Q1 The force is the interaction between the magnet's field and the eddy currents induced in the plate via electromagnetic induction. See Fig. 29–19b, where it's clear that there is a retarding force exerted on the moving plate/disk. The induced emf is proportional to the rate of change of magnetic flux through the plate, so the faster you change that flux, the larger will be the induced emf and thus induced current.

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2 First the lines go through at the best possible angle. $\Phi_B = \vec{B}\cdot\vec{A} = BA\cos 0° = (6\times10^{-5}\text{T})(12\times10^{-4}\text{m}^2) = 7.2\times10^{-8}\text{T}\cdot\text{m}^2$. Afterward they "go through" at the worst: $\Phi_B = \vec{B}\cdot\vec{A} = B\ A\cos 90° = 0$. Per loop,

$\overline{\mathcal{E}} = \frac{\Delta\Phi_B}{\Delta t} = \frac{7.2\times10^{-8}\text{T}\cdot\text{m}^2}{0.04\text{s}} = 1.8\times10^{-6}\text{V}$. Each, in series, develops the same emf. $1.8\times10^{-6}\text{V}\cdot200 = 0.36\text{mV}$

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18 The B–field in winding A is *to the left and increasing*, inducing current in Winding B to produce it's own field *to the right*, meaning current right to left through R.
(b) Winding A field is *to right and decreasing* ⇒ Winding B field is to right, meaning current in R right to left
(c) Winding A field is *to right and increasing* ⇒ Winding B field is to left, meaning current in R left to right

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25 $\mathcal{E} = B\ \ell\ v = (0.8\text{T})(0.5\text{m})(7.5\text{m/s}) = 3\text{V}$. (b) Magnetic forces on charge carriers in rod is toward end *a*, so it is the positive terminal of the battery, and current flows from *b* to *a*. (Alternatively, Φ_B is into page and increasing, implying counterclock current flow in loop, to produce B out of page.) (c) $I = \mathcal{E}/R = 3\text{V}/(1.5\Omega) = 2\text{A}$. $F = I\ \ell\ B = (2\text{A})(0.5\text{m})(0.8\text{T}) = 0.8\text{N}$, to right. (d) $Fv = (0.8\text{N})(7.5\text{m/s}) = 6\text{W}$. $I^2R = (2\text{A})^2(1.5\Omega) = 6\text{W}$. They're equal, and they must be. Nothing else partakes of energy transfer. Work → electrical energy → heat.
[Note: Resistance could be constant only if top and bottom rails have essentially none––their lengths change!]

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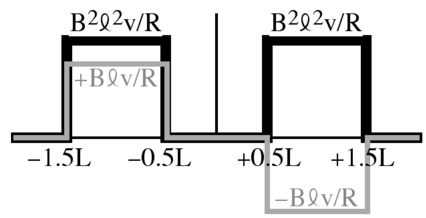
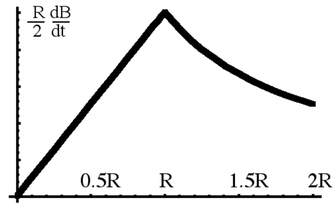
26 When the loop's center reaches −1.5L, an into–page flux begins to increase, and $\mathcal{E} = B\ dA/dt = B\ \ell\ v$. $I = \mathcal{E}/R = B\ell v/R$, and is counterclock, to produce its own B out of the page, opposing the change in Φ_B.
$F = I\ \ell\ B = B^2\ell^2v/R$. The magnetic force on the front segment (the one in the field) is to the left, requiring me to push to the right. Once it gets to x = −0.5L, the flux doesn't change (or, alternatively, the front and back



segments are both batteries, but "plus–to–plus", leading to no current flow). When it reaches x = +0.5L, the into–page flux begins to decrease, inducing current clockwise, to produce an into–page field. The magnetic force on the back segment (the one in the field) is again to the left, requiring me again to push to the right.

29 This investigates what a changing magnetic field *really* produces: an E–field. Yes, $\frac{d\Phi_B}{dt} = -\mathcal{E}$, but it's often better to think of this Law in a more fundamental form $\frac{d\Phi_B}{dt} = -\oint \vec{E}\cdot d\vec{\ell}$, and just remember that in many cases we don't really need to know E, so much as $\oint \vec{E}\cdot d\vec{\ell}$, which is $\mathcal{E}$. In this problem, we are asked for E. (a) The B–field is uniform, so $\frac{d\Phi_B}{dt} = \frac{d}{dt}\int \vec{B}\cdot d\vec{A} = \frac{d}{dt} B \int dA = \frac{d}{dt} B\ A = A\frac{dB}{dt} = \pi r_1^2 \frac{dB}{dt}$. (b) The induced E–field, as shown in Figure 29.17, is circular in character; it's what really drives the charges around. If we're centered inside a solenoid of circular cross–section, the *usual symmetry arguments must apply* for $\oint \vec{E}\cdot d\vec{\ell}$: It *has* to be $E2\pi r_1$. Setting this equal to the rate of change of flux gives $E = \frac{1}{2\pi r_1}\pi r_1^2 \frac{dB}{dt} = \frac{r_1}{2}\frac{dB}{dt}$. (c) $\oint \vec{E}\cdot d\vec{\ell}$ has to be $E2\pi r_2$, and the flux change rate is $\pi R^2 \frac{dB}{dt}$, for the field is strong and uniform everywhere inside, and negligible outside. Setting equal, $E = \frac{1}{2\pi r_2}\pi R^2 \frac{dB}{dt} = \frac{R^2}{2r_2}\frac{dB}{dt}$ (d) From the results, it increases linearly till $r = R$, then decreases as $1/r$ outside. (e–g) These *could* be answered if section 29.5 didn't exist, so it's a bit puzzling what they're doing here. $|\mathcal{E}| = \left|\frac{d\Phi_B}{dt}\right| = A\frac{dB}{dt}$ = (e) $\pi(R/2)^2 \frac{dB}{dt}$ (f) $\pi R^2 \frac{dB}{dt}$ (g) $\pi R^2 \frac{dB}{dt}$. Well, *if* you contended that $\mathcal{E}$ is $\oint \vec{E}\cdot d\vec{\ell}$ you'd have to multiply E by $2\pi r$ to get $\mathcal{E}$. Doing so would give exactly the same answers. The interesting thing is that they *do* agree. In one view, once you are outside the solenoid, the changing flux is entirely enclosed (the B–field being negligible outside), so the emf shouldn't vary with r. This is weird in the sense that there is no B–field, yet there would be an effect on charges in a wire. In the other view, there is something to push the charges: the induced E–field. It gets weaker ($\propto 1/r$), but $2\pi r$ gets bigger, and you reach the same conclusion, that $\oint \vec{E}\cdot d\vec{\ell}$, or $\mathcal{E}$, doesn't vary.



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61 Motional emf is $B\ell v$, but each little battery in the segment experiences a different B, for they're different distances from the wire. So adding means integrating. $\mathcal{E} = \int d\mathcal{E} = \int B(dy)v = \int_d^{d+L} \frac{\mu_o I}{2\pi y} dy\ v = \frac{\mu_o I v}{2\pi} \ln(\frac{L+d}{d})$, where the field for a long straight wire has been used. (b) B due to the wire is into the page, so the magnetic force on positive charge carriers is toward a. (c) The flux doesn't change through the loop as it moves––or, equivalently, the batteries in the front and back segments are "plus–to–plus"––so no current.

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69 $\oint \vec{E}\cdot d\vec{\ell} = \int_{bottom} \vec{E}\cdot d\vec{\ell} + \int_{top} \vec{E}\cdot d\vec{\ell} + \int_{sides} \vec{E}\cdot d\vec{\ell}$. The 1st integral is just EL. The 2nd, along the top, is zero, because by assumption the field is zero there. The 3rd is zero because the path is $\perp$ to $\vec{E}$. Thus, $\oint \vec{E}\cdot d\vec{\ell} = EL$. *But this path encloses no changing Φ_B*, so the circulation integral has to be zero. The contradiction. (Does this look familiar?!)