13. **Un alambre con una masa por unidad de longitud de**

29.13 $F_B = ILB\sin\theta$ with $F_B = F_g = mg$

$mg = ILB\sin\theta$ so $\frac{m}{L}g = IB\sin\theta$

$I = 2.00\text{ A}$ and $\frac{m}{L} = (0.500\text{ g/cm})\left(\frac{100\text{ cm/m}}{1000\text{ g/kg}}\right) = 5.00\times10^{-2}\text{ kg/m}$

Thus $(5.00\times10^{-2})(9.80) = (2.00)B\sin 90.0°$

$B = \boxed{0.245\text{ Tesla}}$ with the direction given by right-hand rule: $\boxed{\text{eastward}}$

Un alambre de 2.80 m de longitud conduce una corrien-

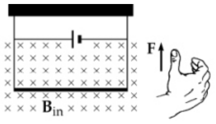
29.15 (a) $F_B = ILB\sin\theta = (5.00\text{ A})(2.80\text{ m})(0.390\text{ T})\sin 60.0° = \boxed{4.73\text{ N}}$

(b) $F_B = (5.00\text{ A})(2.80\text{ m})(0.390\text{ T})\sin 90.0° = \boxed{5.46\text{ N}}$

(c) $F_B = (5.00\text{ A})(2.80\text{ m})(0.390\text{ T})\sin 120° = \boxed{4.73\text{ N}}$

Un conductor suspendido por dos alambres flexibles, co-

29.16 $\frac{|\mathbf{F}_B|}{L} = \frac{mg}{L} = \frac{I|\mathbf{L}\times\mathbf{B}|}{L}$



$I = \frac{mg}{BL} = \frac{(0.0400\text{ kg/m})(9.80\text{ m/s}^2)}{3.60\text{ T}} = \boxed{0.109\text{ A}}$

The direction of I in the bar is $\boxed{\text{to the right}}$.

Suponga un alambre uniforme muy largo que tiene una

29.17 The magnetic and gravitational forces must balance. Therefore, it is necessary to have $F_B = BIL = mg$, or $I = (mg/BL) = (\lambda g/B)$ [λ is the mass per unit length of the wire].

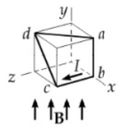
Thus, $I = \frac{(1.00\times10^{-3}\text{ kg/m})(9.80\text{ m/s}^2)}{(5.00\times10^{-5}\text{ T})} = \boxed{196\text{ A}}$ (if $B = 50.0\ \mu\text{T}$)

The required direction of the current is $\boxed{\text{eastward}}$, since East × North = Up.

En la figura P29.18 el cubo mide 40.0 cm en cada lado.

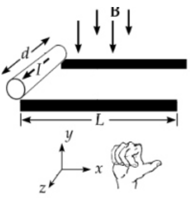
29.18 For each segment, $I = 5.00\text{ A}$ and $\mathbf{B} = 0.0200\text{ N/A}\cdot\text{m}\,\mathbf{j}$

Segment	$\mathbf{L}$	$\mathbf{F}_B = I(\mathbf{L}\times\mathbf{B})$
ab	$-0.400\text{ m}\,\mathbf{j}$	$\boxed{0}$
bc	$0.400\text{ m}\,\mathbf{k}$	$\boxed{(40.0\text{ mN})(-\mathbf{i})}$
cd	$-0.400\text{ m}\,\mathbf{i} + 0.400\text{ m}\,\mathbf{j}$	$\boxed{(40.0\text{ mN})(-\mathbf{k})}$
da	$0.400\text{ m}\,\mathbf{i} - 0.400\text{ m}\,\mathbf{k}$	$\boxed{(40.0\text{ mN})(\mathbf{k}+\mathbf{i})}$



Problema de repaso. Una barra de 0.720 kg de masa y

29.19 The rod feels force $\mathbf{F}_B = I(\mathbf{d}\times\mathbf{B}) = Id(\mathbf{k})\times B(-\mathbf{j}) = IdB(\mathbf{i})$



The work-energy theorem is $(K_{\text{trans}} + K_{\text{rot}})_i + \Delta E = (K_{\text{trans}} + K_{\text{rot}})_f$

$0 + 0 + Fs\cos\theta = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$IdBL\cos 0° = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{1}{2}mR^2\right)\left(\frac{v}{R}\right)^2$ and $IdBL = \frac{3}{4}mv^2$

$v = \sqrt{\frac{4IdBL}{3m}} = \sqrt{\frac{4(48.0\text{ A})(0.120\text{ m})(0.240\text{ T})(0.450\text{ m})}{3(0.720\text{ kg})}} = \boxed{1.07\text{ m/s}}$

Problema de repaso. Una barra de masa *m* y radio *R*

29.20 The rod feels force $\mathbf{F}_B = I(\mathbf{d}\times\mathbf{B}) = Id(\mathbf{k})\times B(-\mathbf{j}) = IdB(\mathbf{i})$

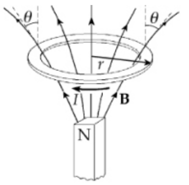
The work-energy theorem is $(K_{\text{trans}} + K_{\text{rot}})_i + \Delta E = (K_{\text{trans}} + K_{\text{rot}})_f$

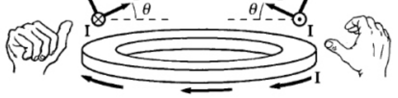
$0 + 0 + Fs\cos\theta = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$IdBL\cos 0° = \frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{1}{2}mR^2\right)\left(\frac{v}{R}\right)^2$ and $v = \boxed{\sqrt{\frac{4IdBL}{3m}}}$

Un campo magnético no uniforme ejerce una fuerza neta sobre

29.21 The magnetic force on each bit of ring is $I\,d\mathbf{s}\times\mathbf{B} = I\,ds\,B$ radially inward and upward, at angle θ above the radial line. The radially inward components tend to squeeze the ring but all cancel out as forces. The upward components $I\,ds\,B\sin\theta$ all add to $\boxed{I\,2\pi rB\sin\theta\text{ up}}$.





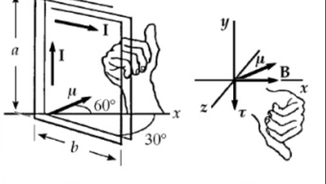
Una espira rectangular consta de $N = 100$ vueltas enro-

29.25 $\tau = NBAI\sin\theta$

$\tau = 100(0.800\text{ T})(0.400\times0.300\text{ m}^2)(1.20\text{ A})\sin 60°$

$\tau = \boxed{9.98\text{ N}\cdot\text{m}}$

Note that θ is the angle between the magnetic moment and the B field. The loop will rotate so as to align the magnetic moment with the B field. Looking down along the y-axis, the loop will rotate in a $\boxed{\text{clockwise}}$ direction.



(a) (b)

Un ion positivo con una sola carga tiene una masa de

29.32 (a) $\frac{1}{2}mv^2 = q(\Delta V)$ $\qquad \frac{1}{2}(3.20\times10^{-26}\text{ kg})\,v^2 = (1.60\times10^{-19}\text{ C})(833\text{ V})$ $\qquad v = 91.3\text{ km/s}$

The magnetic force provides the centripetal force: $qvB\sin\theta = \dfrac{mv^2}{r}$

$$r = \frac{mv}{qB\sin 90.0^\circ} = \frac{(3.20\times10^{-26}\text{ kg})(9.13\times10^4\text{ m/s})}{(1.60\times10^{-19}\text{ C})(0.920\text{ N}\cdot\text{s/C}\cdot\text{m})} = \boxed{1.98\text{ cm}}$$

Un protón (carga $+e$, masa m_p), un deuterón (carga $+e$,

29.35 $q(\Delta V) = \frac{1}{2}mv^2$ or $v = \sqrt{\dfrac{2q(\Delta V)}{m}}$

Also, $qvB = \dfrac{mv^2}{r}$ so $r = \dfrac{mv}{qB} = \dfrac{m}{qB}\sqrt{\dfrac{2q(\Delta V)}{m}} = \sqrt{\dfrac{2m(\Delta V)}{qB^2}}$

Therefore, $r_p^2 = \dfrac{2m_p(\Delta V)}{eB^2}$

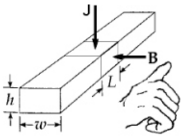
$$r_d^2 = \frac{2m_d(\Delta V)}{q_dB^2} = \frac{2(2m_p)(\Delta V)}{eB^2} = 2\left(\frac{2m_p(\Delta V)}{eB^2}\right) = 2r_p^2$$

and $$r_\alpha{}^2 = \frac{2m_\alpha(\Delta V)}{q_\alpha B^2} = \frac{2(4m_p)(\Delta V)}{(2e)B^2} = 2\left(\frac{2m_p(\Delta V)}{eB^2}\right) = 2r_p{}^2$$

The conclusion is: $\boxed{r_\alpha = r_d = \sqrt{2}\,r_p}$

El sodio se funde a 99°C. El sodio líquido, un excelente

29.55 (a) The $\boxed{\text{electric current experiences a magnetic force}}$.



$I(\mathbf{h}\times\mathbf{B})$ in the direction of $\mathbf{L}$.

(b) The sodium, consisting of ions and electrons, flows along the pipe transporting no net charge. But inside the section of length L, electrons drift upward to constitute downward electric current $\mathbf{J}\times(\text{area}) = \mathbf{J}Lw$.

The current then feels a magnetic force $I|\mathbf{h}\times\mathbf{B}| = JLwhB\sin 90^\circ$

This force along the pipe axis will make the fluid move, exerting pressure

$$\frac{F}{\text{area}} = \frac{JLwhB}{hw} = \boxed{JLB}$$

Una barra metálica con una masa por unidad de longi-

29.63 Call the length of the rod L and the tension in each wire alone $T/2$. Then, at equilibrium:

$\Sigma F_x = T\sin\theta - ILB\sin 90.0^0 = 0$ or $T\sin\theta = ILB$

$\Sigma F_y = T\cos\theta - mg = 0,$ or $T\cos\theta = mg$

Therefore, $\tan\theta = \dfrac{ILB}{mg} = \dfrac{IB}{(m/L)g}$ or $B = \dfrac{(m/L)g}{I}\tan\theta$

$$B = \frac{(0.0100\text{ kg/m})(9.80\text{ m/s}^2)}{5.00\text{ A}}\tan(45.0^\circ) = \boxed{19.6\text{ mT}}$$

64. Una barra metálica con una masa por unidad de longitud μ conduce una corriente I. La barra cuelga de dos

29.64 Call the length of the rod L and the tension in each wire alone $T/2$. Then, at equilibrium:

$\Sigma F_x = T\sin\theta - ILB\sin 90.0^0 = 0$ or $T\sin\theta = ILB$

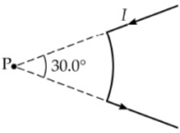
$\Sigma F_y = T\cos\theta - mg = 0,$ or $T\cos\theta = mg$

$\tan\theta = \dfrac{ILB}{mg} = \dfrac{IB}{(m/L)g}$ or $B = \dfrac{(m/L)g}{I}\tan\theta = \boxed{\dfrac{\mu g}{I}\tan\theta}$

Una trayectoria de corriente con la forma mostrada en la figura P30.2 produce un campo magnético en P, el

*30.2 We use the Biot-Savart law. For bits of wire along the straight-line sections, ds is at 0° or 180° to ~, so $ds \times \sim = 0$. Thus, only the curved section of wire contributes to B at P. Hence, ds is tangent to the arc and ~ is radially inward; so $ds \times \sim = |ds|\ 1 \sin 90° = |ds|\ \otimes$. All points along the curve are the same distance $r = 0.600$ m from the field point, so

$$B = \int_{\text{all current}} |dB| = \int \frac{\mu_0}{4\pi}\frac{I|ds \times \sim|}{r^2} = \frac{\mu_0}{4\pi}\frac{I}{r^2}\int |ds| = \frac{\mu_0}{4\pi}\frac{I}{r^2}\ s$$



where s is the arclength of the curved wire,

$$s = r\theta = (0.600\text{ m})30.0°\left(\frac{2\pi}{360°}\right) = 0.314\text{ m}$$

$$\text{Then, } B = \left(10^{-7}\frac{\text{T}\cdot\text{m}}{\text{A}}\right)\frac{(3.00\text{ A})}{(0.600\text{ m})^2}(0.314\text{ m})$$

$$B = \boxed{261\text{ nT into the page}}$$

a) Un conductor en forma de un cuadrado de longitud de lado $\ell = 0.400$ m conduce una corriente $I = 10.0$ A

30.3 (a) $B = \frac{4\mu_0 I}{4\pi a}\left(\cos\frac{\pi}{4} - \cos\frac{3\pi}{4}\right)$ where $a = \frac{1}{2}$

is the distance from any side to the center.

$$B = \frac{4.00 \times 10^{-6}}{0.200}\left(\frac{\sqrt{2}}{2} + \frac{\sqrt{2}}{2}\right) = 2\sqrt{2} \times 10^{-5}\text{ T} = \boxed{28.3\ \mu\text{T into the paper}}$$

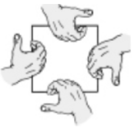


Figure for Goal Solution

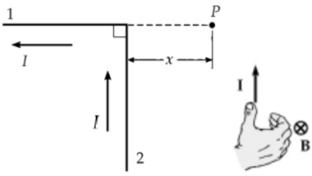
(b) For a single circular turn with $4 1 = 2\pi R$,

$$B = \frac{\mu_0 I}{2R} = \frac{\mu_0 \pi I}{4 1} = \frac{(4\pi^2 \times 10^{-7})(10.0)}{4(0.400)} = \boxed{24.7\ \mu\text{T into the paper}}$$

Determine el campo magnético en un punto P localizado a una distancia x de la esquina de un alambre infini-

30.5 For leg 1, $ds \times \sim = 0$, so there is no contribution to the field from this segment. For leg 2, the wire is only semi-infinite; thus,

$$B = \frac{1}{2}\left(\frac{\mu_0 I}{2\pi x}\right) = \boxed{\frac{\mu_0 I}{4\pi x}\text{ into the paper}}$$



Un conductor consiste de una espira circular de radio $R = 0.100$ m y de dos largas secciones rectas, como se mues-

30.7 We can think of the total magnetic field as the superposition of the field due to the long straight wire (having magnitude $\mu_0 I/2\pi R$ and directed into the page) and the field due to the circular loop (having magnitude $\mu_0 I/2R$ and directed into the page). The resultant magnetic field is:

$$B = \left(1 + \frac{1}{\pi}\right)\frac{\mu_0 I}{2R} = \left(1 + \frac{1}{\pi}\right)\frac{(4\pi \times 10^{-7}\text{ T}\cdot\text{m}/\text{A})(7.00\text{ A})}{2(0.100\text{ m})} = 5.80 \times 10^{-5}\text{ T}$$

or $\boxed{B = 58.0\ \mu\text{T}\quad\text{(directed into the page)}}$

Un conductor consta de una espira circular de radio R y dos largas secciones rectas, como se ve en la figura P30.7.

30.8 We can think of the total magnetic field as the superposition of the field due to the long straight wire (having magnitude $\mu_0 I/2\pi R$ and directed into the page) and the field due to the circular loop (having magnitude $\mu_0 I/2R$ and directed into the page). The resultant magnetic field is:

$$\boxed{B = \left(1 + \frac{1}{\pi}\right)\frac{\mu_0 I}{2R}\ \text{(directed into the page)}}$$

Considere la espira que conduce corriente mostrada en la figura P30.11, formada de líneas radiales y segmentos

30.11 $$dB = \frac{\mu_0 I}{4\pi}\frac{|d1 \times \sim|}{r^2}$$

$$B = \frac{\mu_0 I}{4\pi}\left(\frac{\frac{1}{6}2\pi a}{a^2} - \frac{\frac{1}{6}2\pi b}{b^2}\right)$$

$$B = \boxed{\frac{\mu_0 I}{12}\left(\frac{1}{a} - \frac{1}{b}\right)\text{ directed out of the paper}}$$

Determine el campo magnético (en términos de I, a y d) en el origen debido a la espira de corriente mostrada en

30.12 Apply Equation 30.4 three times:

$$B = \frac{\mu_0 I}{4\pi a}\left(\cos 0 - \frac{d}{\sqrt{d^2 + a^2}}\right)\text{ toward you}$$

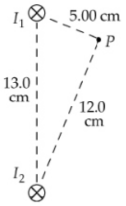
$$+ \frac{\mu_0 I}{4\pi d}\left(\frac{a}{\sqrt{d^2 + a^2}} + \frac{a}{\sqrt{d^2 + a^2}}\right)\text{ away from you}$$

$$+ \frac{\mu_0 I}{4\pi a}\left(\frac{-d}{\sqrt{d^2 + a^2}} - \cos 180°\right)\text{ toward you}$$

$$B = \boxed{\frac{\mu_0 I\left(a^2 + d^2 - d\sqrt{a^2 + d^2}\right)}{2\pi a d\sqrt{a^2 + d^2}}\text{ away from you}}$$

Dos largos conductores paralelos conducen las corrien-
tes I_1 = 3.00 A e I_2 = 3.00 A, ambas dirigidas hacia aden-

30.15 Take the x-direction to the right and the y-direction up in the plane of the paper. Current 1 creates at P a field



$$B_1 = \frac{\mu_0 I}{2\pi a} = \frac{(2.00\times 10^{-7}\ \mathrm{T\cdot m})(3.00\ \mathrm{A})}{\mathrm{A}(0.0500\ \mathrm{m})}$$

$\mathbf{B}_1 = 12.0\ \mu\mathrm{T}$ downward and leftward, at angle 67.4° below the $-x$ axis.

Current 2 contributes

$$B_2 = \frac{(2.00\times 10^{-7}\ \mathrm{T\cdot m})(3.00\ \mathrm{A})}{\mathrm{A}(0.120\ \mathrm{m})}$$ clockwise perpendicular to 12.0 cm

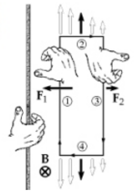
$\mathbf{B}_2 = 5.00\ \mu\mathrm{T}$ to the right and down, at angle $-22.6°$

Then, $\mathbf{B} = \mathbf{B}_1 + \mathbf{B}_2 = (12.0\ \mu\mathrm{T})(-\mathbf{i}\cos 67.4° - \mathbf{j}\sin 67.4°) + (5.00\ \mu\mathrm{T})(\mathbf{i}\cos 22.6° - \mathbf{j}\sin 22.6°)$

$$\mathbf{B} = (-11.1\ \mu\mathrm{T})\mathbf{j} - (1.92\ \mu\mathrm{T})\mathbf{j} = \boxed{(-13.0\ \mu\mathrm{T})\mathbf{j}}$$

En la figura P30.17 la corriente en el largo alambre rec-
to es I_1 = 5.00 A y el alambre se ubica en el plano de la

30.17 By symmetry, we note that the magnetic forces on the top and bottom segments of the rectangle cancel. The net force on the vertical segments of the rectangle is (using Equation 30.12)

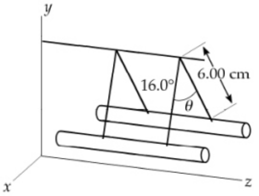


$$\mathbf{F}_B = \frac{\mu_0 I_1 I_2 1}{2\pi}\left(\frac{1}{c+a} - \frac{1}{c}\right)\mathbf{i}$$

Substituting given values $\mathbf{F}_B = -2.70\times 10^{-5}\ \mathbf{i}\ \mathrm{N} = \boxed{-27.0\ \mu\mathrm{N}\ \mathbf{i}}$

La unidad de flujo magnético debe su nombre a Wil-
helm Weber. La magnitud práctica de la unidad del cam-

30.18 The separation between the wires is



$a = 2(6.00\ \mathrm{cm})\sin 8.00° = 1.67\ \mathrm{cm}$.

(a) Because the wires repel, the currents are in

$\boxed{\text{opposite directions}}$.

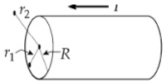
(b) Because the magnetic force acts horizontally,

$$\frac{F_B}{F_g} = \frac{\mu_0 I^2 1}{2\pi a\ mg} = \tan 8.00°$$

$$I^2 = \frac{mg\ 2\pi a}{1\ \mu_0}\tan 8.00° \quad \text{so} \quad I = \boxed{67.8\ \mathrm{A}}$$

Un largo conductor cilíndrico de radio R conduce una
corriente I, como se muestra en la figura P30.27. Sin em-

30.27 Use Ampère's law, $\oint \mathbf{B}\cdot d\mathbf{s} = \mu_0 I$. For current density $\mathbf{J}$, this becomes



$$\oint \mathbf{B}\cdot d\mathbf{s} = \mu_0\int \mathbf{J}\cdot d\mathbf{A}$$

(a) For $r_1 < R$, this gives

$$2\pi r_1 = \mu_0\int_0^{r_1}(br)(2\pi r\ dr) \quad \text{and}$$

$$B = \boxed{\frac{\mu_0 b r_1^2}{3} \quad (\text{for } r_1 < R \text{ or inside the cylinder})}$$

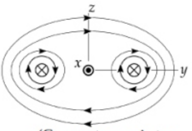
(b) When $r_2 > R$, Ampère's law yields

$$(2\pi r_2)B = \mu_0\int_0^R (br)(2\pi r\ dr) = 2\pi\mu_0 b R^3/3,$$

or $$B = \boxed{\frac{\mu_0 b R^3}{3r_2} \quad (\text{for } r_2 > R \text{ or outside the cylinder})}$$

En la figura P30.28, ambas corrientes están en la direc-
ción x negativa. a) Dibuje el patrón de campo magnéti-

30.28 (a) See Figure (a) to the right.



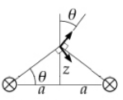
(Currents are into the paper)

Figure (a)

(b) At a point on the z axis, the contribution from each wire has magnitude $B = \dfrac{\mu_0 I}{2\pi\sqrt{a^2+z^2}}$ and is perpendicular to the line from this point to the wire as shown in Figure (b). Combining fields, the vertical components cancel while the horizontal components add, yielding

$$B_y = 2\left(\frac{\mu_0 I}{2\pi\sqrt{a^2+z^2}}\sin\theta\right) = \frac{\mu_0 I}{\pi\sqrt{a^2+z^2}}\left(\frac{z}{\sqrt{a^2+z^2}}\right) = \frac{\mu_0 I z}{\pi(a^2+z^2)}$$

The condition for a maximum is:



At a distance z above the plane of the conductors

Figure (b)

$$\frac{dB_y}{dz} = \frac{-\mu_0 I z(2z)}{\pi(a^2+z^2)^2} + \frac{\mu_0 I}{\pi(a^2+z^2)} = 0, \quad \text{or} \quad \frac{\mu_0 I}{\pi}\frac{(a^2-z^2)}{(a^2+z^2)^2} = 0$$

Thus, along the z axis, the field is a maximum at $\boxed{d = a}$.