FOUNDATION OF ENGINEERING DESIGN

~Structures + Design~

-> To understand fundamentals of design so that designs are safe, economical and function well

You will gain:

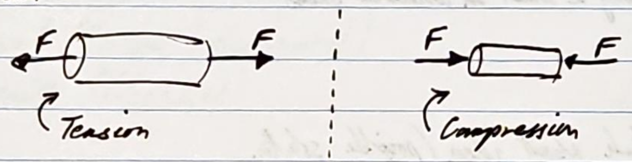
-> knowledge to: design your project structure + other structures

-> ability to become an efficient engineer

- engineering isn't an isolated job ∴ will learn about the other professions you'll be working with

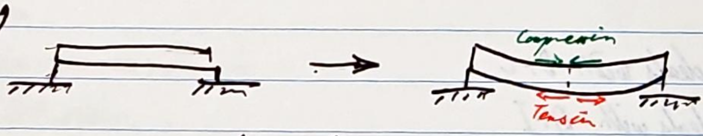
Structural Actions

1. Axial



e.g. columns in a carpark under a bridge | e.g. cables on a tower

2. Bending



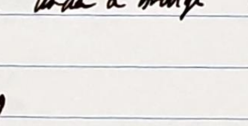
e.g. floor beams, slabs, bridge decks

3. Shear Force

- often occurs near a support/under a large load

4. Torsion

- caused by unsymmetrical loading



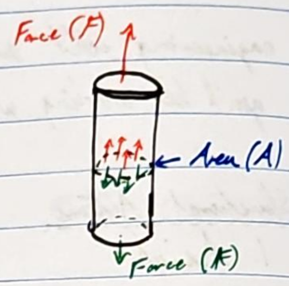
Role of Structural Design Engineer

1. identify material
2. identify which carry loads
   - ↳ structural / non-structural
3. identify structural action (axial and/or bending)
4. size the members (design codes)
5. determine member forces
6. check member capacity to carry forces

(Axial) Stress

• Def: $\sigma = \frac{F}{A}$

σ = Stress (Nm^{-2} or Pa)
F = Applied Force applied (N)
A = cross-sectional Area (m^2)



HINT: There's normally a limit on allowable stress

CDIO Framework

→ C - Conceive - think about idea / possible solution
→ D - Design
→ I - Implement
→ O - Operate

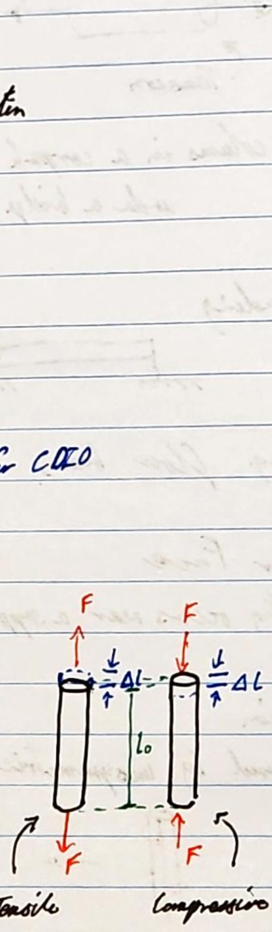
- EGB100 deals with D + C
- EGB111 deals with D + I
- EGB113 and MZB115 deals with Knowledge + Skills for CDIO

(Axial) Strain

- ratio of change in length to original length
- Dimensionless - no units

$\varepsilon = \frac{\Delta L}{L_0}$

ε = strain
ΔL = change in length (m)
L_0 = original length (m)



~ Foundations of Engineering Design Project Brief ~

→ can be found on Blackboard

Task: build something in order to lift a "statue" from one place to another

- There is a bugdet for power, amount spent, ~~the~~ time taken to accomplish etc.

HINT: have a look at material prior to lecture (on Blackboard)

~ Knowledge Required ~

- Statistics / Structures (Civil)
- Moments / Torque (Mechanical)
- Circuits (Electrical)

Practical: <u>MUST</u> have enclosed footwear

~ Why should teamwork be important to you? ~

- enhances employability

- Things go wrong when:
  - → one person takes over / dominates
  - → people don't deliver
  - → people rely on others, not themselves
  - → there's conflict, not agreement
  - → one person wants it to be perfect
- Suggestions:
  - → know your strengths + flaws
  - → as a team discuss goals, expectations, procedure + consequences
  - → learn from experience
  - → talk to your project manager

~ Young's Modulus ~

- also known as modulus of elasticity
- describes an important material property of a structural member when it is stretched (in tension) or compressed (under compression)
- definition: ratio of (axial) stress to (axial) strain

$$E = \frac{\sigma}{\varepsilon}$$

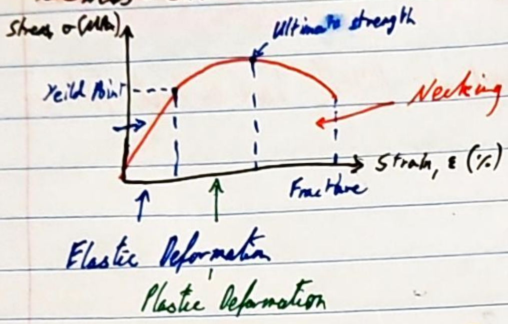
E = Young's Modulus (Nm^{-2})

σ = Stress (Nm^{-2})

ε = strain

a measure of the ability of a material to withstand changes in length under lengthwise tension or compression

~ Stress - Strain Curve ~



- DC geared motor - best motor for design project
- Testing - Weeks 12-13
- must be

~ Equilibrium of Systems - Statics ~

- **Equilibrium** - a state of rest or balance due to the equal action of opposing forces

- 3 equations to satisfy equilibrium of a structure in 2D
  - → 2 help to balance forces
  - → 1 helps to balance moments / turning effects

1. Moment (of a force)

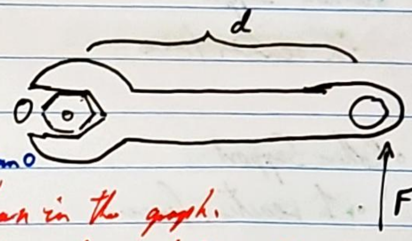
↳ a measure of the rotational (turning) effect of a force about an axis normal to the 2D plane (aka torque)

→ used to determine support reactions

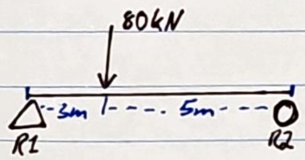
→ Magnitude (M) of F (force) about the point 'O':

$$M = F \times d$$

M = magnitude
F = force
d = distance from O



→ **Example 1:** A weight sits on a table, as shown in the graph. How much weight is being shared between R1 and R2?



$\Sigma M_1 = 0$ → $R_2 \times 8 - 80 \times 3 = 0$

$\therefore R_2 = \frac{80 \times 3}{8} = 30\,kN$

$R_1 + R_2 = 80 \quad \therefore R_1 = 80 - 30 = 50\,kN$

2. Equilibrium of Structures

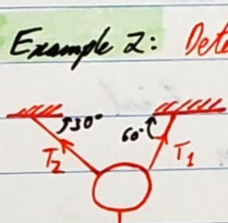
→ for a structure in the 2D plane, the necessary conditions of equilibrium are:

→ $\Sigma F_x = 0$ → $\Sigma F_y = 0$ → $\Sigma M_z = 0$

resulting force

sum of moments of all forces

- **Example 2:** Determine T_1 and T_2.



$\Sigma F_x = 0 \quad \xrightarrow{+}$

$T_1 \cos 60° - T_2 \cos 30° = 0$

$T_1 \cos 60° = T_2 \cos 30°$

$T_1 (0.5) - T_2 (0.87) = 0$

$T_1 = T_2 \left(\frac{0.87}{0.5}\right) = 1.73 \times T_2 \quad (1)$

$\Sigma F_y = 0 \quad +\uparrow$

$T_1 \sin 60° + T_2 \sin 30° - 100 = 0$

$T_1 (0.87) + T_2 (0.5) = 100 \quad (2)$

Sub (1) in (2): $(T_2(1.73)) + T_2(0.5) = 100$

$\therefore T_2 \approx 50\,kN$

from (1)

$T_1 = 1.73 \times T_2 = 1.73 \times 50$

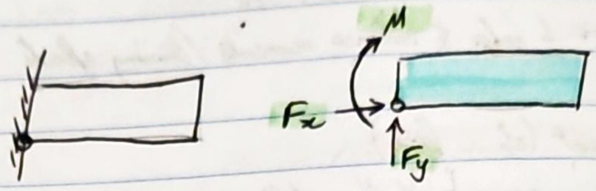
$\therefore T_1 \approx 87\,kN$

~ Truss Structures ~

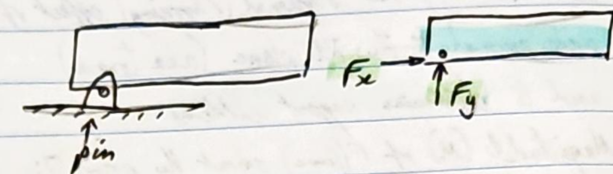
↳ important as they carry axial loads

~ Support Types ~

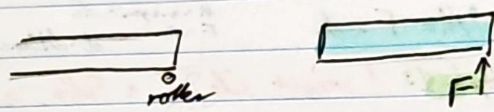
- Fixed Support
  - → 2 reaction forces
  - → 1 reaction moment



- Pinned Support
  - 2 reaction forces



- Roller Support
  - 1 reaction force



Buckling

→ when a straight column undergoes bending

→ Critical Buckling load F_{cr}: ← Euler's critical load

$$F_{cr} = \frac{\pi^2 E I}{(KL)^2}$$

I = moment of inertia about axis of buckling

K = effective length factor based on end boundary conditions

E = Young's Modulus of column material

L = unsupported length of column

Week 3 Tutorial

~ Structural Materials ~

· enquiries : enquiries.egb111@qut.edu.au

· learning: the failure of axially loaded materials

· Mass – measure of amount of matter

· Weight – the amount of force gravity has on an object

· Axial Forces:

→ compression 

→ Tension 

IMPORTANT EQUATIONS:

Stress: $\sigma = \frac{F}{A_0}$ (N/m^2 or Pa)

Strain: $\varepsilon = \frac{\Delta L}{L_0}$

Elastic Modulus: $E = \frac{\sigma}{\varepsilon}$ (N/m^2 or Pa)

· Example 1:

a) Calculate the axial stress in a cylindrical rod with a 10mm diameter if the axial forces is 10kN. (127.3 MPa)

HINT: $1 MPa = 1 N/mm^2$

10mm in m: $10 \div 1000 = 0.01m$

$A = \pi \cdot 2 \approx 0.031416 m^2$

10kN in N: $10 \times 1000 = 10000 N$

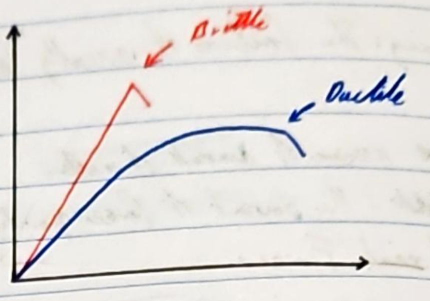
$\therefore \varepsilon = \frac{F}{A_0}$

$= 31830$

b) An aluminium rod was originally 200mm long, and after applying a tensile load the length of the rod is now 215mm. Calculate the strain in the rod, assuming the deformation is entirely elastic. (Ans: 0.075)

c) A 100mm long steel bar with a 20mm × 20mm cross section is pulled in tension with a load of 89kN, and experiences an elongation of 0.1mm. Assuming the deformation is entirely elastic, calculate the Young's (Elastic) Modulus of the steel. (Ans: 222.5 GPa)

- Brittle vs Ductile red
  - → Brittle Materials (blue)
    - e.g. woods, glass, acrylic
    - small/no plastic deformation
    - stress = fracture stress
  - → Ductile Materials (~~red~~) blue
    - ultimate tensile stress > yield stress
    - both elastic + plastic region
    - e.g. many metals + plastics



- Mechanical Properties
  - → Yield Stress (σ_y):
    - stress level at which deformation begins (yielding occurs)
    - stress below yield stress = elastic
    - stress above yield stress = plastic
  - → Ultimate Strength (σ_{UTS})
    - Stress that causes material to fail

Types of Failure Modes:
Tension → Exceeding UTS
Compression → Buckling

- Failure of Axially Loaded Materials
  - → Tension
    - Material will plastically deform when $\sigma_{y,T} < \sigma < \sigma_{UTS,T}$
    - Material when break when $\sigma > \sigma_{UTS,T}$

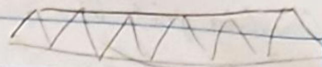
To note:

$$F_{cr} = \frac{\pi^2 E I}{(KL)^2}$$ (the critical buckling load)

What is buckling? Exceeding the Young's Modulus σ_{UTS}?

~ Truss Structures ~

- carry only axial loads – tension or compression
- light + efficient w/ min. material
- many applications
- Found in bridges, cranes + roof trusses, transmission towers



- Truss analysis – Method of Joints

1. Determine the support reactions by using $\sum F_y = 0$ and $\sum M = 0$

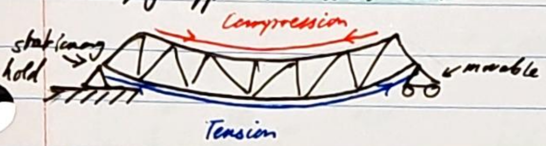
2. Start w/ a support or a joint where we have a known force + max of 2 unknown forces.

3. Apply force equations of equilibrium $\sum F_x = 0$, $\sum F_y = 0$ to determine truss member forces. Do same @ all joints to determine forces in all truss members

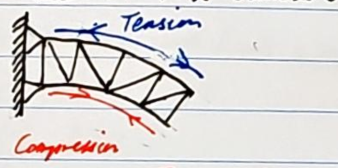
4. Indicate tension/compression in member forces

- Deformed Shapes of Truss Structures

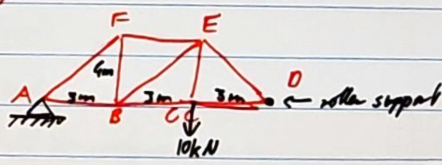
→ Simply-supported Truss Structure



→ Cantilevered Truss Structure



- Example 1: Find the support reactions at A and D and the forces in members AF, AB, DC, DE and CE.



Step 1: determine reaction forces:

$\sum F_x = 0 \therefore A_x = 0$

$\sum F_y = 0$

$A_y + D_y - 10 = 0$

$A_y + D_y = 10$

$\sum M_D = 0$

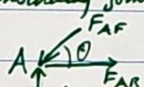
$(A_y \times 9) - (10 \times 3) = 0$

$9A_y = 30$

$\therefore A_y = \frac{30}{9} = 3.33\,kN$

$\therefore D_y = 10 - \frac{10}{3} = \frac{20}{3} \approx 6.67\,kN$

Considering joint A: $\tan\theta = \frac{4}{3}$, $\sin\theta = \frac{4}{5}$, $\cos\theta = \frac{3}{5}$



$\sum F_y = 0$

$F_{AF}\sin\theta - \frac{10}{3} = 0$

$\therefore F_{AF} = \frac{10}{3} \times \frac{5}{4} = \frac{25}{6}\,kN$

$\sum F_x = 0$

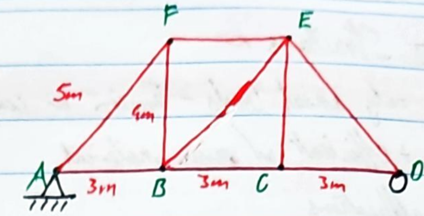
$F_{AB} - F_{AF}\cos\theta = 0$

$\therefore F_{AB} = \frac{25}{6} \times \frac{3}{5} = \frac{5}{2}\,kN$

∴ Member AB is in tension and Member AF is in compression.

cont... →

Example 1 cont...



Considering joint D:

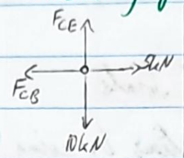
$\tan\theta = \frac{4}{3}$, $\sin\theta = \frac{4}{5}$, $\cos\theta = \frac{3}{5}$

$\sum F_y = 0$	$\sum F_x = 0$
$F_{DE}\sin\theta - \frac{20}{3} = 0$	$F_{DE}\cos\theta - F_{DC} = 0$
$\therefore F_{DE} = \frac{20}{3} \times \frac{5}{4}$	$\therefore F_{DC} = \frac{25}{3} \times \frac{3}{5} = 5kN$
$= \frac{25}{3} kN$	

Member DE is in compression

Member DC is in Tension

Considering joint C:



$\sum F_y = 0$	$\sum F_x = 0$
$F_{CE} - 10 = 0$	$5 - F_{CB} = 0$
$\therefore F_{CE} = 10kN$	$\therefore F_{CB} = 5kN$

Both CE and CB are in Tension.

Design Considerations:

1 → Develop shape (stability)

2 → Material

3 → Capacity (tensile + compressive) - from testing

4 → No overturning

5 → Check member stresses are within limits - is there a Factor of Safety?

6 → Construct Structure

7 → Test

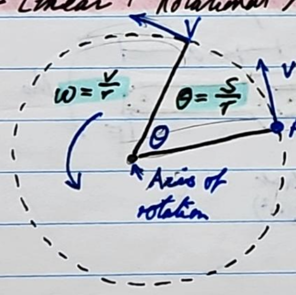
Week 5: Mechanical Systems Analysis ~

~ What is an Mechanical Engineer? ~

- Mechanical engineering: concerned with design, development, research, evaluation, manufacture, installation, testing, operation, maintenance and management of machines, mechanical and mechatronic systems, automated systems and robotic devices, heat transfer processes etc.
- Aspects of Mechanical engineering:
  - ⇾ Design: create things that turn energy into action
  - ⇾ Fluid Mechanics: create things that use fluids and travel through fluids
  - ⇾ Thermodynamics: create things that harness temperature
  - ⇾ Process/Systems Engineering: make stuff work together effectively
    make systems that link things together to do things
  - ⇾ Management, Maintenance: coordinates things to make things happen, and keep happening
  - ⇾ Materials Engineering: makes sure you build out of stuff that doesn't break

~ Newton's Laws ~

~ Linear + Rotational Motion ~



⇾ a point on the outside of the circle travels a length of:

$$s_p = r\theta$$

which we can differentiate:

$$V_p = r\frac{d\theta}{dt} = r\omega$$

$$a_p = r\frac{d\omega}{dt} = r\alpha$$

⇾ Angular Position = $\theta(t)$ (in radians)

⇾ Angular velocity (in radians):

$$\omega(t) = \frac{d\theta}{dt}$$

$$\omega(t) = 2\pi f$$

⇾ Angular acceleration (in rad/s²):

$$\alpha(t) = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

- Example 1: The platter of a hard drive spins at 4500rpm.

a) What is the angular velocity?

$f = 4500\,rpm$

$\omega = 2\pi f$

$4500\,rpm = \frac{4500}{60} = 75\,Hz$

$\omega = 2\pi f = 2\times\pi\times 75 = 471\,rad/s$

b) If the reading head is located 3cm from the rotation axis, what is the speed of the disk below it?

$v = r\omega = 0.03\times 471$

$v = 14\,m/s$

c) What is the linear tangential acceleration at this point?

$\omega = constant = 471\,rad/s$

$\alpha = \frac{d\omega}{dt} = 0$

$\therefore a = R\alpha = 0$

d) If a single bit required $0.5\mu m$ of length in the motion direction, how many bits per second can the writing head write when it is 3cm from the rotation axis?

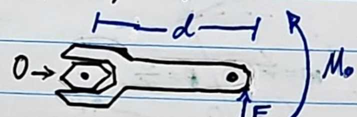
$v = \frac{14\,m/s}{0.5\times10^{-6}\,m} = 28\,Mb/s$

e) If the disc took 3.6s to spin up to 4500rpm from rest, what is its average angular acceleration?

$\alpha = \frac{d\omega}{dt} = \frac{471}{3.6} = 131\,rad/s^2$

- We can state similar equations for rotational motion about a fixed point, but we need some definitions first.

→ Remember: $M_O = d\times F$ ← Torque (Nm)

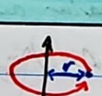
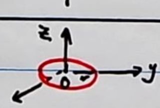
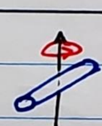


→ For rotation about a fixed axis at O:

$$\sum M_O = I_O \alpha$$

I_O = moment of inertia about the axis at point O (kgm^2) ("rotational mass")

- Newton's 2nd Law (rotational):

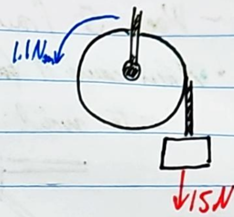
Shape		I_O
Point Mass		mr^2
Uniform Disk of radius r		$\frac{1}{2}mr^2$
Uniform bar of length l rotating about its centre		$\frac{1}{12}ml^2$

→ how fast you rotate depends on where the mass is

slower spin

faster spin

· Example 2: A 15N force is applied to a pulley. The pulley has a mass 4kg and a radius 33cm. The pulley accelerates from rest to 30rad/s in 3 seconds. There is friction from the pulley of 1.10 Nm. Find the moment of Inertia.



$\sum M = I\alpha$

$= F \times d$ (perpendicular)

$= (15 \times 0.33) - 1.1$

$= 3.85\ Nm$

$\alpha = \frac{d\omega}{dt}$

$= (30\ rad/s) \div (3s) = 10\ rad/s^2$

$\therefore I = \frac{\sum M}{\alpha} = \frac{3.85}{10} = 0.385\ kgm^2$

· Truss determinancy:

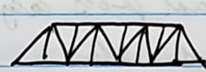
$2j = m + r$

$\begin{cases} j = \text{no. joints} \\ m = \text{no. members} \\ r = \text{no. support reactions} \end{cases}$

· Method of joints overview

→ Apply $\sum F_x = 0$, $\sum F_y = 0$ at each joint to determine up to 2 unknown forces

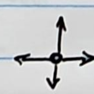
→ Step 1: draw free body diagram



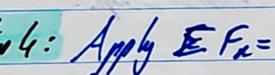
→ Step 2: solve for reaction forces:

$\sum M_o = 0 \quad \sum F_y = 0 \quad \sum F_x = 0$

→ Step 3: find joint w/ 2 unknowns and draw free body diagram of the joint (+force = tension, −force = compression)



Member in Tension



Joint opposing Member in Tension

→ Step 4: Apply $\sum F_x = 0$ and $\sum F_y = 0$ to solve the 2 unknown forces (always put T and C to indicate tension or compression)

→ Step 5: repeat steps 3 and 4.

~ Week 5 Practical ~

- Main cause of failure for bridge trusses was joint failure
  - → to avoid: add gusset plates

→ increases contact area for glue

→ slightly shortens member (careful w/ compression)

What you can do to avoid failure in trusses / be aware of:

- Gusset plates
  - → helps avoid joint failure
- Bracing
  - → to negate the effect of torsional loads (twisting)
  - → cannot calculate how much bracing you need: use judgment and observe deformation
- Supports
  - → can only use pinned + roller supports for truss
  - → axial forces only; fixed support would result in moment in truss members
  - → might need to simplify support types for purpose of calculations
  - → will truss be determinate? (3 equations = max. 3 unknowns)
- Over-turning
  - → can be issue in unfixed devices
  - → restabilising options:
    - reduce overturning moment
    - increase restoring moment
    - adjust feet calculations
    - change weight distribution of truss
    - consider counterweights

- Factor of Safety (FOS)
  - → Failure will occur when force from applied ~~force~~ load is greater than member capacity
  - → FOS of 1 will support only design load (0.5kg), but any additional load will cause failure
  - → FOS allows for accidental loading
  - → FOS of 2: must be able to hold 1kg statue
  - → FOS of 3: must fail (1.5kg statue)
  - → aim for FOS of 2 to 2.5 (1.25kg)

$$FOS = \frac{\text{max stress}}{\text{typical (working) stress}}$$

- Balsa Wood Notes
  - → natural material - properties will be inconsistent
  - → tensile + compression strength are density dependent
  - → Tensile strength range: 7MPa - 32MPa
  - → Compressive strength range: 5MPa - 20MPa
  - → properties will vary depending if cut with/across wood grain 

For Truss Design:

- Truss analysis using method of joints
  - → find forces in members under applied load
  - → max compression + tension in internal forces
- Materials testing
  - → find capacity of truss members
  - → compression + tension
  - → max load at failure
- To determine failure:
  - → 0.5kg statue: all forces should be less than capacity
  - → 1.5kg statue: some members should be greater than capacity

· Truss design summary

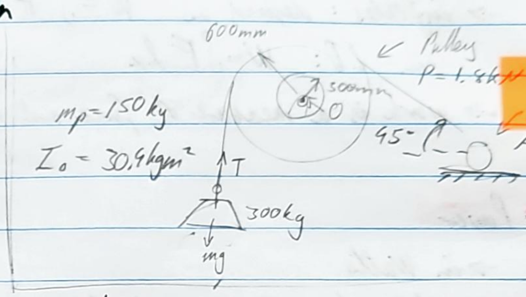
1. Design truss
2. Simplify to 2D → one side = half load!
3. Identify all loads applied to truss
4. Calculate support reaction forces
5. Calculate truss member forces
6. Identify max compression and tension members
7. Compare to materials testing data
8. Check for failure between 1kg and 1.5kg static loads
9. If not, redesign!
10. Check need for bracing

~ Lecture Week 6: Machines ~

- Equilibrium

- when a structure is not in equilibrium, it would be accelerating
  - → e.g. in project: statue moving won't be in equilibrium but everything else will be in equilibrium

- Example 1: Find the acceleration of the 300kg mass.

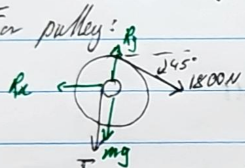


$\Sigma F_y = m_m a_y$

$= T - mg$

$\hookrightarrow T = m_m a_y + m_m g$

For pulley:



→ pulley is in equilibrium $\therefore \Sigma F_x = 0$

$= -R_x + 1800\cos 45$

$R_x = 1800\cos 45$

$\Sigma F_y \uparrow^{+} = 0$

$0 = -T - m_{pulley}\,g + R_y - 1800\sin 45$

$\Sigma M_o = I\alpha = F \times d^{+}$ inner radius

$= 1800 \times 0.6 - (T \times 0.3)$

$I\alpha = 1800 \times 0.6 - (T \times 0.3)$ $a = r \times \alpha$

$= 1800 \times 0.6 - (m_g a_y + m_p g)(0.3)$

$I\alpha = 1800 \times 0.6 - (300 \times (0.3\alpha) + (300 \times 9.8))(0.3)$

$\therefore \alpha = 3.43\,rad/s^2$

$a = r \cdot \alpha$

$= 0.3 \times 3.43$

$= 1.03\,ms^{-2}$

- Power and Work
  - → need to know how much power's needed in a system, and how much work the system is doing

- Work
  - → in Joules: defined as $W = \int F \cdot dr$ ← where F + dr are force + position vectors
    in 1D: $W = \int F \, dx$
  - → work is a measure of force and distance

- Power
  - → in Watts
  - → it's the rate of work done

$$P = \frac{dW}{dt} = \frac{d}{dt}\int F \, dx = \frac{d}{dt}\int F v \, dt$$

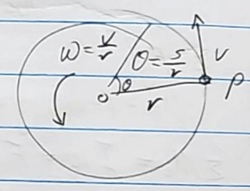
$$= Fv = iV$$ ← for mechanical motion

Power is about Forces distance and time

  - → Power (rotation): for a point mass rotating about a fixed axis (O), rotational mechanical power is:

$$P = Fv = \frac{M_o}{r} \cdot \omega r = M_o \omega$$

M_o = moment (torque)
ω = rotational velocity



- Electrical Power + Efficiency
  - → devices will lose power due to heat, friction etc., limiting am. usable power after each device

$$\eta = \frac{P_{out}}{P_{in}}$$ η = efficiency

Efficiency and Systems

- For task:
  1. Find required electrical Power
     including Mechanical power, estimate efficiency + required electrical power
  2. Control supply of electrical Power
     see electrical lectures

Power supply $\xrightarrow{\text{Electrical Power, } P_e}$ Motor $\xrightarrow{\text{Mechanical Power, } P_m}$ Mechanical System → Load

↓ losses (Power supply) ↓ losses (Motor) ↓ losses (Mechanical System)

- Before designing you need to analyse
- Power train Diagram:

Power supply $\xrightarrow{\text{Electrical Power, } P_e}$ Motor $\xrightarrow{\text{Rotational Power, } P_m}$ Gear Train $\xrightarrow{\text{Rotational Power, } P_g}$ Rotational Load

↓ losses (Power supply) ↓ losses (Motor) ↓ losses (Gear Train)

$$\eta_{motor} = \frac{P_m}{P_e} \qquad \eta_{gears} = \frac{P_g}{P_m}$$

- Example 2: Suppose we have the device as outlined above, with $\eta_{motor} = 0.8$ and $\eta_{gear} = 0.95$. If the rotational speed is 5 rad/s, and the rotational load is 10 Nm, what is the electrical power required from the power supply?

$\eta_{motor} = \frac{P_{mech}}{P_{elec}}$

$\eta_{gears} = \frac{P_{gears}}{P_{motor}}$

$P = M\omega$

$= 10\,Nm \times 5\,rad/s$

$= 50\,W$

$\eta_{total} = \eta_{motor} \times \eta_{gears}$

$\eta_{total} = \frac{P_{rot}}{P_{elec}} \therefore P_{elec} = \frac{P_{rot}}{\eta_{total}}$

$= \frac{P_{rot}}{\eta_{motor} \times \eta_{gears}}$

$\therefore \frac{50}{0.8 \times 0.95} = 67\,W$

Helpful Equations:

→ Angular to linear: $v = \frac{s}{t}$

→ Ang. to lin. velocity: $v = \omega \times r$

→ $F = ma$

→ Mechanical power of linear motion: $P = Fv$

→ Efficiency: $\eta = \frac{P_{out}}{P_{in}}$

→ Ohm's Law: $V = IR$ = voltage = current × resistance

→ Electrical Power: $P = IV$

~ Week 7 - Motors and Machines ~

Gears

→ able to manipulate moment by decreasing force required and increasing distance covered

- large gear: big radius, exerting force on teeth on the edge
- small gear: little radius, can exert a lot more force on the edge

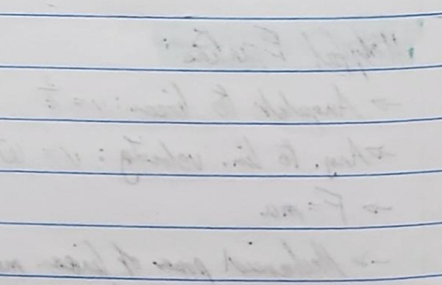
→ mechanical advantage (MA):

$$MA = \frac{Force_{load}}{Force_{effort}} = \frac{N_E}{N_L}$$ related to the no. teeth

$$\Sigma M = 0 = F_E r_E - F_L r_L \;\therefore\; \frac{F_L}{F_E} = \frac{r_E}{r_L} = \frac{N_E}{N_L}$$

→ gears can transmit high forces
→ highly efficient (~~90%~~) (90% +) due to rolling contact
- we are taking advantage of it already moving

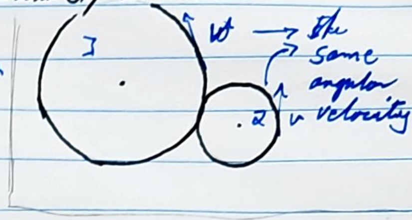
→ commonly used for:
- power transmissions (low-high and high-low)
- reversing direction of rotation
- to move rotational motion along a different axis
- to keep rotation of 2 axles in sync



→ Pinion: smaller of the 2 meshing gears
→ Gear: larger of the 2 gears
→ Pitch Circle: circle on both gears which share same linear speed; the circles meet @ pitch point

Gear Analysis

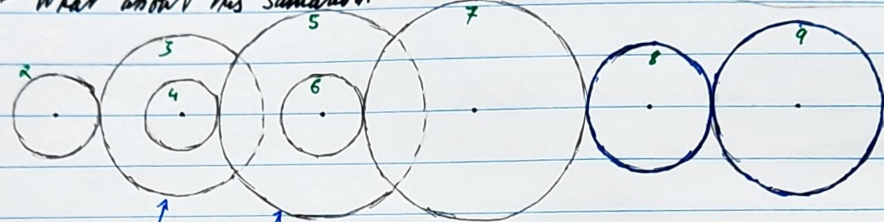
→ assuming roll without slip at the pitch point, the relationship between the angular velocities of the cylinders:



$$\frac{T_2}{T_3} = \frac{\omega_3}{\omega_2} = -\frac{r_2}{r_3} = -\frac{N_2}{N_3}$$

no. teeth on each gear

→ What about this situation?



3+4 and 5+6 are connected

Ratios of 2-7 can be solved:

$$\left|\frac{\omega_7}{\omega_2}\right| = \frac{N_2}{N_3} \times \frac{N_4}{N_5} \times \frac{N_6}{N_7} = \frac{\pi N(\text{drivers})}{\pi N(\text{driven})}$$

Would gear 8 change the overall gear ratio?

$$\eta = \frac{N_2}{N_3} \times \frac{N_4}{N_5} \times \frac{N_6}{\cancel{N_7}} \times \frac{\cancel{N_7}}{\cancel{N_8}} \times \frac{\cancel{N_8}}{N_9}$$

$$= \frac{N_2}{N_3} \times \frac{N_4}{N_5} \times \frac{N_6}{N_9}$$

Spur Gears:

→ 98-99% efficient

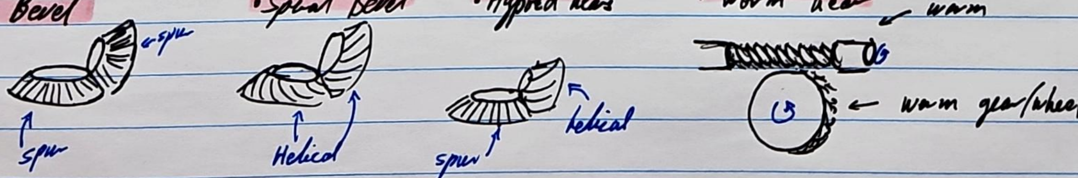
Helical Gears:

→ teeth follow at an angle

→ gears are quieter due to more gradual contact, but experience greater friction

→ 96-98% efficient

- Bevel
- Spiral Bevel
- Hypoid Gears
- Worm Gear

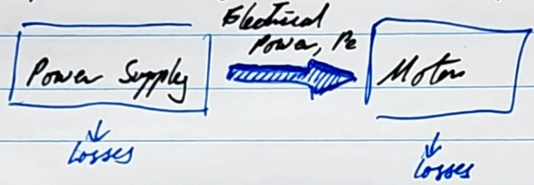


~Week 8 - Electrical Systems~

- Electrical engineering: a field of engineering that deals w/ study and application of electricity, electronics + electromagnetism
- Includes:
  - → generation + distribution
  - → electrical installation
  - → telecommunications
  - → instrumentation + control (robotics, mechatronics, computer software)

Context

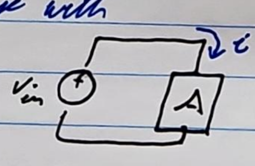
- Looking @ power supply + distribution of power for crane project



- Project Brief:
  - → "Power supplies providing 24 V DC and 3 A; power drawn can't exceed 10 W. Must run off 1 power supply; supply settings can't be changed during test."
    - Direct Current
  - → Electromechanical system w/ FOS between 1 and 2
  1. Find required Electrical Power
  2. Control supply of Electrical Power
     - ↳ How to design circuit to meet specifications?

- Current: rate of flow of charge (Amps)
- Voltage: am. energy in an amount of charge (Volts)
- Power: product of current × voltage: $P = VI$ (Watts)

- Voltage source
  - → produces/dissipates power at a specified voltage with whatever current is required
  - → v_{in} is specified
  - → i varies depending on circuit element A.

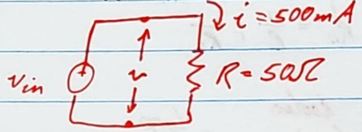


- Resistor: dissipates power so that voltage across terminals is proportional to the current (Ohms, Ω)
  - → handy if e.g. your motor gives 24 V but system only uses 12 V... resistors can eliminate any leftover energy

- Ohm's Law
  - → "voltage is the product of current in a resistor"

$$v = i \cdot R \rightarrow i = \frac{v}{R}$$

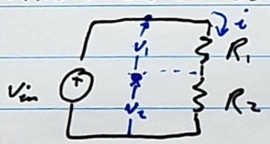
  - → Example 1:



Find v.

$$v = i \cdot R = 50 \times 0.5A = \underline{25V}$$

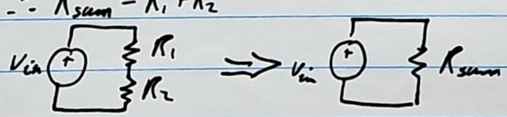
- Resistances in Series



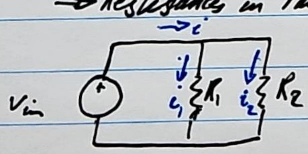
  - voltage drops add to equal voltage: $v = v_1 + v_2$
  - all components share same (equal) current

- Kirchoff's Voltage Law (KVL)
  - → the sum of all voltages = 0
  - → consider equation from above: $v = v_1 + v_2 \rightarrow = R_1 i + R_2 i = (R_1 + R_2) i = R_{sum} i$

$$\therefore R_{sum} = R_1 + R_2$$



- → Resistances in Parallel



  - → Branch currents add to equal total current: $i = i_1 + i_2$
  - → all components share same (equal) voltage

- → Example 2: Find i_{total}.

$v = 12V$
$i_2 = 300mA$
$R_1 = 1.2k\Omega$
$i = ?$

in relation to graph ↑

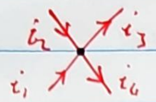
$$i = i_1 + i_2$$

$$v_1 = i_1 \cdot R_1$$

$$i_1 = \frac{v_1}{R_1} = \frac{12V}{1200\Omega} = 10mA$$

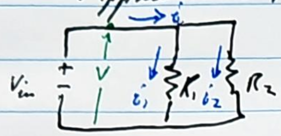
$$\therefore i = i_1 + i_2 = 310mA$$

- Kirchoff's Current Law (KCL)



$i_1 + i_2 = i_3 + i_4$

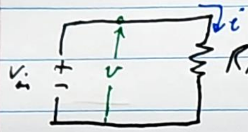
→ Application to Resistors in Parallel:



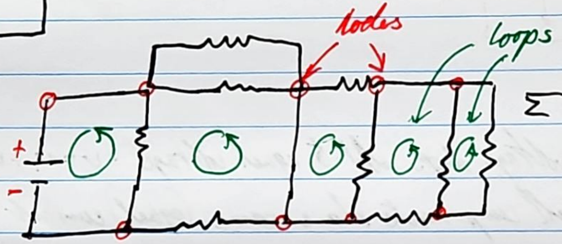
$i = i_1 + i_2 \rightarrow i = \frac{V}{R_1} + \frac{V}{R_2}$

$= V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

$= \frac{V}{R_{11}}$ ← R_{11} = parallel resistors



$\therefore \frac{1}{R_{11}} = \frac{1}{R_1} + \frac{1}{R_2}$



$\Sigma V_{Loop} = 0$