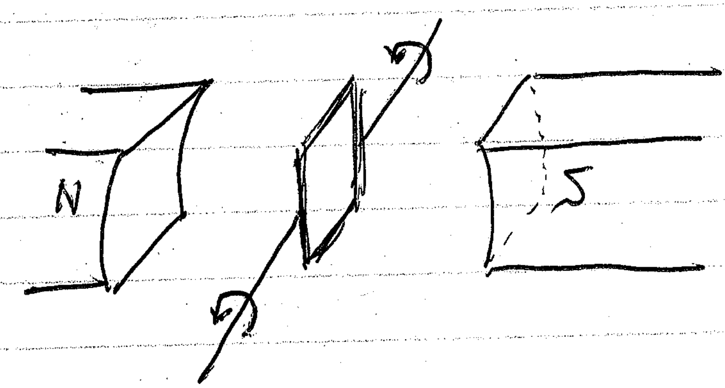
① Phys 1402 2016-10-18 Lec 16

Both "halves" of HW4 are posted.

AC Electricity

Origin: Alternator

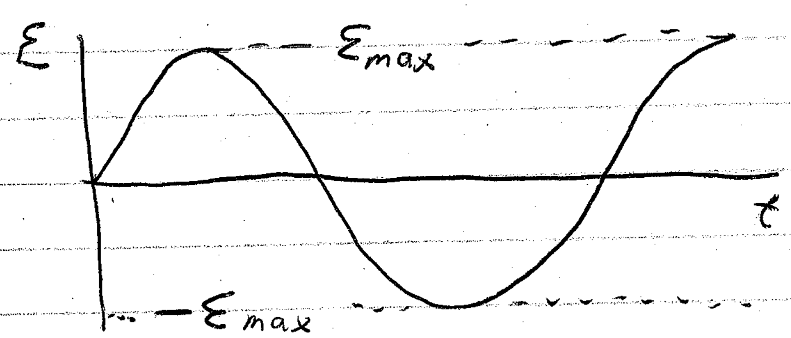


Spinning the coil generates voltage

Magnetic Flux maximum: $\Phi_B = NBA$

EMF Maximum: $\mathcal{E} = NBA\omega$

N = # loops
A = Area of coil
ω = rotational speed



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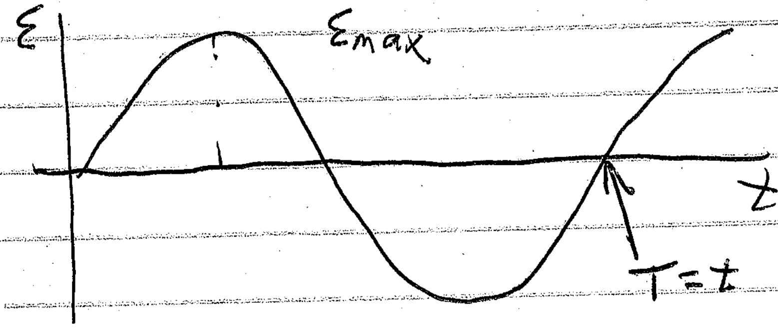


Looks like $\sin(\theta)$

$$\mathcal{E} = \mathcal{E}_{max} \sin(2\pi f t)$$

↑ Amplitude

$\sin(\theta)$ repeats every $\underline{2\pi}$ radians

$$\cancel{2\pi} = \cancel{2\pi} f T \quad \text{is a special time}$$

$$1 = fT$$

$T = 1/f$ is the time to repeat the oscillation

T = "Period" of osc.

In the US, we use AC electricity with $T = (1/60)\ s \approx 0.01667\ s$

Usually for "fast" signals, we give

$$f = 1/T$$

US AC Elec: $f = 60\ Hz = 60\ \frac{cycles}{s}$

US AC $\mathcal{E}_{max} = 170\ V$

③

How does AC Affect devices?

Resistors: Light bulbs, heaters, energy users.

Ohm's Law $V = IR$

① V is oscillating
② R is constant
∴ ③ I is oscillating

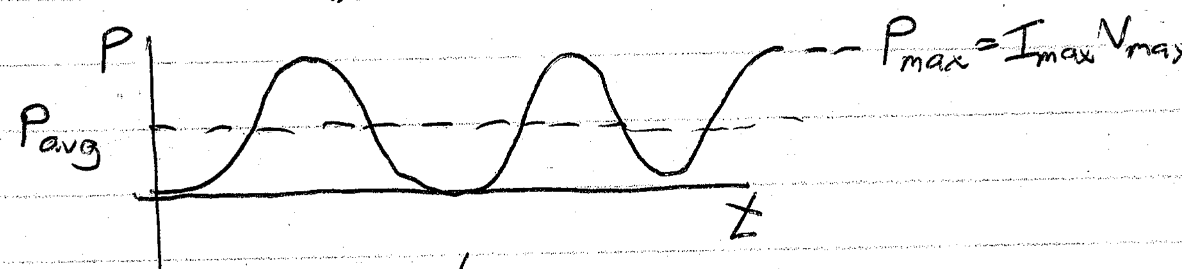
$$I = I_{max} \sin(2\pi f t)$$

$$V_{max} \sin(2\pi f t) = I_{max} \sin(2\pi f t) R$$

Conclusion: $V_{max} = I_{max} R$

Power of resistor

$$P = IV$$
$$= I_{max} V_{max} \sin^2(\sim)$$



On Average, the resistor uses

$$P_{avg} = \frac{1}{2} P_{max} = \frac{1}{2}(I_{max} V_{max})$$

$$= \frac{1}{2}(I_{max}^2 R)$$

For DC: $P = I^2 R$

Define I_{RMS} to build an AC equation
└ Root Mean Square

$$P_{avg} = I_{RMS}^2 R$$

How is this related to I_{max}?

$$I_{rms}^2 \cancel{R} = \frac{1}{2} I_{max}^2 \cancel{R}$$

$$I_{rms} = \frac{1}{\sqrt{2}} I_{max}$$

Why? Average power tells us long-term energy use.

$$P_{Avg} = \frac{Energy}{Time}$$

I_{rms} is an "effective" value of AC current.

The same is true for voltage.

$$V_{RMS} = \frac{1}{\sqrt{2}} V_{max} \qquad V_{RMS} = I_{RMS} R$$

For R: $P_{avg} = I_{rms} V_{rms}$

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Ex: 60 W Incandescent Light Bulb

Designed for US $V_{rms} = 120$ V

Current: $P_{avg} = I_{rms} V_{rms}$

$(60\text{ W}) = I_{rms}\ (120\text{ V})$

$0.5\text{A} = I_{rms}$

Resistance: $V_{rms} = I_{rms}\ R$

$(120\text{ V}) = (0.5\text{A})\ R$

$240\,\Omega = R$

I measured a light bulb and got $R = 60\,\Omega$.
Why? My measurement was <u>cold</u>.
Metals have more R at higher temperature.

Energy: Time = 1 month = 30 days = 720 hours
$= 2.6 \times 10^{6}$ s

Energy $= P_{avg}\,\Delta t = (60\text{ W})(2.6\times10^{6}\text{ s}) = 1.55\times10^{8}$ J

$= (0.060\text{ kW})(720\text{ hr}) = 43.2$ kWh

Cost: Cost = Rate · Amount = (\$0.12/kWh)(43.2 kWh)
= \$5.18

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Equivalent LED bulb uses

$9\ W = P_{avg}$

Cost : $(\$5.18)\dfrac{9}{60} = \$0.78$

Let's say you use it 6 hr/day.

$\Delta t = \frac{1}{4}$ of old value

Cheap Bulb : $(\$5.18)\left(\frac{1}{4}\right) = \$1.30$

LED Bulb : $= \$0.19$