Convention

- Your workings must be neat and easily understood.
- All calculations must include formulas.
- All values must be stated in your solutions.
- Assumptions must be stated in your solutions.
- Pay attention to small details, such as the difference between $\dot{W}$ and W
- All explanations can be as simple as bullet point style.
- Significant figures must be determined and stated next to the result.
- Use the sign conventions of the course. i.e. when work leaves a system, it is negative.
- Δ in this course means 'initial - final'.
- Draw block diagrams
- Define system boundaries

Systems, DoF, Energy

L1, L2, L3

- Definitions and units
- System Principles
  - Accumulation
  - Open/Closed systems
  - Block Diagrams
  - Energy Transfer via heat
    - Conduction
    - Convection
    - Radiation
  - Degrees-of-freedom analysis
  - Mass Balances

Mass Balance:

$M = \text{in} - \text{out}$

where M is the accumulation of the system

$\sum \dot{m}_{\text{in}} = \sum \dot{m}_{\text{out}}$

where $\dot{m}$ is the mass flow rate

DoF Analysis: $n_{\text{dof}} = n_{\text{unknowns}} - n_{\text{ind. eq}} - n_{\text{other eq.}}$

$n_{\text{dof}} = 0$ means the problem is well defined

Total internal energy: $\Delta U = \Delta E - \Delta E_{\text{kin}} - \Delta E_{\text{pot}}$

Remember Δ is initial - final in this course

Enthalpy: $H = U + pV$

where H is enthalpy, U is internal energy, p is pressure and V is volume

Wind Power

L9, L10, L11

- Social license to operate
- Not in my backyard. Wind power is very loud/ugly.
- Working principle of a turbine
- creativity in wind

Creativity

L6, L10

- Bend, Break, Blend

Creativity in wind

- Offshore wind
- Large turbines
- Flexible blades (inspired by insect)

Hydro

L4, L6

- Renewable Energy Sources
- Energy transfer through shaft work
- Simplified mass and energy balance to find shaft work
- Calculation of power output through the potential kinetic energy per unit time of water
- Micro Hydro
- Power density (electrical power generated per horizontal m^2)

Solar

L12, L13

- Solar as a renewable energy source
- Power density of solar is relatively low
- Application of energy balance

$E_{\text{photon}} = \frac{hC}{\lambda}$

Calculating properties of solar plants:

$\eta_{\max} = \frac{P_{\max}}{P_{\text{inc}}}$

$P_{\max} = I_{\max} \times V_{\max}$

$A = \frac{P_{\text{required}}}{P_{\max}}$

where P is power, V is voltage, I is current, A is cell area, η is Efficiency

Batteries

L14, L15, L16

- Battery as energy storage solutions
- Working principles of
  - Galvanic Cell
  - PbA battery
  - Li-ion battery
- Redox reactions, cell notion
- OIL RIG
- AnOX & REDcat
- Comparing values of Gibbs free energy shows where it is stored

Calculation of Gibbs free energy (if $\Delta_r G^\circ > 0$ then spontaneous)

$\Delta_r G^\circ = \sum G^\circ_{\text{products}} - \sum G^\circ_{\text{reactants}}$

EMF of a cell: $E^\circ_{\text{cell}} = E^\circ_{\text{red}} + E^\circ_{\text{ox}}$

E° = EMF = voltage = cell potential

Current equation: $It = v_e n F$

where I is the current during time t, v_e is the number of electrons transferred, n is the number of moles and $F = 96500$

Ethics

L L17

Resource Management Act

Sections 5,6,7,8

Ethics/Batteries

What materials go into a battery (or a solar panel) and where do they come from

Engineering NZ code of ethical conduct

Geothermal

L24, L25, L26, L29

- Difference between a dry steam, flash and binary plant
- Fluid carries heat
- Porosity of rock determines the amount of fluid in the rock
- Permeability, Darcy's law for fluid flow
- The use of thermal energy not converted to electricity (direct use)

Stored heat equation: $Q = Ah\rho C(T_r - T_o)$

where Q is the stored heat energy, A is the area of the plant, h is the depth of the plant, ρ the density of the rock, C is the specific heat capacity of the rock and T_r and T_o are the reservoir and lowest temperatures

Heat energy in the fluid: $Q_{\text{fluid}} = \phi(h_{\text{fluid}} - h_o)$

where Q_{fluid} is the heat energy stored in 1m^3 of rock, ϕ is porosity and h is enthalpy

Darcy's Law: $Q = \frac{kA}{\mu}\frac{dp}{dx}$

where k is permeability, A is area, μ the dynamic viscosity and $\frac{dp}{dx}$ the pressure gradient

Heat Engines

L21

- Carnot cycle (ideal world)
- Rankine cycle (real world, power plants)
- Working principle:

4-step cyclic process where working fluid is continuously vaporized and condensed to run a steam turbine that extracts shaft work.

- Steam tables and phase transition diagram
- Application of mass and energy balance

Energy Balance

$$\Delta\dot{E}_{\text{System}} = \dot{E}_{\text{in}} - \dot{E}_{\text{out}}$$

$$0 = \sum[\dot{m}_{\text{in}}(\frac{1}{2}v_{\text{in}}^2 + gh_{\text{in}} + \hat{H}_{\text{in}})] - \sum[\dot{m}_{\text{out}}(\frac{1}{2}v_{\text{out}}^2 + gh_{\text{out}} + \hat{H}_{\text{out}})] + \dot{Q} + \dot{W}_{\text{S}} + \dot{W}_{\text{EC}}$$

Biofuels

L22, L23

- Biomass from biofuels
- Working principle of a CHP plant
- Terminology, formation of biomass and chemical reactions
- Application of mass and energy balances
- Ideal Gas Law, Gibbs Free Energy
- Entropy

Decision Making

L27, L28

- Multicriteria Decision Making
- Lexographic Method
- Dominance Graphs
- Probability Distributions