}$$

making the glass appear to be $13.8 - 9.0 = \boxed{4.8\,\mathrm{cm}}$ thick.

11. Serway, Problem 36.24 (3 points)

Solution

Writing both object and image heights in terms of the angles they subtend at their respective distances from the interface, we have

$$\begin{aligned} h &= p\tan\theta_1; \\ -h' &= q\tan\theta_2. \end{aligned}$$

Meanwhile,

$$n_1\tan\theta_1 = n_2\tan\theta_2$$

or

$$\tan\theta_2 = \frac{n_1}{n_2}\tan\theta_1.$$

Thus

$$\begin{aligned} M \equiv \frac{h'}{h} &= -\frac{q\tan\theta_2}{p\tan\theta_1} \\ &= -\frac{n_1 q\,\cancel{\tan\theta_1}}{n_2 p\,\cancel{\tan\theta_1}} \\ &= -\frac{n_1 q}{n_2 p}, \qquad \text{qed.} \end{aligned}$$

12. Serway, Problem 36.26 (3 points)

Solution

Since the expression

$$\frac{p}{n_1} = -\frac{q}{n_2}$$

is true for any p and q, we write

$$\frac{\Delta p}{n_1} = -\frac{\Delta q}{n_2}$$

Dividing by Δt and solving for the image speed, we have

$$\begin{aligned} |v_{\mathsf{image}}| = \left|\frac{\Delta q}{\Delta t}\right| &= \left|-\frac{n_2}{n_1}\frac{\Delta p}{\Delta t}\right| \\ &= \left|-\frac{1.00}{1.33}(0.02)\right| \\ &= \boxed{1.5\,\mathrm{cm/s}}. \end{aligned}$$

13. Serway, Problem 23.36 (2 points)

Solution

(a) The acceleration of the proton is given by

$$\begin{aligned} a &= \frac{F_E}{m_{\mathsf{p}}} \\ &= \frac{eE}{m_{\mathsf{p}}} \\ &= \frac{(1.6\times10^{-19})(-6.00\times10^{5})}{1.67\times10^{-27}} \\ &= \boxed{-5.74\times10^{13}\,\mathrm{m/s^2}\,\mathbf{i}}. \end{aligned}$$

(b) The initial speed of the proton is

$$\begin{aligned} v_i &= \sqrt{v_f^2 - 2a\Delta x} \\ &= \sqrt{-2(-5.74\times10^{13})(0.07)} \\ &= \boxed{2.83\times10^{6}\,\mathrm{m/s}}. \end{aligned}$$

(c) The time interval over which the proton comes to rest is

$$\begin{aligned} \Delta t &= \left|\frac{\Delta v}{a}\right| \\ &= \frac{2.83\times10^{6}}{5.74\times10^{13}} \\ &= \boxed{49\,\mathrm{ns}}. \end{aligned}$$

14. Serway, Problem 24.18 (3 points)

    Solution

    In each case, the total charge responsible for the electric field may be treated as a point charge at distance r. The magnitude of the fields are as follows:

    (a) for $r = 0$:

$$E = 0;$$

    (b) for $r = 10$ cm:

$$\begin{aligned} E &= k\frac{q}{r^2} \\ &= k\frac{\rho V_{\text{enc}}}{r^2} \\ &= k\frac{QV_{\text{enc}}}{V_{\text{sphere}}r^2} \\ &= k\frac{Qr}{R^3} \\ &= (9\times10^9)\frac{(2.6\times10^{-5})(0.10)}{(0.40)^3} \\ &= \boxed{3.66\times10^5\ \text{N/C}}; \end{aligned}$$

    (c) for $r = 40$ cm:

$$\begin{aligned} E &= k\frac{Q}{r^2} \\ &= (9\times10^9)\frac{2.6\times10^{-5}}{(0.40)^2} \\ &= \boxed{1.46\times10^6\ \text{N/C}}; \end{aligned}$$

    (d) for $r = 60$ cm:

$$\begin{aligned} E &= k\frac{Q}{r^2} \\ &= (9\times10^9)\frac{2.6\times10^{-5}}{(0.60)^2} \\ &= \boxed{6.50\times10^5\ \text{N/C}}. \end{aligned}$$

15. Serway, Problem 25.38 (3 points)

    Solution

By superposition, we find

$$\begin{aligned} V_{\mathcal{O}} &= V_{\text{semicircle}} + 2V_{\text{segment}} \\ &= k\lambda\left(\int_0^{\pi} d\theta + 2\int_R^{3R}\frac{dx}{x}\right) \\ &= k\lambda(\pi + 2\ln 3) \\ &= \boxed{4.8\times 10^{10}\lambda}, \end{aligned}$$

an interesting result, in that it does not depend on R!

16. Serway, Problem 26.14 (3 points)

Solution

(a) The equivalent capacitance is

$$\begin{aligned} C_{\text{eq}} &= \frac{(3C)(6C)}{3C+6C} \\ &= \frac{18C^{\cancel{2}}}{9\cancel{C}} \\ &= \boxed{2C}. \end{aligned}$$

(b) The stored charges are

$$\begin{aligned} Q_1 &= 2C\mathcal{E}, \\ Q_2 &= \frac{1}{3}C\mathcal{E}, \\ Q_3 &= \frac{5}{3}C\mathcal{E}, \end{aligned}$$

thus

$$\boxed{Q_1 > Q_3 > Q_2}.$$

(c) The voltage drops are

$$\begin{aligned} \Delta V_1 &= \frac{2}{3}\mathcal{E}, \\ \Delta V_2 &= \frac{\mathcal{E}}{3}, \\ \Delta V_3 &= \frac{\mathcal{E}}{3}, \end{aligned}$$

thus

$$\boxed{\Delta V_1 > \Delta V_2 = \Delta V_3}.$$

(d) The effects on stored charges of an increase in C_3 is evinced by the expressions

$$\begin{aligned} Q_1 &= Q_{\text{tot}} \\ &= C_{\text{eq}}\mathcal{E} \\ &= C_1\mathcal{E}\left(\frac{C_2+C_3}{C_1+C_2+C_3}\right); \end{aligned}$$

$$\begin{aligned} Q_2 &= C_2\Delta V_2 \\ &= C_2(\mathcal{E}-\Delta V_1) \\ &= C_2\left(\mathcal{E}-\frac{Q_{\text{tot}}}{C_1}\right) \\ &= C_2\mathcal{E}\left(1-\frac{C_2+C_3}{C_1+C_2+C_3}\right); \end{aligned}$$

$$\begin{aligned} Q_3 &= C_3\Delta V_3 \\ &= C_3\mathcal{E}\left(1-\frac{C_2+C_3}{C_1+C_2+C_3}\right). \end{aligned}$$

All of these contain the quotient

$$\frac{C_2+C_3}{C_1+C_2+C_3} < 1,$$

for positive C_1, C_2, and C_3, and yet

$$\lim_{C_3\to\infty}\frac{C_2+C_3}{C_1+C_2+C_3} = 1,$$

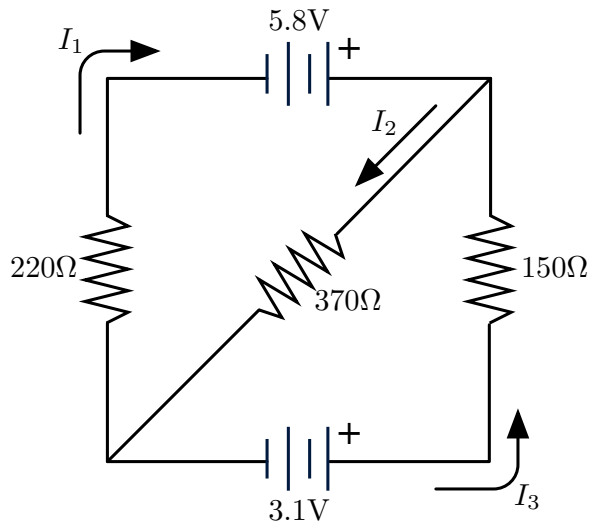
and so must increase with increasing C_3. For C_1, this means an increase in stored charge. For C_2, it means a decrease. For C_3, the decrease in the second term is overtaken by the increase in the first, and so the stored charge also increases for this capacitor.

17. Serway, Problem 27.28 (3 points)

Solution

(a) The efficiency of the battery is given by

$$\begin{aligned} \eta &= \frac{U_-}{U_+} \\ &= \frac{\mathscr{P}_-\Delta t_-}{\mathscr{P}_+\Delta t_+} \\ &= \frac{I_-\Delta V_-\Delta t_-}{I_+\Delta V_+\Delta t_+} \\ &= \frac{(0.018)(1.6)(2.4)}{(0.0135)(2.3)(4.2)} \\ &= \boxed{53\%}. \end{aligned}$$



18. Serway, Problem 28.20 (3 points)

Solution

(a) The circuit may be drawn as shown.

(b) To solve for the currents we use the junction rule equation to rewrite the loop rule equations as

$$-220I_1 + 5.8 - 370(I_1 + I_3) = 0,$$
$$370(I_1 + I_3) + 150I_3 - 3.1 = 0,$$

by which we find

$$I_1 = \boxed{11.0\,\text{mA}};$$
$$I_2 = \boxed{9.14\,\text{mA}};$$
$$I_3 = \boxed{-1.86\,\text{mA}}.$$

19. Serway, Problem 29.10 (3 points)

Solution

(a) Under the influence of gravity, the electrons will deflect

$$\begin{aligned}\Delta z &= v_{zi} + \frac{1}{2}a_z t^2 \\ &= \frac{1}{2}g\left(\frac{\Delta x}{v_x}\right)^2 \\ &= \frac{g m_e (\Delta x)^2}{4e\Delta V} \\ &= \frac{(9.8)(9.11\times10^{-31})(0.35)^2}{4(1.6\times10^{-19})(2500)} \\ &= \boxed{0.684\,\text{fm}}\end{aligned}$$

downward.

(b) Under the influence of the magnetic field $\mathbf{B} = -20.0\,\mu\mathrm{T}\,\mathbf{k}$, the electrons will follow a curved path in the xy plane subtending an angle $\frac{\pi}{2} - \theta$ about their center of curvature, and deflect

$$\begin{aligned}
\Delta y &= r - r\sin\theta \\
&= r\left\{1 - \sin\left[\cos^{-1}\left(\frac{\Delta x}{r}\right)\right]\right\} \\
&= r\left[1 - \sqrt{1 - \left(\frac{\Delta x}{r}\right)^2}\right] \\
&= \frac{m_e v}{eB}\left[1 - \sqrt{1 - \left(\frac{eB\Delta x}{m_e v}\right)^2}\right] \\
&= \sqrt{\frac{2m_e\Delta V}{eB^2}}\left[1 - \sqrt{1 - \frac{eB^2}{2m_e\Delta V}(\Delta x)^2}\right] \\
&= \sqrt{71.2}\left[1 - \sqrt{1 - \frac{(0.35)^2}{71.2}}\right] \\
&= \boxed{7.26\,\mathrm{mm}}
\end{aligned}$$

eastward.

20. Serway, Problem 30.6 (3 points)

Solution

A plot of the function

$$\frac{B_x}{B_0} = \frac{a^3}{(a^2 + x^2)^{3/2}}$$

with $a = 1$ is shown below.

21. Serway, Problem 31.28 (2 points)

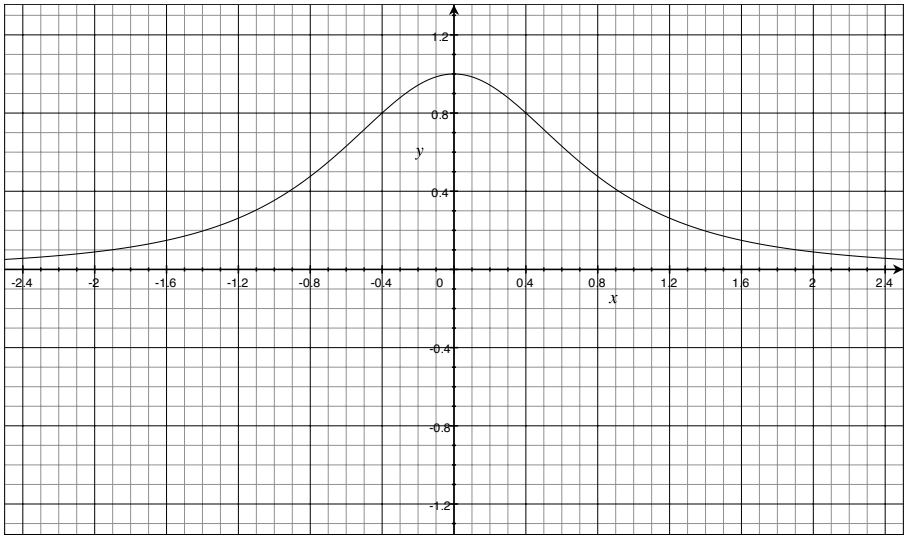
Solution

(a) When the bar magnet moves to the left, a decreasing magnetic flux in the coil induces a current that opposes the decrease, namely: counter-clockwise in the circuit, and so $\boxed{\text{left to right}}$ through the resistor.

(b) When the battery is connected, an increasing current arises counter-clockwise in the first circuit. This creates an increasing magnetic flux right to left, which induces an opposing current in the second circuit, that is: $\boxed{\text{out of the page}}$ through the resistor.

(c) A decrease in I leads to a decrease in B into the page in the region of the loop, inducing a clockwise current in the loop opposing the decrease, or $\boxed{\text{left to right}}$ through the resistor.

(d) For positive charges deflecting up and negative charges deflecting down, we require a magnetic field directed $\boxed{\text{into the paper}}$.



22. Serway, Problem 32.20 (3 points)

    Solution

    With $I_{\text{max}} = 10.0$ A and $t_0 = 200\ \mu$s, the current in the inductor may be defined piecewise as

$$I = \begin{cases} I_{\text{max}}\left(1 - e^{-t/\tau}\right), & 0 \le t \le t_0 \\ I'_{\text{max}} e^{-t'/\tau}, & t > t_0 \end{cases}$$

    or

$$\boxed{I = \begin{cases} I_{\text{max}}\left(1 - e^{-t/\tau}\right), & 0 \le t \le t_0 \\ I_{\text{max}}\left(e^{t_0/\tau} - 1\right) e^{-t/\tau}, & t > t_0 \end{cases}}.$$

23. Serway, Problem 34.40 (2 points)

    Solution

    See tables below.

Frequency	Classification
2 Hz	radio
2 kHz	radio
2 MHz	radio
2 GHz	microwave
2 THz	infrared
2 PHz	ultraviolet
2 EHz	X-ray
2 ZHz	gamma ray
2 YHz	gamma ray

Wavelength	Classification
2 km	radio
2 m	radio
2 mm	microwave
2 μm	infrared
2 nm	ultraviolet or X-ray
2 pm	X-ray or gamma ray
2 fm	gamma ray
2 am	gamma ray

24. Memorize Maxwell's equations. Be prepared to:

    (a) name each of Maxwell's equations (e.g. "Faraday's Law");
    (b) state each of Maxwell's equations in words (describe what each of Maxwell's equations relates);
    (c) write each of Maxwell's equations on the board;

    Each partnership's efforts will be assessed in class when this assignment is turned in. (5 points)
    Solution

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{q}{\epsilon_0}$$

$$\oint \mathbf{B} \cdot d\mathbf{A} = 0$$

$$\oint \mathbf{E} \cdot d\mathbf{s} = -\frac{d\Phi_B}{dt}$$

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I + \epsilon_0 \mu_0 \frac{d\Phi_E}{dt}$$

Index	Problem	Part	Answer	Points
1	35.28		$\theta_1 = \sin^{-1}\left[\sqrt{n^2-1}\sin\Phi - \cos\Phi\right]$	5
2	35.52	a	105 m/s	1
		b	$v = r\omega\left(1+\frac{x^2}{r^2}\right)$	1
		c	ωr at $x = 0$	1
		d	c or ∞	1
		e	45 ms	1
3	35.58		qed	5
4	35.64		$n_{\text{water}} \approx 1.33$	5
5	36.2		4.6 m	2
6	36.4		10, 30, and 40	2
7	36.8		virtual, upright, diminished ($q = -0.27$, $M = 0.027$)	2
8	36.14		-0.79 cm	2
9	36.18	a	25.55 m	1
		b	3.36°	1
		c	2.51 m	
		d	1.37°	
		e	63 m	1
10	36.20		4.8 cm	3
11	36.24		qed	3
12	36.26		1.5 cm/s	3
13	23.36	a	-5.74×10^{13} m/s^2 **i**	
		b	2.83×10^6 m/s	1
		c	49 ns	1
14	24.18	a	0	
		b	3.66×10^5 N/C	1
		c	1.46×10^6 N/C	1
		d	6.50×10^5 N/C	1
15	25.38		$4.8 \times 10^{10}\lambda$ or $k\lambda(\pi + 2\ln 3)$	3
16	26.14	a	2C	
		b	$Q_1 > Q_3 > Q_2$	1
		c	$\Delta V_1 > \Delta V_2 = \Delta V_3$	1
		d	Q_1 increases, Q_2 decreases, Q_3 increases	1
17	27.28	a	53%	3
		b	221 J	
		c	15.1°C	
18	28.20	a	(circuit diagram)	1
		b	$I_1 = 11.0$ mA, $I_2 = 9.14$ mA, $I_3 = -1.86$ mA	2
19	29.10	a	0.684 fm downward	1
		b	7.26 mm eastward	2
20	30.6		(plot)	3
21	31.28	a	left to right	1
		b	out of the page	1
		c	left to right	
		d	into the paper	
22	32.20		$I_{0\le t\le 200} = 10(1-e^{-10^4 t})$, $I_{t>200} = 63.9e^{-10^4 t}$	3
23	34.40		(tables)	2
24			(oral)	5