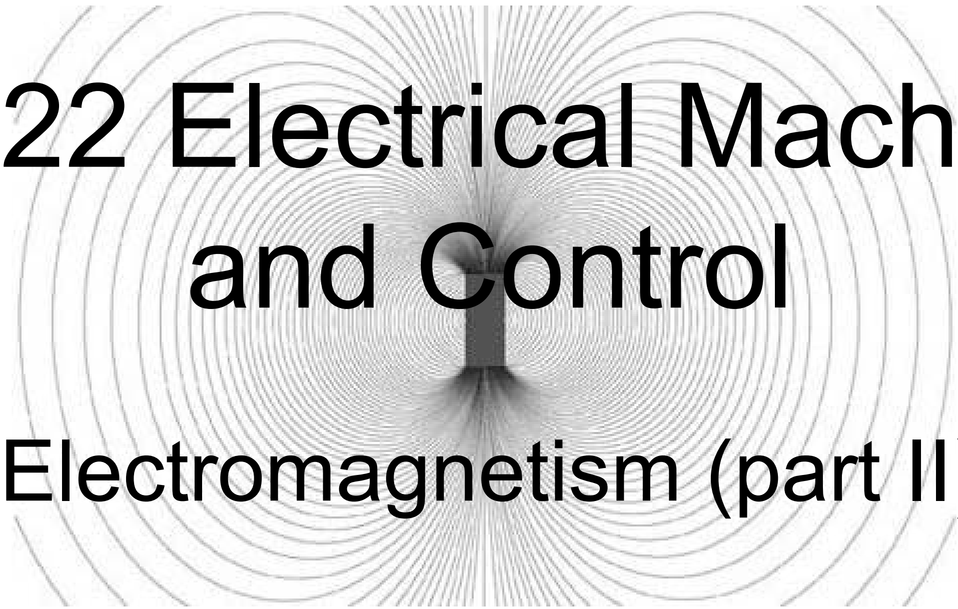
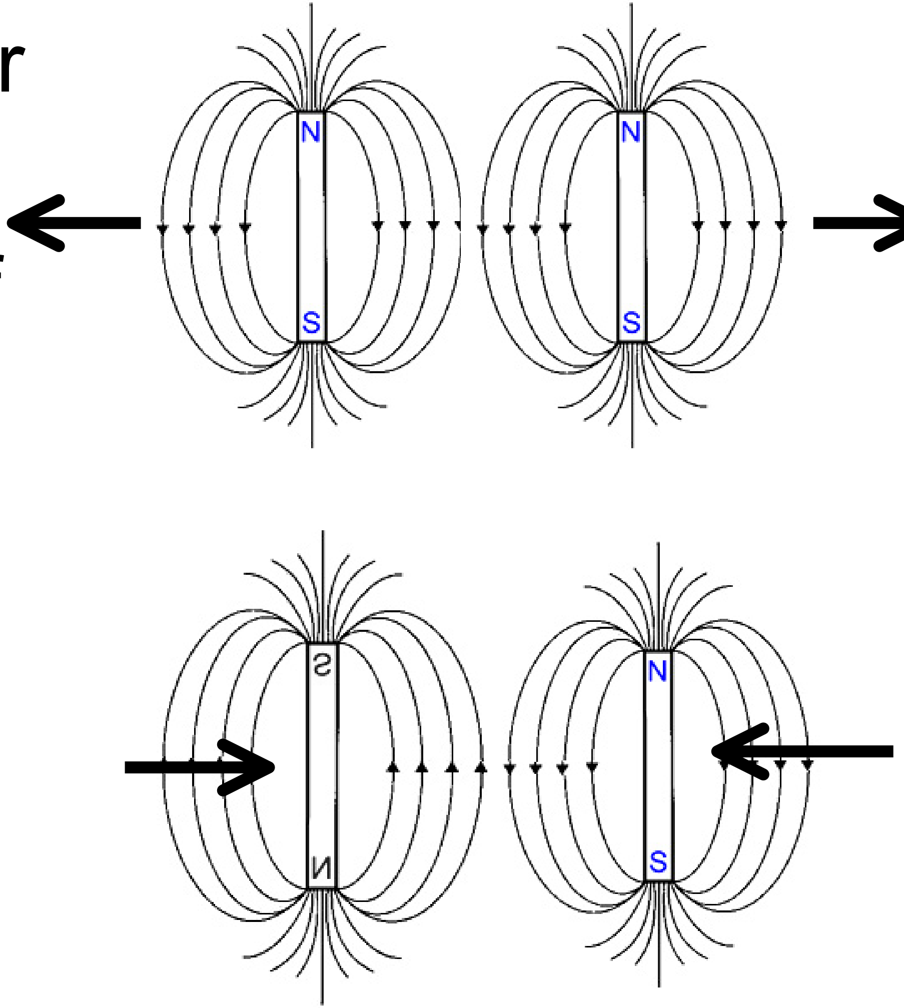
19222 Electrical Machines and Control



Electromagnetism (part II)

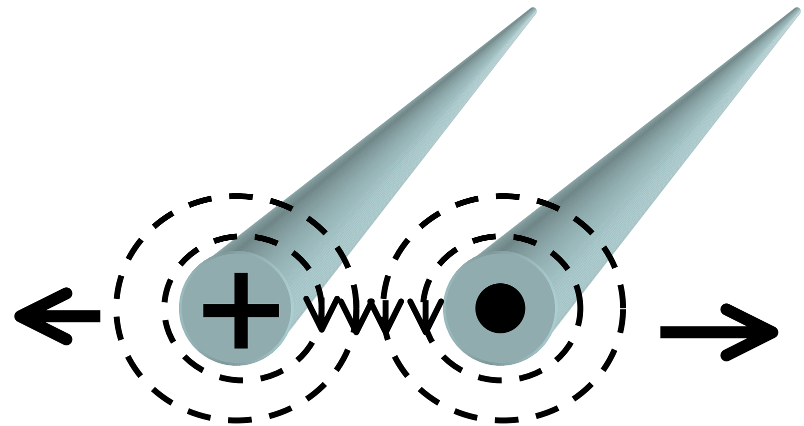
Electromagnetic Force

- Magnets can repel or attract
- Related to density of magnetic flux B (T)
- Force acts from regions of high flux density to low flux density



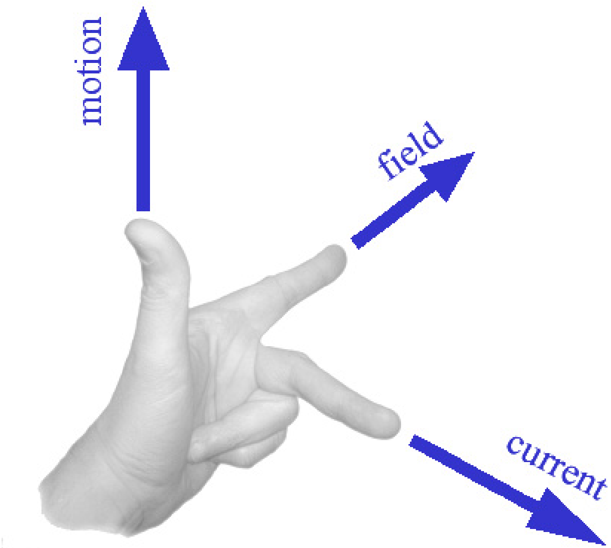
Electromagnetic Force

- Similar case arises with current carrying conductors
- Force acts from high flux density to low flux density
- Force perpendicular to flux



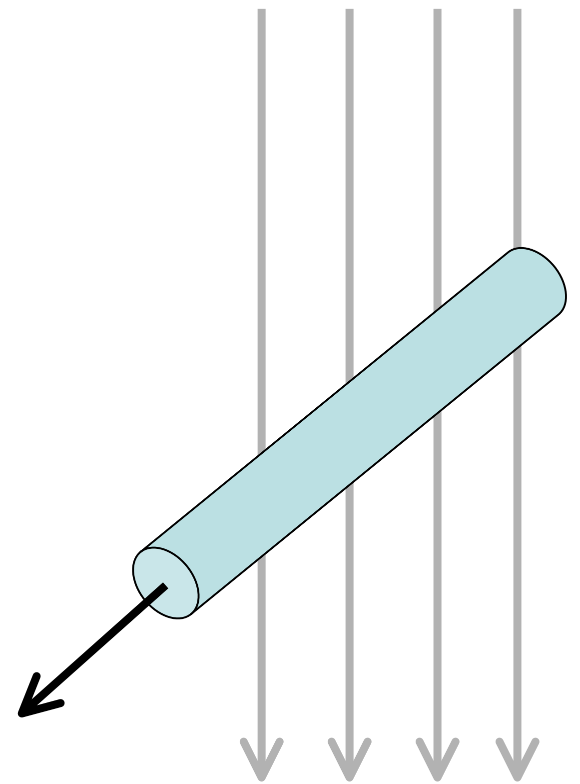
Left Hand (motor) Rule

- Relationship between thrust (force), field and current – force on wire due to field and current
- Use aide memoire – left hand rule
- thu**M**b – **M**otion (force)
- **F**irst finger – **F**ield
- se**C**ond finger - **C**urrent

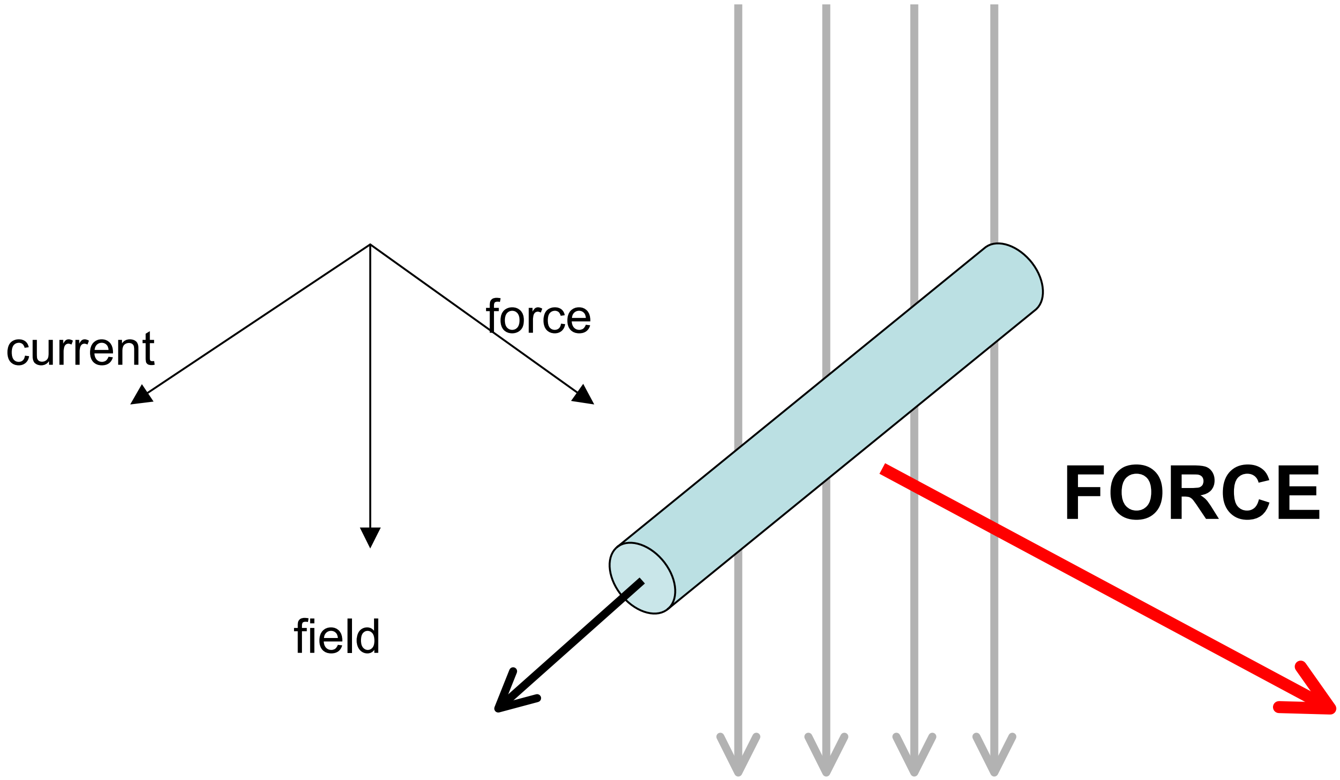


Simple Example

- Current carrying conductor in a magnetic field
- Direction of the force?



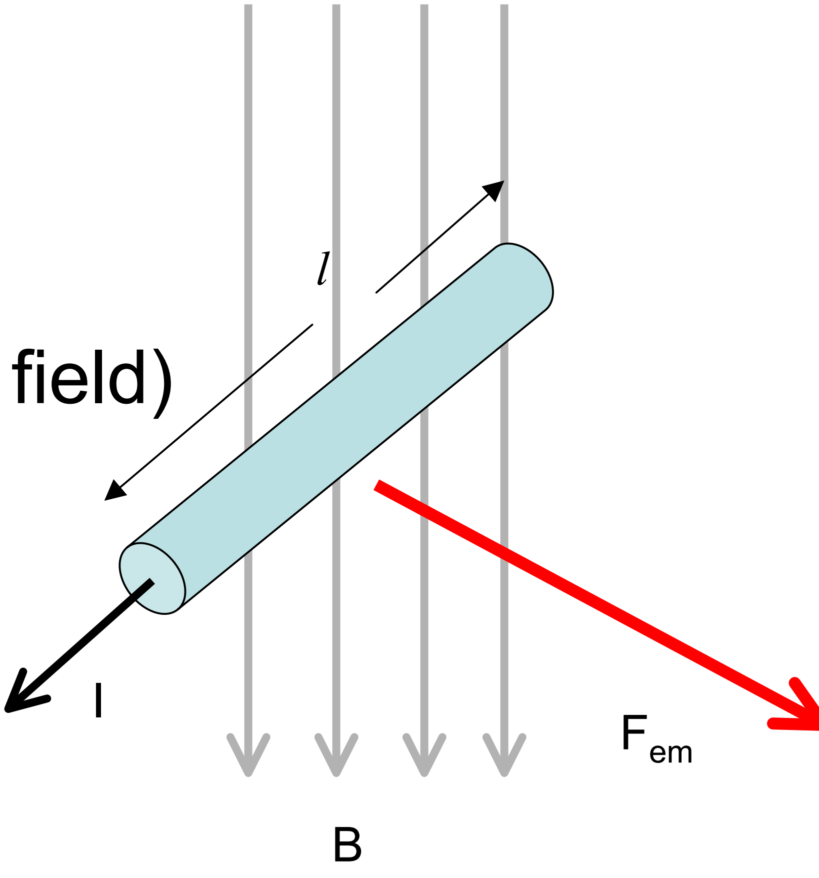
Simple Example



Simple Example

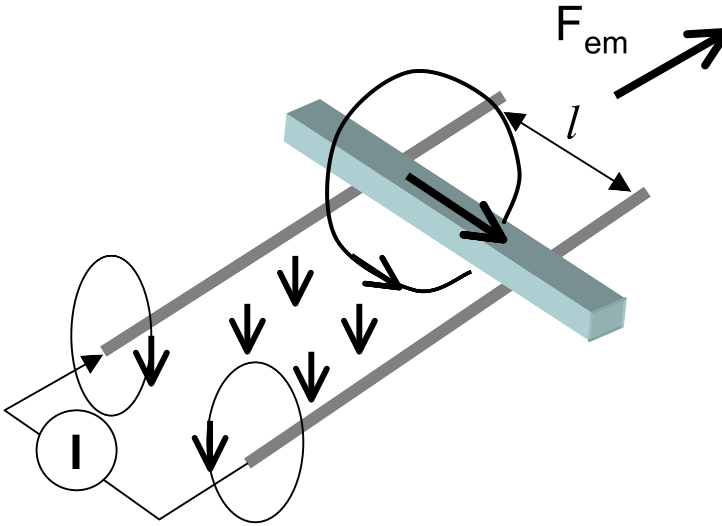
- If we look at this example closely we have:
  - wire length l (m - within field)
  - flux density B (T)
  - current I (A)

$$F_{em} = BIl$$



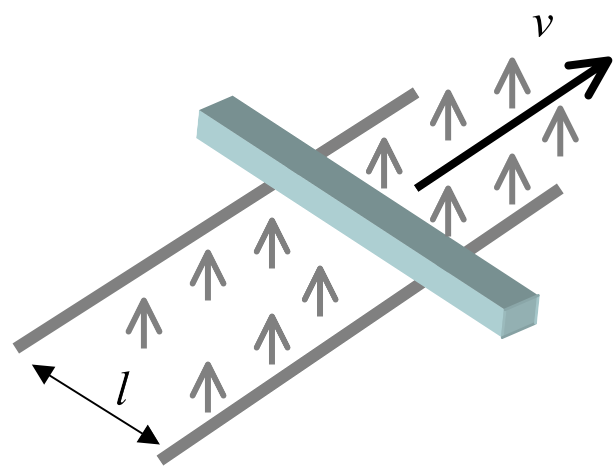
Linear Motor

- Induced force on the current carrying conductor is the basis for electric motors
- **current ⇒ flux ⇒motion**
- Elementary motor (rail gun)
- Current applied to rails to move sliding conductor



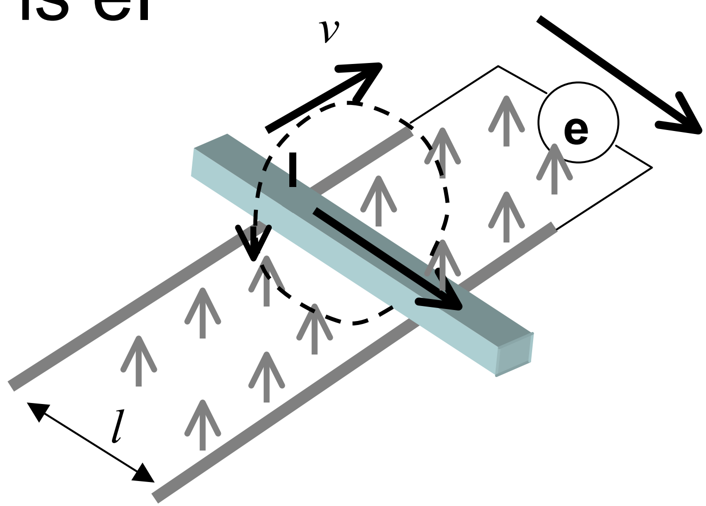
Linear Generator

- Consider the opposite situation
- We force conductor through external magnetic field with velocity ***v***
- Induces a voltage (EMF) between rails and a flow of current



Linear Generator

- Induced EMF and current oppose external force acting on conductor
- Electrical power of this force is eI
- Mechanical power Fv
- Remember F=BIl

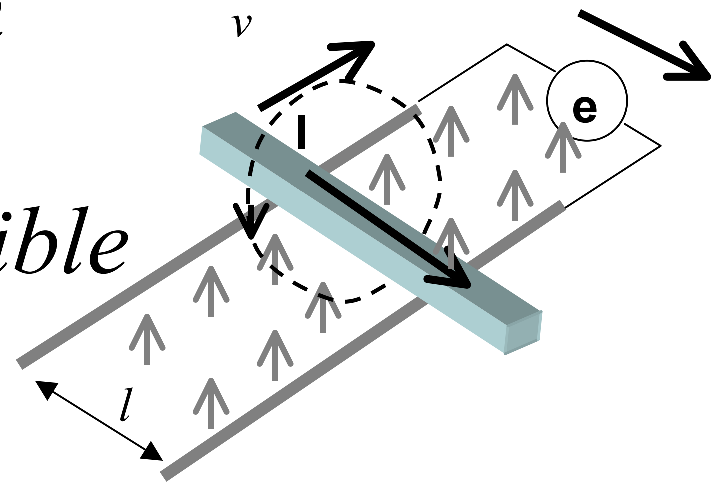


$$eI = BIlv$$

$$e = Blv$$

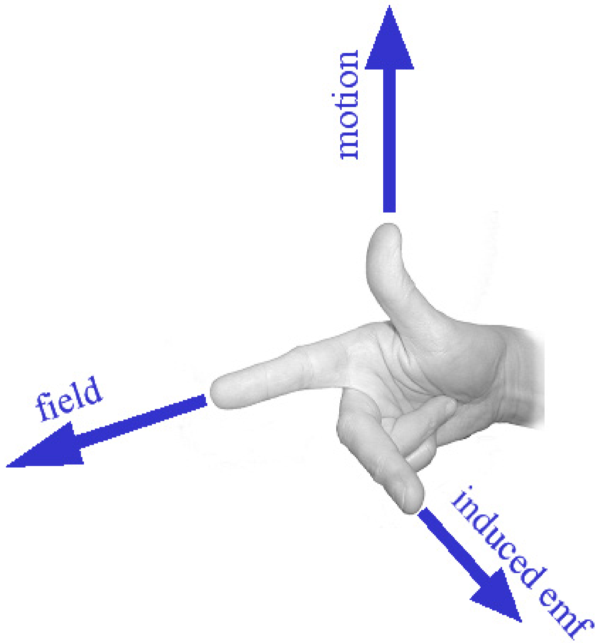
Lenz's Law

- *The direction of the emf is such that it tends to induce a current which opposes the motion or change in flux responsible for inducing the emf*



Right Hand (generator) Rule

- Relationship between velocity (force), field and emf – wire moved through field inducing emf
- Use aide memoire – *right* hand rule
- thu**M**b – **M**otion
- **F**irst finger – **F**ield
- s**E**cond finger - EMF



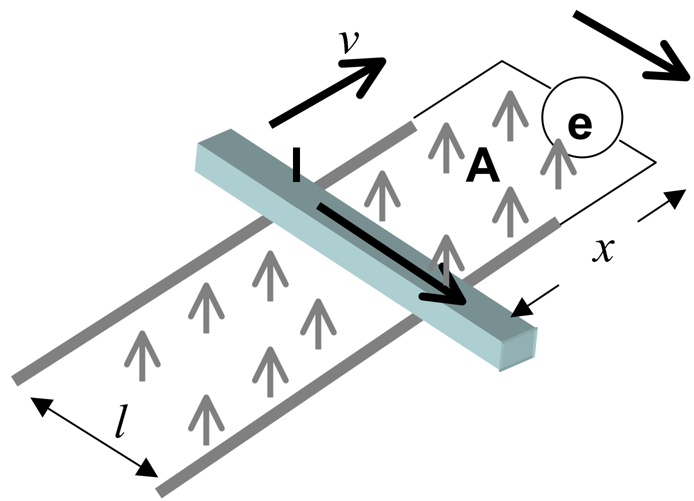
Linear Generator

$$e = Blv \qquad v = \frac{dx}{dt}$$

$$e = Bl\frac{dx}{dt} = B\frac{dA}{dt}$$

$$= \frac{dBA}{dt} \qquad \Phi = BA$$

$$e = \frac{d\Phi}{dt}$$



- Voltage induced proportional to magnetic flux passing through loop area **A**

Faraday’s Law

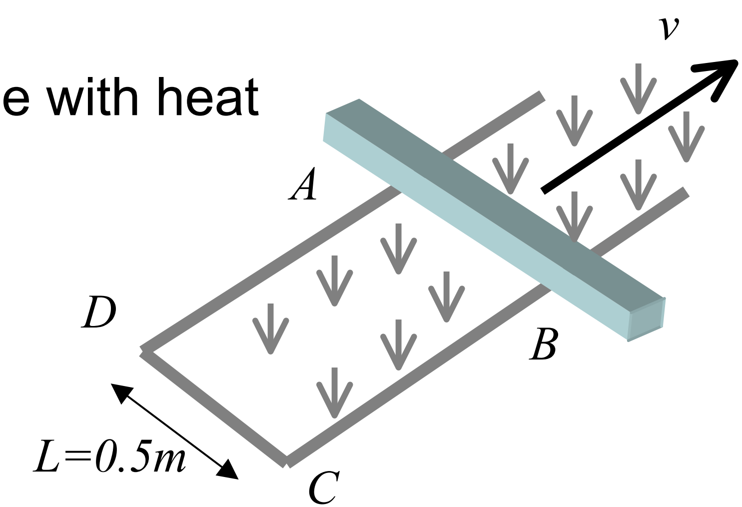
- Linear generator was equivalent to magnetic flux passing through a coil of 1 turn
- For magnetic flux passing through a coil of N turns the induced emf is:

$$e = N\frac{d\Phi}{dt}$$

- Otherwise known as **Faraday’s Law**

Example

- Sliding rod AB is in contact with rails AD and BC uniform magnetic field of 0.5 (T)
- Calculate the magnitude and direction of the induced EMF if the rod is moved to the right at 4m/s
- If the total resistance ABCD is 0.2 ohms find the force needed to keep the rod in motion
- Compare the mechanical work done with heat dissipation (I^2R)



Example

$$e = Blv = 0.5 \times 0.5 \times 4 = 1\,V$$

- Use right hand rule for EMF
- Force $F = BIl \quad I = \frac{V}{R} = \frac{1}{0.2} = 5\,A$

$$F = 0.5 \times 5 \times 0.5 = 1.25N$$

- Rate of mechanical work = power $P_m = Fv = 1.25 \times 4 = 5W$
- Rate of heat development (electrical power)

$$P_e = I^2 R = 5^2 \times 0.2 = 5W$$