Energy Transfer by Work

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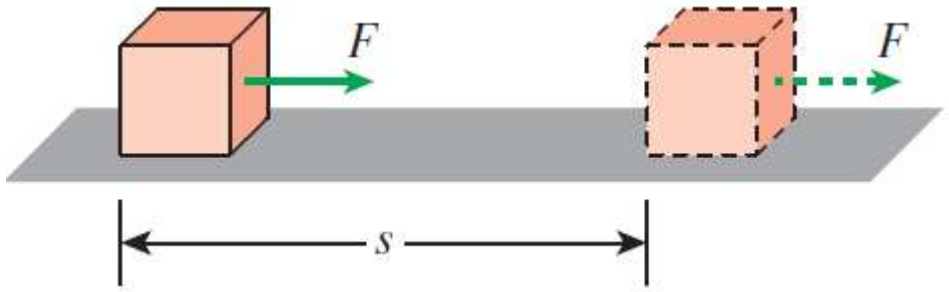
Mechanical "Engineering" Energy & 1st TD Law

- "Form of energy that can be converted to mechanical work completely and directly by an ideal mechanical device like ideal turbine"

(Cengel & Boles: TD)

$$\Delta \boldsymbol{U = Change\ in\ Internal\ Energy\ U = "Heat\ \&\ work\ exchange" = "q - W"}$$

Work from mechanics



Work = Force × Distance

$$W = Fs \qquad (\text{kJ})$$

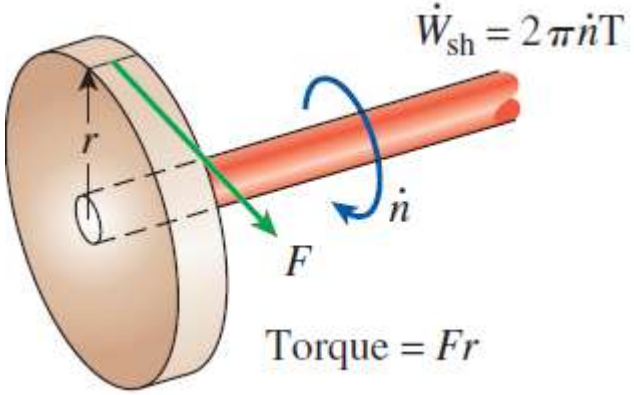
When force is not constant

$$W = \int_1^2 F\, ds \qquad (\text{kJ})$$

No reference to “reversible” & “quasi-static” transformation

Cengel & Boles: TD

Shaft Work

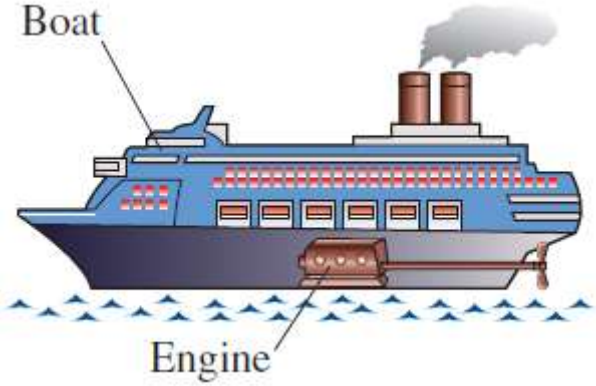


A force F acting through a moment arm r generates a torque T

$$T = Fr \quad \rightarrow \quad F = \frac{T}{r}$$

This force acts through a distance s

$$s = (2\pi r)n$$



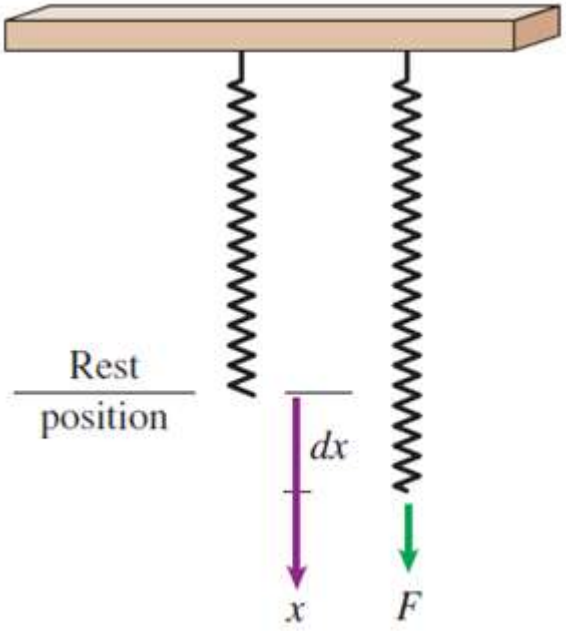
Shaft work

$$W_{sh} = Fs = \left(\frac{T}{r}\right)(2\pi rn) = 2\pi nT \qquad \text{(kJ)}$$

The power transmitted through the shaft is the shaft work done per unit time

$$\dot{W}_{sh} = 2\pi\dot{n}T \qquad \text{(kW)}$$

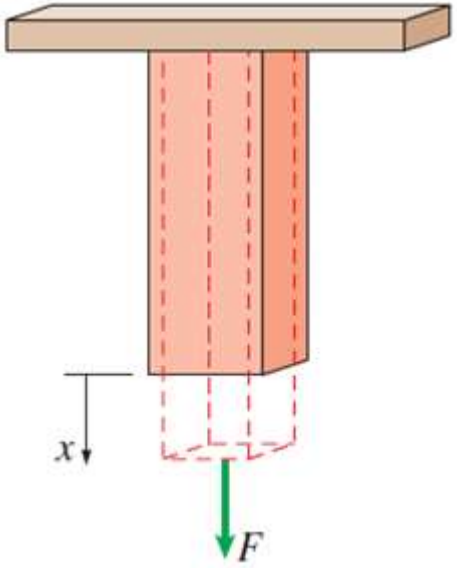
ElastoMechanical Work



$$F = kx \qquad \text{(kN)}$$

$$\delta W_{\text{spring}} = F\,dx$$

$$W_{\text{spring}} = \tfrac{1}{2}k(x_2^2 - x_1^2) \qquad \text{(kJ)}$$



$$W_{\text{elastic}} = \int_1^2 F\,dx = \int_1^2 \sigma_n A\,dx \qquad \text{(kJ)}$$

This & the previous examples of a block & shaft are covered within mechanics

Cengel & Boles: TD

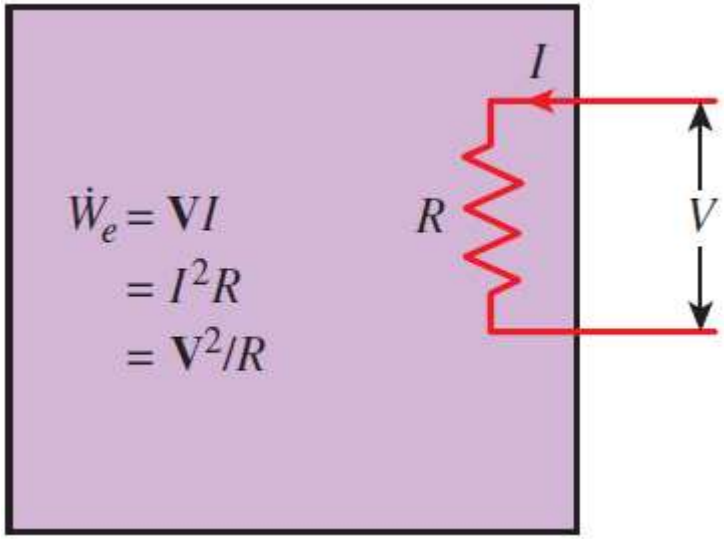
Electrical Work

Electrical work

$$W_e = \mathbf{V}N$$

Electrical power

$$\dot{W}_e = \mathbf{V}I \qquad (\mathrm{W})$$



When potential difference and current remain constant

$$W_e = \mathbf{V}I\ \Delta t \qquad (\mathrm{kJ})$$

When potential difference and current change with time

$$W_e = \int_1^2 \mathbf{V}I\, dt \qquad (\mathrm{kJ})$$

Figs: Cengel & Boles: TD

TD definition of work by Planck & Keenan

- "Work done by a system on the surrounding during a Process is defined as that interaction whose sole effect, external to the system, could be viewed as the raising of a mass through a distance against gravitational force"

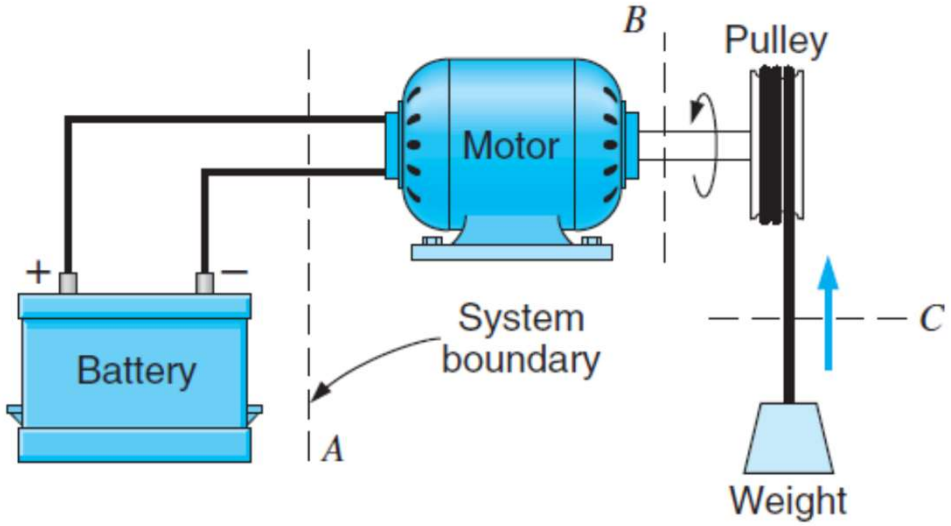
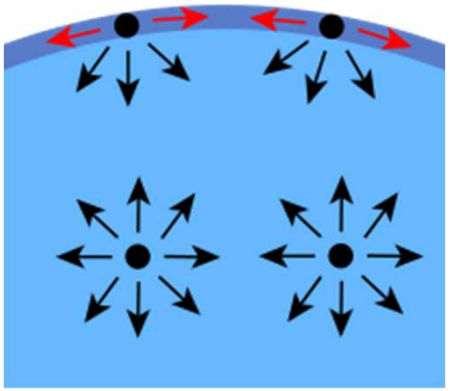
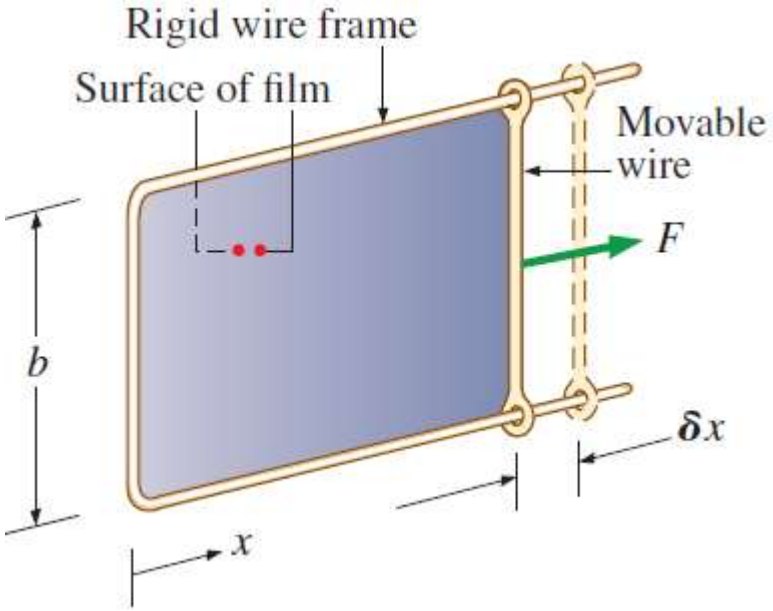


Fig: Borgnakke & Sonntag: TD

Work associated with surface tension





$$W_{\text{surface}} = \int_1^2 \sigma_s \, dA \qquad \text{(kJ)}$$

Surface tension is a thermodynamic variable

Cengel & Boles: TD
https://en.wikipedia.org/wiki/Surface_tension

Electrochemical Work

- Voltmeter measures the energy difference between “electron reservoirs”
- Energy levels in the “electron reservoirs” are thermodynamic quantities, i.e. Chemical Potential (T, P) or Fermi level (T,P)
- W=(Potential Energy Difference,V or EMF)*(Charge transferred)
- Power(P)=V*Current(I)

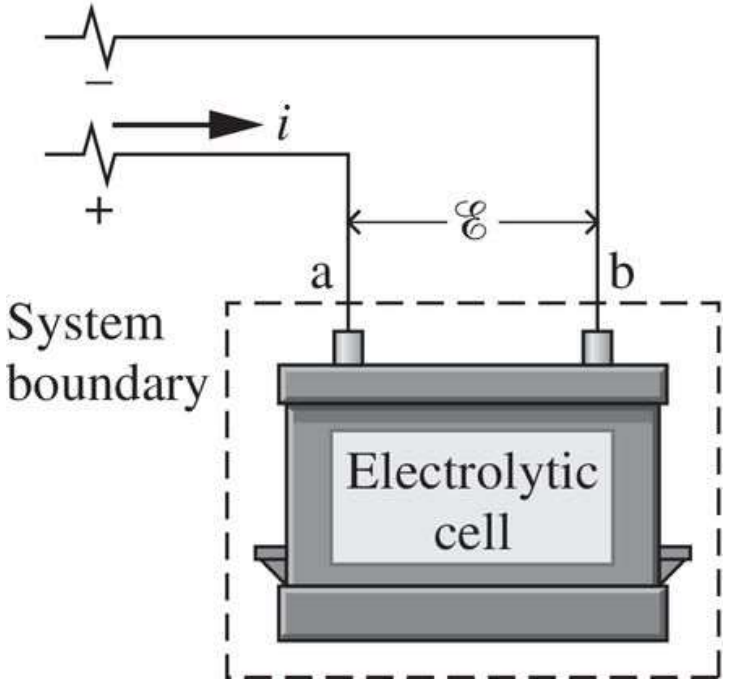


Fig: Moran & Shapiro: TD

Magnetism & Work…Dielectric

- Magnetic force does no work on a moving charge: $F = q(\vec{v}x\vec{B})$
- Magnetic torque on a current loop does work: $\Delta W = \tau \Delta \theta$
- Current loop at the atomic level lead to magnetic moments due to electronic orbital angular momentum
- In addition, there is a "spin-angular momentum"
- Polarization of these magnetic moment in paramagnets involve work interactions in a manner similar to magnetic torque & current loop
- $W = -\mu H * d(vM)$; μ=permeability of free space, v=volume, H=Magnetic field strength, M=Magnetic dipole moment
- Dielectric medium: $W = -E * d(vP)$; P=polarization

Generalized forces & displacement

- W=p*dV-σ*d(A)-v*dq-μH*d(vM) -E*d(vP)...
- Generalized force-Intensive
- Generalized displacement-Extensive
- "Reversible transformation": Infinitesimal...While undertaking Cyclic transformation both the system & surrounding should come to the same state...All *states* should be represented in the state diagram during the transformation

Fig: Borgnakke & Sonntag: TD