

Levers, Gears, Torque, Horsepower

Part 14c of
“Electronics and Telecommunications”
A Fairfield University E-Course
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Section 14 Schedule

Session 14a	11/19	Intro to Applied Technical Mathematics	Notes: Binary/Octal/Hex, Powers of 10, Basic Algebra
Session 14b	11/24	DC & AC Motors	Elect1-7: pp. 7-39: 7-69, pp. 7-89: 7-117
Session 14c	11/26	Levers/gears, Torque/HP/RPM	Notes
Quiz 14 Review (Quiz 14 due 12/07)	12/01		
Quiz 14 Results	12/08		
MT8 (Sat,Cheshire)	12/13		
MT8 Results	12/15		

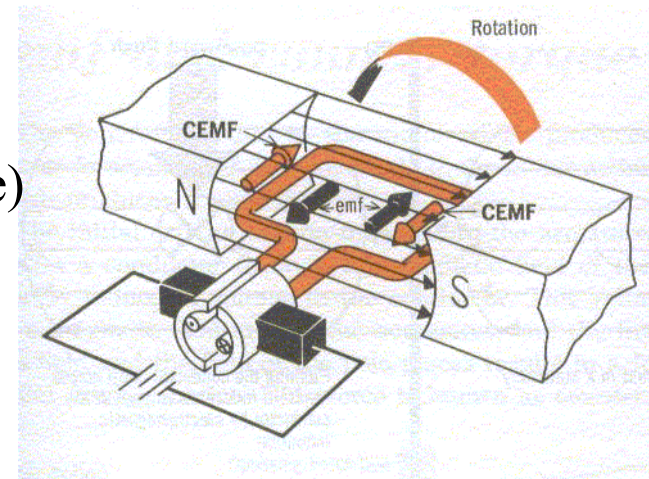
Section 14:

Applied Technical Mathematics

- Math review
 - Binary numbers (Hex and Octal)
 - Powers of ten
 - Working with equations
- DC & AC Motors and Generators
 - Simple relationships and vocabulary
- Levers and Gears
 - Relating linear force and motion to rotational torque and motion
 - $F=M*A$ vs $T=J*\alpha$
- Torque, RPM and Horsepower
 - Simple relationships and vocabulary

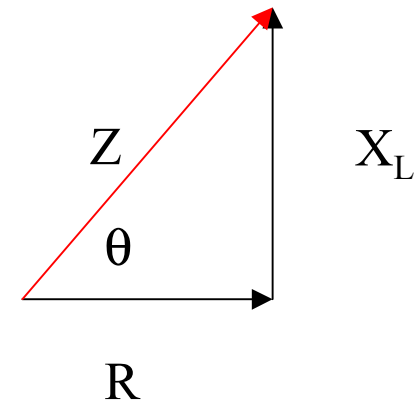
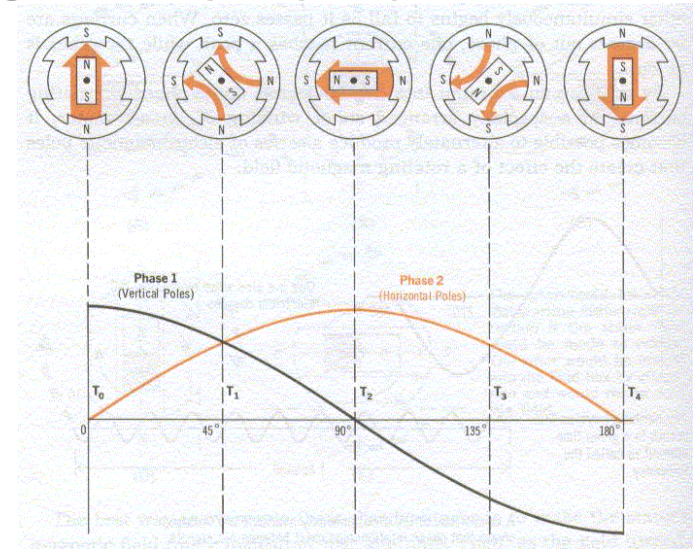
Last Time – 1: DC Motors/Generators

- Electro Motive Force (Voltage)
 - Applied EMF (armature battery voltage)
 - Counter EMF (Generated armature voltage)
- DC Motor / Generator
(Which one depends on power flow direction)
 - Operation
 - Armature spins in a magnetic field
 - Armature current causes rotational force (Motor action due to Applied EMF)
 - Rotation creates Counter EMF (CEMF – Generator Action)
 - DC Motor Facts
 - Steady-State Speed is approximately proportional to Applied EMF
 - Steady-State Armature current is whatever is required to provide the Power (736 Watts = one Horsepower) needed to turn the load at the Steady-State speed
 - There is a high starting current (locked rotor \Rightarrow overload)
 - If the magnetic field strength is increased, the CEMF increases and the motor slows down



Last Time – 2: AC Motors

- Rotating Field
 - Armature tries to stay aligned with the field
 - Armature aligns with field
- Characteristics
 - Guarantees rotational direction
 - Speed determined by frequency and the number of poles
- Coils (Armature and Field)
 - Resistance (R)
 - Inductance ($X_L = 2\pi fL$)
- Impedance ($Z = \vec{R} + \vec{X}_L$)
 - Length: $|Z| = \text{SQRT}(R^2 + X_L^2)$
 - Angle: $\theta = \text{ARCTAN}(X_L/R)$

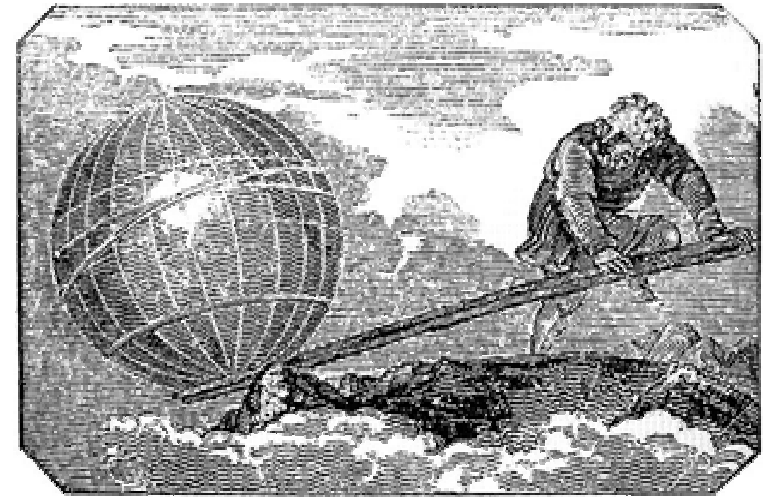


Last Time – 3: Equations

- $EMF = I * R$ (Ohms Law)
- $X_L = 2 * \pi * L$ (Inductive reactance, remember vectors)
- $Power = I * V$ (in Watts, I & V are RMS values)
(1 HP = 736 Watts)
- $cemf = V_{total} - (I_a * R_a) - (I_{field} * R_{field})$
(just Kirchoff, armature winding & field winding in series, same current in both windings)
- $T = (hp)(5252) / N_a$ ($N_a = \text{rev/min}$, T in ft-lbs)
- $Nm = (T) * 1Nm / 0.73756 \text{ lb-ft}$ (Nm = Newton-meter)
- $K_{emf} = cemf / (I_{field} * N_a)$ - the generator constant
- $Hp = (lb-ft) * (\text{rev/min}) / 5252$
- $Synchronous\ speed = 120 * \text{frequency} / \text{no. of poles}$

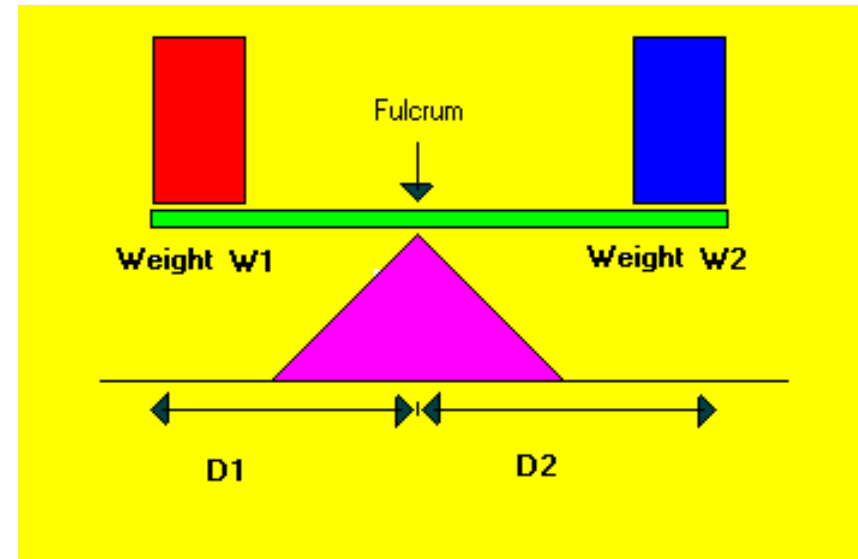
Levers and Torque

- $F^1 * D^1 = F^2 * D^2 = \text{Torque}$
- Torque units
 - Foot-Lbs
 - Newton-Meters
- Rotational acceleration
 - $T = J * \alpha$
 - J is “moment of inertia”
 - α is “angular acceleration”



ΔΟΣ ΜΟΙ ΠΟΥ ΣΤΩ ΚΑΙ ΚΙΝΩ ΤΗΝ ΓΗΝ
Give me where [to]stand and [I will]move the earth

Archimedes 340 AD



Gears

- Operation
 - Gears are mechanical transformers
 - $\text{RPM}_1 * R_1 = \text{RPM}_2 * R_2$
 - $T_1 / R_1 = T_2 / R_2$
 - You can use the number of teeth instead of the radius
- Belts and Pulleys work the same way as gears



Equations again

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Practice problem

A 24 volt, ½ HP, series connected, 1800 RPM, DC motor uses 20 amps at its rated output.

(This is all stated on the motor “Nameplate”)

- What is the CEMF if $R_a=0.1$ and $R_f = 0.2$

$$\text{cemf} = V_{\text{total}} - (I_a * R_a) - (I_{\text{field}} * R_{\text{field}})$$

$$\text{cemf} = 24 - (20 * 0.1) - (20 * 0.2)$$

$$\text{cemf} = 24 - 2 - 4 = 18 \text{ volts}$$

- What is the K_{emf} for this motor?

$$K_{\text{emf}} = \text{cemf} / (I_{\text{field}} * N_a)$$

$$K_{\text{emf}} = 18 / (20 * 1800) = 1/2000 = 0.0005 = 0.5 * 10^{-3}$$

- Find the Motor Efficiency and Torque

- Power in = $V * I = 24 * 20 = 480$
- Power out = $0.5 \text{ HP} = 0.5 * 736 \text{ (W/HP)} = 368 \text{ Watts}$
- Efficiency = $368/480 = \mathbf{0.77 \text{ or } 77\%}$
- Torque = $\text{HP} * 5252 / N_a = 0.5 * 5252 / 1800 = \mathbf{1.46 \text{ ft-lbs}}$
- Torque = $1.46 / 0.73756 = \mathbf{1.98 \text{ newton-meters}}$

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