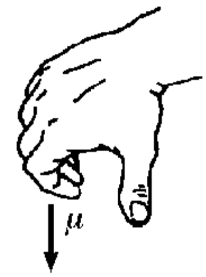
22.43 (a) $I = \dfrac{ev}{2\pi r}$ $\qquad \mu = IA = \left(\dfrac{ev}{2\pi r}\right)\pi r^2 = \boxed{9.27 \times 10^{-24}\ \text{A}\cdot\text{m}^2}$



The Bohr model predicts the correct magnetic moment. However, the "planetary model" is seriously deficient in other regards.

(b) Because the electron is (–), its [conventional] current is clockwise, as seen from above, and μ points $\boxed{\text{downward}}$.

***22.44** We model a sample of material magnetized to saturation as a collection of equal parallel magnetic moments. The field B they together produce must be proportional to the value of each magnetic moment μ. The field must be proportional to the magnetic permeability of space μ_0, as in equation 22.26. The uniform average field is finally proportional to the number density of the magnetic moments. Although we do not prove it here, the proportionality constant is exactly 1. We have $B = \mu_0 \mu x n$ where n is the number of atoms per volume and x is the number of electrons per atom contributing.

Then $$x = \frac{B}{\mu_0 \mu n} = \frac{2.00\ \text{T}}{\left(8.50 \times 10^{28}\ \text{m}^{-3}\right)\left(9.27 \times 10^{-24}\ \text{N}\cdot\text{m/T}\right)\left(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A}\right)} = \boxed{2.02}$$

22.57 (a) $$\text{Number of unpaired electrons} = \frac{8.00 \times 10^{22}\ \text{A}\cdot\text{m}^2}{9.27 \times 10^{-24}\ \text{A}\cdot\text{m}^2} = \boxed{8.63 \times 10^{45}}$$

Each iron atom has two unpaired electrons, so the number of iron atoms required is $\frac{1}{2}\left(8.63 \times 10^{45}\right)$.

(b) $$\text{Mass} = \frac{\left(4.31 \times 10^{45}\ \text{atoms}\right)\left(7900\ \text{kg/m}^3\right)}{\left(8.50 \times 10^{28}\ \text{atoms/m}^3\right)} = \boxed{4.01 \times 10^{20}\ \text{kg}}$$

***22.60** (a) $B = \frac{\mu_0 I}{2\pi r} = \frac{(4\pi \times 10^{-7}\ \text{T}\cdot\text{m/A})(24.0\ \text{A})}{2\pi(0.0175\ \text{m})} = \boxed{2.74 \times 10^{-4}\ \text{T}}$

(b) At point C, conductor AB produces a field $\frac{1}{2}(2.74 \times 10^{-4}\ \text{T})(-\mathbf{j})$,  conductor DE produces a field of $\frac{1}{2}(2.74 \times 10^{-4}\ \text{T})(-\mathbf{j})$,  BD produces no field, and AE produces negligible field. The total field at C is $\boxed{2.74 \times 10^{-4}\ \text{T}(-\mathbf{j})}$

(c) $\mathbf{F}_B = I\boldsymbol{\ell} \times \mathbf{B} = (24.0\ \text{A})(0.0350\ \text{m}\ \mathbf{k}) \times \left[5(2.74 \times 10^{-4}\ \text{T})(-\mathbf{j})\right] = \boxed{(1.15 \times 10^{-3}\ \text{N})\mathbf{i}}$ 

(d) $\mathbf{a} = \frac{\Sigma \mathbf{F}}{m} = \frac{(1.15 \times 10^{-3}\ \text{N})\mathbf{i}}{3.00 \times 10^{-3}\ \text{kg}} = \boxed{(0.384\ \text{m/s}^2)\mathbf{i}}$

(e) The bar is already so far from AE that it moves through nearly constant magnetic field. The force acting on the bar is constant, and therefore the bar's $\boxed{\text{acceleration is constant}}$

(f) $v_f^2 = v_i^2 + 2ax = 0 + 2(0.384\ \text{m/s}^2)(1.30\ \text{m})$, so $\mathbf{v}_f = \boxed{(0.999\ \text{m/s})\mathbf{i}}$

23.2

$$\mathcal{E} = -N\frac{\Delta BA\cos\theta}{\Delta t} = -NB\pi r^2\left(\frac{\cos\theta_f - \cos\theta_i}{\Delta t}\right) = -25.0(50.0 \times 10^{-6}\ \text{T})\left[\pi(0.500\ \text{m})^2\right]\left(\frac{\cos 180° - \cos 0°}{0.200\ \text{s}}\right)$$

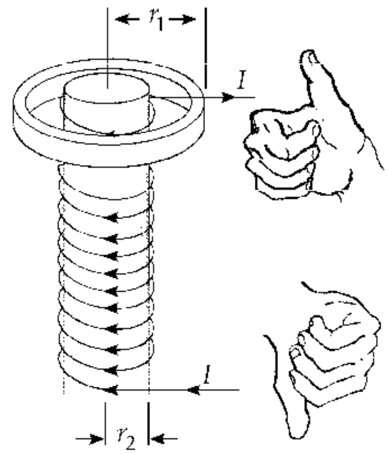
$$\mathcal{E} = \boxed{+9.82\ \text{mV}}$$

23.3 Noting unit conversions from $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$ and $U = qV$, the induced voltage is

$$\mathcal{E} = -N\frac{d(\mathbf{B}\cdot\mathbf{A})}{dt} = -N\left(\frac{0 - B_i A\cos\theta}{\Delta t}\right) = \frac{+200(1.60\ \text{T})(0.200\ \text{m}^2)\cos 0°}{20.0 \times 10^{-3}\ \text{s}}\left(\frac{1\ \text{N}\cdot\text{s}}{1\ \text{T}\cdot\text{C}\cdot\text{m}}\right)\left(\frac{1\ \text{V}\cdot\text{C}}{\text{N}\cdot\text{m}}\right) = 3200\ \text{V}$$

$$I = \frac{\mathcal{E}}{R} = \frac{3200\ \text{V}}{20.0\ \Omega} = \boxed{160\ \text{A}}$$

23.4 $$|\mathcal{E}| = \frac{d(BA)}{dt} = 0.500\ \mu_0 n A \frac{dI}{dt} = 0.500\ \mu_0 n \pi r_2^2 \frac{\Delta I}{\Delta t}$$

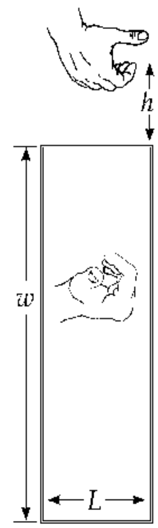


(a) $$I_{\text{ring}} = \frac{\mathcal{E}}{R} = \boxed{\frac{\mu_0 n \pi r_2^2}{2R} \frac{\Delta I}{\Delta t}}$$

(b) $$B = \frac{\mu_0 I}{2r_1} = \boxed{\frac{\mu_0^2 n \pi r_2^2}{4 r_1 R} \frac{\Delta I}{\Delta t}}$$

(c) The coil's field points downward, and is increasing, so $\boxed{B_{\text{ring}} \text{ points upward}}$

***23.6** (a) $$d\Phi_B = \mathbf{B} \cdot d\mathbf{A} = \frac{\mu_0 I}{2\pi x} L\,dx: \qquad \Phi_B = \int_h^{h+w} \frac{\mu_0 I L}{2\pi} \frac{dx}{x} = \boxed{\frac{\mu_0 I L}{2\pi} \ln\left(\frac{h+w}{h}\right)}$$



(b) $$\mathcal{E} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}\left[\frac{\mu_0 I L}{2\pi} \ln\left(\frac{h+w}{h}\right)\right] = -\left[\frac{\mu_0 L}{2\pi} \ln\left(\frac{h+w}{h}\right)\right] \frac{dI}{dt}$$

$$\mathcal{E} = -\frac{(4\pi \times 10^{-7}\ \text{T} \cdot \text{m/A})(1.00\ \text{m})}{2\pi} \ln\left(\frac{1.00 + 10.0}{1.00}\right)(10.0\ \text{A/s}) = \boxed{-4.80\ \mu\text{V}}$$

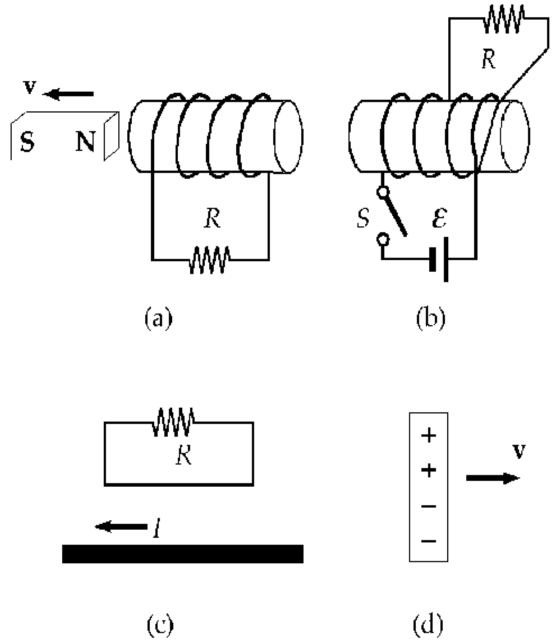
The long wire produces magnetic flux into the page through the rectangle, shown by the first hand in the figure to the right.

As the magnetic flux increases, the rectangle produces its own magnetic field out of the page, which it does by carrying $\boxed{\text{counterclockwise}}$ current (second hand in the figure).

***23.7** $$|\mathcal{E}| = \left|\frac{\Delta \Phi_B}{\Delta t}\right| = N\left(\frac{dB}{dt}\right) A = N(0.0100 + 0.0800t) A$$

At $t = 5.00$ s, $$|\mathcal{E}| = 30.0(0.410\ \text{T})\left[\pi(0.0400\ \text{m})^2\right] = \boxed{61.8\ \text{mV}}$$

23.9 (a) $\mathbf{B}_{ext} = B_{ext}\mathbf{i}$ and B_{ext} decreases; therefore, the induced field is $\mathbf{B}_0 = B_0\mathbf{i}$ (to the right) and the current in the resistor is directed $\boxed{\text{to the right}}$.



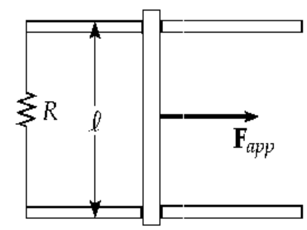
(b) $\mathbf{B}_{ext} = B_{ext}(-\mathbf{i})$ increases; therefore, the induced field $\mathbf{B}_0 = B_0(+\mathbf{i})$ is to the right, and the current in the resistor is directed $\boxed{\text{to the right}}$.

(c) $\mathbf{B}_{ext} = B_{ext}(-\mathbf{k})$ into the paper and B_{ext} decreases; therefore, the induced field is $\mathbf{B}_0 = B_0(-\mathbf{k})$ into the paper, and the current in the resistor is directed $\boxed{\text{to the right}}$

(d) By the magnetic force law, $F_B = q(\mathbf{v}\times\mathbf{B})$. Therefore, a positive charge will move to the top of the bar if $\mathbf{B}$ is $\boxed{\text{into the paper}}$.

23.10 $I = \dfrac{\mathcal{E}}{R} = \dfrac{B\ell v}{R}$

$\boxed{v = 1.00\ \text{m/s}}$



23.12 $F_B = I\ell B$ and $\mathcal{E} = B\ell v$

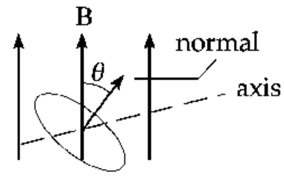
$I = \dfrac{\mathcal{E}}{R} = \dfrac{B\ell v}{R}$ so $B = \dfrac{IR}{\ell v}$

(a) $F_B = \dfrac{I^2\ell R}{\ell v}$ and $I = \sqrt{\dfrac{F_B v}{R}} = \boxed{0.500\ \text{A}}$

(b) $I^2R = \boxed{2.00\ \text{W}}$

(c) For constant force, $\mathcal{P} = \mathbf{F}\cdot\mathbf{v} = (1.00\ \text{N})(2.00\ \text{m/s}) = \boxed{2.00\ \text{W}}$

23.19 (a) $\mathcal{E}_{max} = NAB\omega = (1000)(0.100)(0.200)(120\pi) = \boxed{7.54\text{ kV}}$



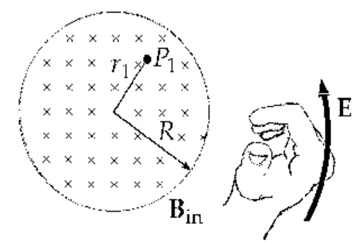
(b) $\mathcal{E}(t) = NBA\omega \cdot \sin\omega t = NBA\omega\sin\theta$

$|\mathcal{E}|$ is maximal when $|\sin\theta| = 1$

or $\theta = \pm\frac{\pi}{2}$

so the $\boxed{\text{plane of coil is parallel to } \mathbf{B}}$

23.21 $\frac{dB}{dt} = 0.0600t$ $\quad |\mathcal{E}| = \frac{d\Phi_B}{dt} = \pi r_1^2 \frac{dB}{dt} = 2\pi r_1 E$



At $t = 3.00$ s,

$$E = \left(\frac{\pi r_1^2}{2\pi r_1}\right)\frac{dB}{dt} = \frac{0.0200\text{ m}}{2}(0.0600\text{ T/s}^2)(3.00\text{ s})\left(\frac{1\text{ N}\cdot\text{s}}{1\text{ T}\cdot\text{C}\cdot\text{m}}\right)$$

$\mathbf{E} = \boxed{1.80\times10^{-3}\text{ N/C perpendicular to } r_1 \text{ and counterclockwise}}$

23.47 We are given $\quad \Phi_B = (6.00t^3 - 18.0t^2)\text{ T}\cdot\text{m}^2$

and $\quad \mathcal{E} = -\frac{d\Phi_B}{dt} = -18.0t^2 + 36.0t$

Maximum $\mathcal{E}$ occurs when $\quad \frac{d\mathcal{E}}{dt} = -36.0t + 36.0 = 0$

which gives $\quad t = 1.00$ s

Therefore, the maximum current (at $t = 1.00$ s) is $\quad I = \frac{\mathcal{E}}{R} = \frac{(-18.0 + 36.0)\text{ V}}{3.00\ \Omega} = \boxed{6.00\text{ A}}$

***23.51** $I = \frac{\mathcal{E}}{R} = \frac{B}{R}\frac{|\Delta A|}{\Delta t}$

so $\quad q = I\Delta t = \frac{(15.0\ \mu\text{T})(0.200\text{ m})^2}{0.500\ \Omega} = \boxed{1.20\ \mu\text{C}}$