Levers, Gears, Torque, Horsepower

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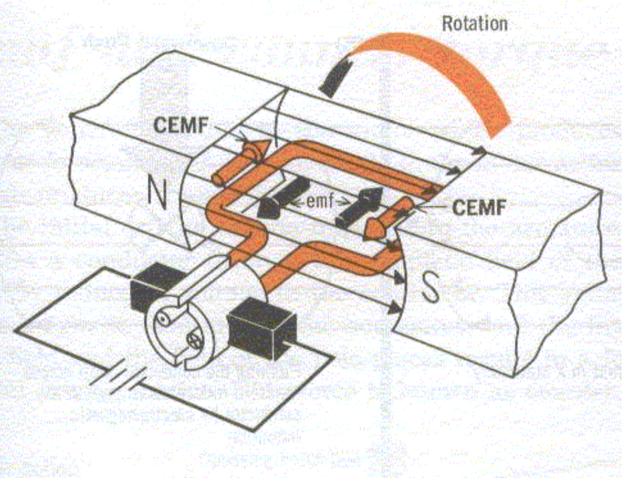
Section 14 Schedule

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

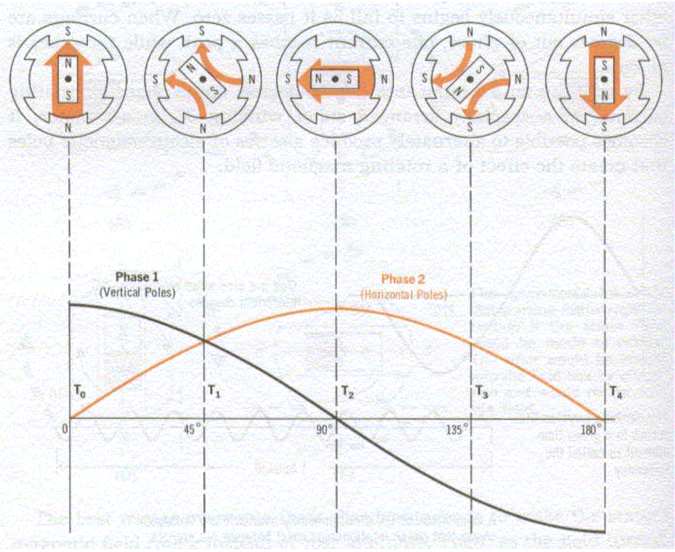
- Math review
  - Binary numbers (Hex and Octal)
  - Powers of ten
  - Working with equations
- DC & AC Motors and Generators
  - Simple relationships and vocabulary
- Levers and Gears
  - Relating linear force and motion to rotational torque and motion
  - $F=M*A$ vs $T=J*\alpha$
- Torque, RPM and Horsepower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

Last Time – 1: DC Motors/Generators

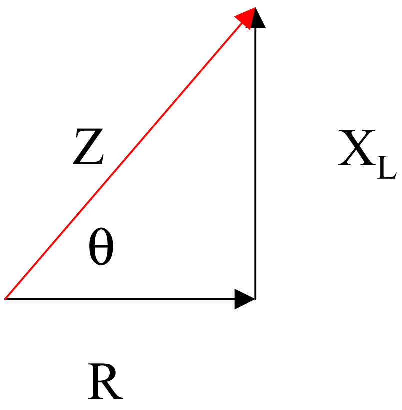


- Electro Motive Force (Voltage)
  - Applied EMF (armature battery voltage)
  - Counter EMF (Generated armature voltage)
- DC Motor / Generator
  (Which one depends on power flow direction)
  - Operation
    - Armature spins in a magnetic field
    - Armature current causes rotational force (Motor action 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 ⇒ 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 ($X_L = 2\pi f L$)
- Impedance ($Z = \vec{R} + \vec{X_L}$)
  - Length: $|Z| = \text{SQRT}(R^2 + X_L^2)$
  - Angle: $\theta = \text{ARCTAN}(X_L/R)$



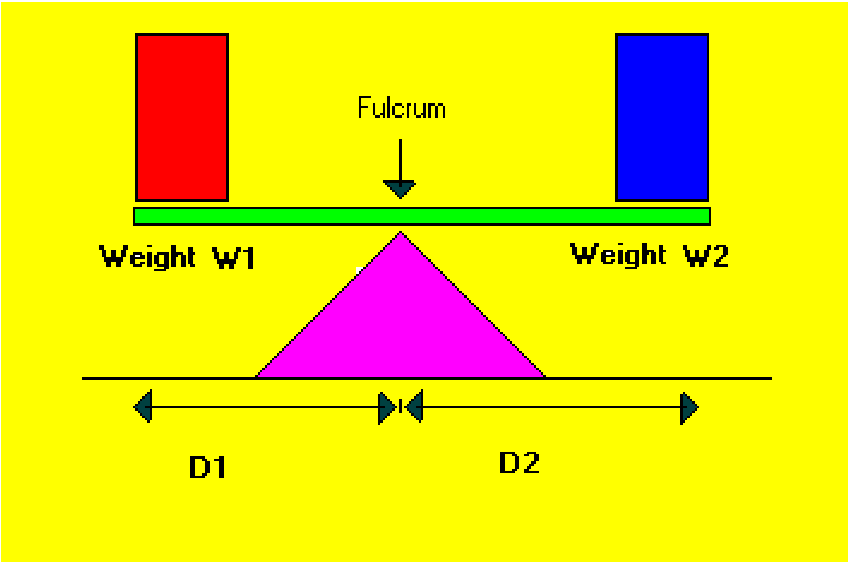
Last Time – 3: Equations

- 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)
- $cemf=V_{total}-(Ia*Ra)-(I_{field}*R_{field})$
  (just Kirchoff, armature winding & field winding in series, same current in both windings)
- T=(hp)(5252)/Na (Na=rev/min, T in ft-lbs)
- Nm=(T)*1Nm/0.73756 lb-ft (Nm =Newton-meter)
- Kemf=cemf/(Ifield*Na) - the generator constant
- Hp=(lb-ft)*(rev/min)/5252
- Synchronous speed=120*frequency/no. of poles

Levers and Torque

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

Archimedes 340 AD



Gears

- Operation
  - Gears are mechanical transformers
  - $RPM_1 * R_1 = RPM_2 * R_2$
  - $T_1 / R_1 = T_2 / R_2$
  - 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 Ra=0.1 and Rf = 0.2

    cemf=Vtotal-(Ia*Ra)-(Ifield*Rfield)
    cemf=24 – (20*0.1) – (20*0.2)
    cemf=24 – 2 – 4 = 18 volts

– What is the Kemf for this motor?

    Kemf=cemf/(Ifield*Na)
    Kemf=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 HP = 0.5 * 736 (W/HP) = 368 Watts
  - Efficiency = 368/480 = **0.77 or 77%**
  - Torque = HP*5252/Na = 0.5*5252/1800 = **1.46 ft-lbs**
  - Torque = 1.46/0.73756 = **1.98 newton-meters**

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