



Home

D&T Theory Notes

Made by Javier (@javierererie)

Sources: Dunman Secondary School Notes

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This document follows the [7059 Syllabus](#) (2025~2026 GCE O-Level Syllabus), or the [K345 Syllabus](#) (2027~ G3 Secondary Education Certificate Syllabus).

Paper	Duration	Assessment Domains			Total
		A Knowledge with Understanding	B Design Thinking Skills	C Design Manipulating Skills	
1 Written Examination	2 hours	25%	10%	5%	40%
2 Design Project	22 weeks	15%	20%	25%	60%
Overall		40%	30%	30%	100%

7059/01 (in entry proof), 2 hours, 80 marks (40%)

Hyperlinks || Weightage

Q1: [Design](#) + [Materials in Design](#) || 26 marks

Q2: [Structure](#) || 18 marks

Q3: [Mechanism](#) || 18 marks

Q4: [Electronics](#) || 18 marks

nooo time to start work



Design

D&T Design Notes

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Sources: Dunman Secondary School Notes, 7059 Syllabus

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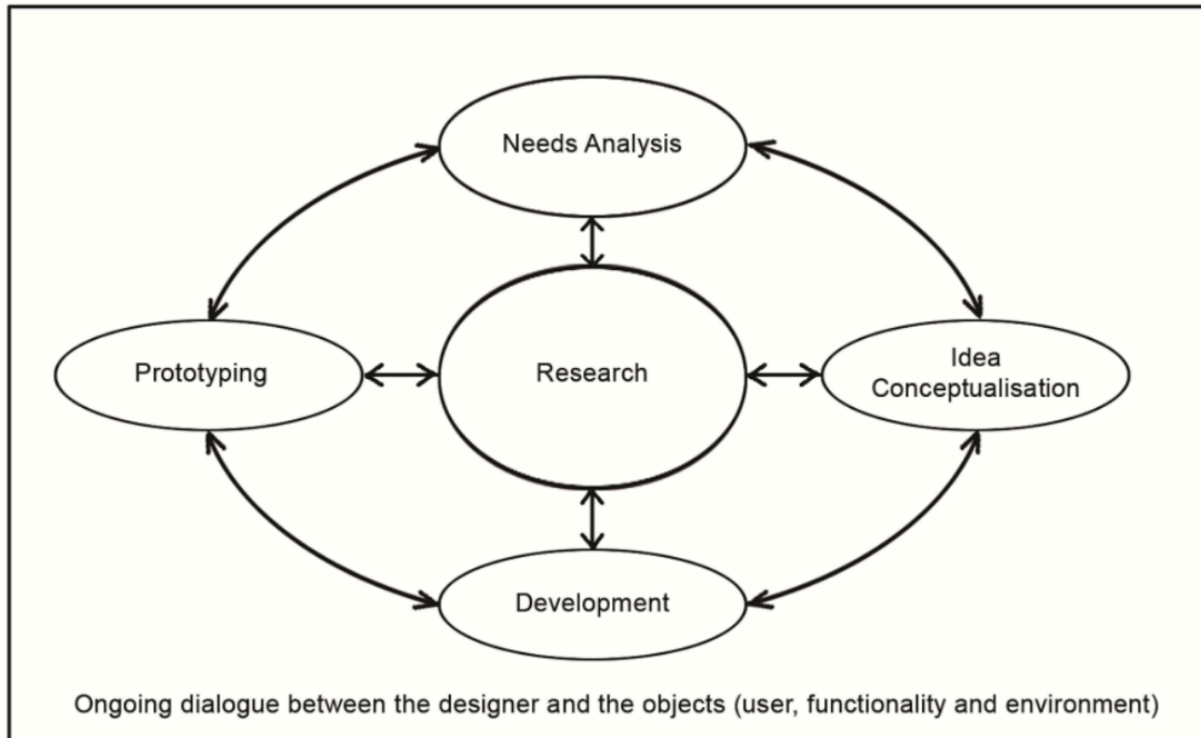
This section may contain resources that can be referenced for **both theory & coursework.**

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[Refer to Materials in Design notes here](#)

The Design Model

Source: SEAB Design & Technology 7059 GCE O-Level Syllabus (2025) Document



The Design Model is the core “basis” of the entire Design process.
You will follow it throughout your entire coursework making process.

Needs Analysis

Identifying Needs

PIES, 5W1H, Product Research, Brainstorming, Mindmapping, Imageboard & Moodboard

PIES	5W1H
• Physical needs • Intellectual needs • Emootional needs • Social needs	• Who - affected? • What - problem? • When - period & duration where problem occurs? • Where - problem found at where? • Why - critical that problem is solved? • How - did problem emerge in the first place / what are the circumstances?
Mindmapping	
• Structure thoughts on paper, showing links between them • Use to analyse theme • After mindmapping, list design opportunities in table to assess pros and cons before concluding	

Problem Situation, Design Brief, Design Specifications

Problem Situation	Design Brief
- Identify with 5W1H <u>Who</u> - target user <u>What</u> - potential problem <u>Where</u> - location <u>Why</u> - reasons leading to problem <u>When</u> - time/period	To design and make a product, for the <u>user/people</u> at <u>place</u> to <u>solve the problem/function</u>.
Design Specifications	
List of attributes of the product - Directly influenced by design considerations - Ensure design and development of a product meets the needs of the target user - Used as a guide for the entire design process by providing clear directions and serves as a reference to the designers.	- Used during: - Ideation - select idea - Development - make suitable design decisions - Evaluation - check if prototype meets DS - Includes critical needs such as: - Aesthetics - Comfort - Size - Safety - Functions - Material
Design Needs	
State a problem and reason with solution (theory)	

Research

Primary/Secondary Data, Observational Research, Product Analysis, Survey

Note: important to make sure info is up to date & applicable to target user!

Primary data	Secondary data
• Data collected by you, comes directly from experiments / contributions from others in discussions and surveys • Example: ◦ Survey ◦ Interview ◦ Observations ◦ Product analysis	• Data collected by someone else, extracted from existing publications or databases • Example: ◦ Internet ◦ Articles ◦ Videos / TV programmes ◦ Statistical information from marketing companies
Observational Research	
• The user looks at an event or activity with an intent to collect information about the problem or user. • Process: 1. Photo-taking / Sketching / Video-recording / Note-taking etc. 2. Write down observations 3. Elaborate problems through writing and sketching 4. Consequence of user's habits / actions	

Product Analysis

Analyse <u>Product</u> : ACCESSFM		Analyse <u>Parts</u>	
<u>Aesthetics</u> Describe looks ➡ Appeal to users? Why? Shape/ colour/ appearance?	<u>Size</u> (L x B x H)mm. Too big/small? Portable?	<u>Function</u> Purpose?	<u>Colour</u> Bright / Dull, & why?
<u>Cost</u> Expensive/Cheap? Will it be a factor for users when buying the product?	<u>Safety</u> Safe to use? Any safety or health concerns when using the products?	<u>Safety / Comfort</u> Comfortable & safe to use? How can you tell? What are the safety features?	<u>Texture</u> Feeling on the surface? Why, & any purpose?
<u>Customer</u> Target users? Why? Addresses the users' needs? Comfortable to use?	<u>Function</u> Purpose of part? Advantage/Disadvantage to have?	<u>Shape</u> Purpose of shape? (e.g. easier to hold/store)	<u>Advantages</u> Positive features of design? Why?
<u>Environment</u> Will the design or materials used impact the environment?	<u>Material and Manufacture</u> Plastic, Metal or Wood? Why? Properties of the material?	<u>Appearance</u> Appealing? Why?	<u>Disadvantages</u> Negative features of design? Why?
- Approach: Identify, Name, and Analyse the parts Sketch to show how the product <u>works</u> & <u>trigger/develop</u> new ideas/solutions Identify the <u>important</u> feature & analysis and summarise learning points at the end of the analysis (may be used for design considerations)		<u>Material</u> Plastic, Metal or Wood? Why? Properties?	<u>Users</u> Target users? Why?

Survey

Questions & Data Representation

- Tools to gather information (needs, habits, etc) about individuals (users), such as their opinions & preferences
- Can be created before or after the product is made.
- Important to craft out the questions properly so responses are useful to use.
- Types of questions: Closed-ended, Structured, Open-ended, Rating
- Present data with:
 - Pie chart
 - Bar graph
 - Summary table
 - Mind maps

Types of Questions	
Closed questions	Structured Questions
• Single, factual response. E.g. What colour are your eyes?	• Break long questions into smaller parts. E.g. Do you own a mobile phone? If your answer to the question was 'yes' then please answer question 1a - 1d. Otherwise, proceed to Q2.
Open-ended questions	Rating questions
• Express opinions freely without being restricted to predefined responses. E.g. What do you like or dislike about this design?	• Indicate an attitude or opinion based on a ranking scale E.g. How would you rate this product? __ Excellent __ Good __ Average __ Poor

Social & Sustainable Design

Socially responsible design

- an attitude that emphasises the **needs & experiences of people > concerns of form or aesthetics**
- may come from **humanist perspectives** emphasising the cultural value & meanings of places
- it ensures that our designs do not negatively impact the environment and society, and instead bring positive benefits to them.

Social Design

- putting people's needs at heart of designing process **rather than just** making a product look aesthetically pleasing
 - Inclusivity

Environmental and Sustainable Design

- Sustainability → preserving earth's natural resources
- **Finite** resources (**cannot** be replaced)
 - Plastics → crude oil
 - Metals → extracted from ores
- **Non-finite** resources (can be replaced)
 - Wood → originates from trees, can be replaced
- **Renewable** resources → replaced at the **same rate** they are used

Methods for sustainability in Design

- Applying the 6Rs when designing: Reduce, Reuse, Recycle, Rethink, Refuse, Repair
- Consider the choice of materials

Ideation Techniques

Brainstorming, Shape borrowing, SCAMPER, Attribute Listing

Brainstorming	Shape borrowing
• Generate a lot of ideas in a short period of time	• Drawing inspiration from surroundings, nature, & things encountered • Shape / form can inspire design of totally different problems / portray emotions • Aesthetics – look and feel of product
SCAMPER	Attribute Listing
• S – Substitute • C – Combine • A – Adapt • M – Modify, magnify, minify • P – Put to other uses • E – Eliminate • R – Reverse, re-arrange Example of SCAMPER on Table Lamp Source: DMN Ideation Technique Notes 	• Generate ideas for a new product based on a set of attributes / features. • Method: ○ Identify product and list its attributes, such as: ■ parts ■ properties ■ qualities ■ design elements ○ Choose interesting or important attributes and think of ways to change each of them ○ Combine these new ideas to create a new product

Detailed Development

CAD Models, Ergonomics, Anthropometric, Interface dimensions, User Feedback

CAD (Computer-aided Design) Models • design with 3D drawing program • Provides realistic view • Can be rendered with different materials and colours • Link with a laser-cutting machine to cut out parts or scale model of design	User Feedback • Feedback from the target user • Helps designers to adjust or improve the design • Determines if the product will be appealing to users
Anthropometric Data • Concerned with size and proportions of human body, such as: ○ height ○ weight ○ hand size ○ maximum reach ○ angles of limbs in various positions	Interface Dimension • Use to obtain product dimension • Use together with anthropometric data ○ Find interface dimension of product & anthropometric dimensions that interacts with the interface ○ Critical dimensions = interface dimensions + anthropometric data
Ergonomics • The study of the design of products so that people can interact with them in a comfortable, safe and efficient way. • E.g.  The angle of the water spout is tilted to ensure the user don't have to tilt his neck too much to the back to ensure better comfort of the user during drinking The shape of the bottle fits the curvature of the user's hand grip so that the user can hold the bottle comfortably and does not slip off easily.	

Using mock-ups to design

Sketch/Block/Development Models, CAD, 3D Printed Models & Documentation

Purposes of modelling • Ensure design looks right from different angles (in terms of proportion & balance) • Design works as per design specifications • Check if ergonomics of design are acceptable • Evaluate the safety of the design • Check if the parts fitted together • Can use it for user's feedback (ref. to DD)	
Sketch Models • quickly constructed to visualise idea in 3D • basic impression of idea, useful to communicate design to others • can use paper, cardboard, foam board & quick construction methods (e.g. hot melt glue, tape)	Computer Model (CAD) & 3D Printing • definition is the same as DD • 3D Printer creates object by 'printing' in very thin layers, one at a time • Material pressed out from heated nozzle onto build plate
Block Models • determine shape & dimensions of design • Test with interface (main functions) and user (ergonomics)	
Development / Experimental Models • When design ideas start taking shape, need to work out on finer details • Use to check if design works as expected	

Model testing and documentation

(note: more coursework-related than actual theory)

When you are **testing** your model, you should:

- take as many pictures as possible in **different angles and parts**, zooming in and out whenever necessary.

When you are **documenting** your model, you should:

- be **purposeful** in your documentation. comment on:
 - how you test for ergonomics & anthropology
 - how you joined the different parts of the model together
 - testing its function with the interface
 - testing its stability, mechanism, shapes, and safety

These should lead to **insightful decision making**

- when evaluating your testing, explain how you tested, and what the results of your testing mean.

This will also allow you to show the **development of your design ideas**

- if there are any issues in your testing, you should make the necessary changes and update the new dimensions as needed

Model materials

Cardboard, Foam, Paper, Objects

Cardboard	Foam
• Cut with scissors or pen knife • Joining parts with masking tape or clear tape • Benefits ○ Durable ○ Made up of wood fibers, recyclable and sustainable ○ Can be cut and folded at different angles to make many different sized and shaped box designs • Drawbacks ○ Difficult to bend into irregular shapes	• Thicker • Cut with penknife or scroll saw machine + sandpaper • Join parts with hot melt glue • Benefits ○ Light & very easy to cut ○ Easily moulded into different forms • Drawbacks ○ Cannot spray paint as will eat into Styrofoam ○ Time-consuming to form into irregular shapes ○ Must wear mask to prevent particles from entering lungs
Paper	Objects
• Cut paper with scissors or pen knife • Join parts with masking tape or clear tape • Benefits ○ Light and thinner than cardboard ○ Can be rolled into circular shape ○ Flexible and can form into irregular shapes easily and quickly • Drawbacks ○ Not able to support heavy weight ○ Tear easily unless multiple layers used	• E.g. Satay sticks, ice-cream sticks, woods, metals, plastic, recycled parts from spoilt products

Evaluation

Evaluate Existing Products, Design Solutions, Survey/Interview, PMI & SWOT

Evaluating Existing Products	Evaluating Design Solutions	Evaluate by Surveys / Interviews
• Compare products against each other or taking them apart • Can be analysed in terms of: ○ Functions, Materials, Manufacture, Ergonomics, Aesthetics, Cost etc. Refer to Product Analysis (Research)	• A good evaluation reveals: ○ How well solution meets the needs identified in the design brief ○ How the design can be improved or made ○ How well the solution satisfies the design specifications Example: Evaluating against design specifications	• Find out reactions of intended users (whether they like, buy or use it), and suggestions to improve solution One way is by using Evaluation forms • used to gather feedback from others about an idea or product • Information recorded in a table, which then can be used to present findings to use to explain the results and conclusions of surveys or interviews

Decision-making: PMI & SWOT

PMI Techniques	SWOT Analysis
• Plus • Minus • Interesting • Used to evaluate ideas • Steps 1. Create a row of Plus heading, write down all the positive points of the ideas. 2. Create a row of Minus heading, write down all the negative points. 3. Create a row of Interesting heading, write down any implications (+ve/-ve) of the ideas. 4. Give a score for all the points of range -10 to 10. 5. Tabulate and choose the one with the highest score.	• Strength • Weakness • Opportunity • Threats • Decision-making method according to: ○ Strength / weaknesses of an idea ○ Opportunities / threats that result from it • Evaluate ideas and problems • Steps: 1. Create a table of selected Ideas for evaluation 2. Perform SWOT Analysis for each Idea 3. Find out which is the most ideal solutions to work on. SWOT Analysis Questions: Strengths: • What are the advantages of the idea? • What does it do well? Weaknesses: • What could be improved? • What is done badly / should be avoided? Threats: • What obstacles do you face? • What are others doing that might affect your idea? • Are there future changes that could threaten the success of the idea? Opportunities: • Where are the good opportunities facing you? • Are there any interesting trends you are aware of?

[Refer to Materials in Design notes here](#)

Yay end of Design



Materials in Design

D&T Materials in Design Notes

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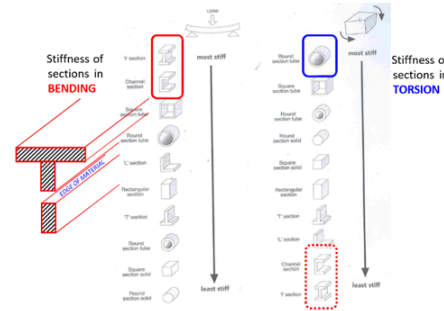
NOTE: This sub-topic will be tested under Design (Q1)

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Materials in Design

Material Properties

Strength, Tensile, Hardness, Toughness, Rigidity, Elasticity, Ductility, Malleability, Stiffness

Strength material's ability to resist a force without breaking	Tensile maximum force the material can stand in tension without breaking	Hardness resistance of the material to cutting / surface indentation
Toughness - amount of energy the material can absorb without breaking - ability to withstand shocks - opposite of brittleness	Rigidity ability of the structure to withstand bending / swaying	Elasticity - length to which the material can be stretched and still return to its original length when released elastic limit: the point beyond which it remains stretched
Ductility length of which the material can be stretched without breaking	Malleability amount of shaping that can be done by hammering / rolling / pressing without the material breaking	Stiffness - depends on the cross-sectional area of the shape - picture below indicates stiffness in bending/torsion, need to roughly know 

Summary of Materials

Wood

Aesthetics	Properties	Types of Wood	
		Natural Timber	Processed Wood
- wood grain patterns - can be finished with lacquer, wood stains, laminates	- light, strong, stiff but may warp if subjected to heavy load - renewable resource	- attractive grain patterns - might have wood defects like shakes, splits, shrinkage - length of wood depends on length of timber	- stronger than natural timber of same thickness - no wood defects and shrinkages as it is treated - available in larger sizes as compared to solid timber
		- jelutong - meranti - pine	- plywood - mdf - veneer

Questions, all in terms of **sustainability** (extracted from DMN Materials in Design Slides):

- When to use plywood over natural wood?
 - stronger than natural wood of same thickness, hence use thinner to achieve required strength (reduces amount of materials used)
- When to use MDF over natural wood?
 - made with left-overs of timber/wood shavings normally discarded (recycle materials)
- When to use veneer-layered wood over natural wood?
 - veneered wood with layer of attractive wood grain pattern can be glued onto MDF or plywood, instead of using a solid piece of natural timber (reduces amount of materials used)

<u>Natural timber</u>	Aesthetics	Properties	Uses
Jelutong	light straw colour straight grains fine & even texture	Soft Not durable	Carvings Picture frames Toys
Meranti	dark reddish brown colour interlocking grains coarse and even texture	Strong Durable	Furniture Railings Door / Window Frames
Pine	honey-coloured to reddish brown heartwood straight grains clearly-defined growth rings	Strong Moderately durable	Furniture Flooring Indoor Handrails

<u>Processed wood</u>	Aesthetics	Properties	Uses
Plywood	Edge bending at side of wood	Increased stability High strength to weight ratio	Floors Walls / Roofs (home construction) Fencing
Medium Density Fiberboard (MDF)	Stronger & denser	Stiff Easily machined	Display / Wall cabinets Storage unit
Veneer	ref. properties	Thinner than 3mm Glued onto core panels	Doors Top / Panel of cabinets Parquet floors Furniture

Advantages vs Disadvantages of Processed Woods

<u>Processed wood</u>	Advantages	Disadvantages
Plywood	dimensionally stable, do not warp high strength , glued together w. grains at 90° of one another	splinter at the ends less attractive than solid wood
MDF	dimensionally stable, do not warp made out of wood residuals , more environmentally-friendly	not water-resistant when exposed to moisture (expands & swells) made from fine particles ➡ does not handle screws and nails well
Chipboard / Particle Board	dimensionally stable, do not warp made out of scraps , more environmentally-friendly	low strength , cannot support heavy loads not water-resistant when exposed to moisture (expands & swells)

Metals

Properties	Types of Metals		
	<u>Ferrous Metal</u>	<u>Non-ferrous Metal</u>	Alloys
- when freshly prepared, polished, or fractured, shows lustrous appearance - conducts electricity & heat relatively well - typically malleable or ductile	- iron - magnetic - little resistance to corrosion	- no iron - non-magnetic - more resistant to corrosion	- metal made by combining two or more metallic elements for greater strength or resistance to corrosion - copper +
	- mild steel - high carbon steel	- aluminium - copper - zinc - tin - lead	- bronze (+ zinc) - brass (+ tin) - pewter (+ tin + antimony) - duralumin (+ aluminium + manganese)

<u>Ferrous</u> metals	Properties	Uses
Mild Steel	Strong Rusts easily	Nuts Bolts and rivets Metal gates Car body panels
High Carbon Steel	Brittle Harder than mild steel	Marking out / Cutting tools (i.e. scribes, files, hacksaw blades)

Alloys (copper + ..)	Properties	Uses
Bronze (+ tin)	Reddish-yellow Corrosion resistant Easy to machine	Gears Bearings Statues Ship propellers Belts
Brass (+ zinc)	Golden-yellow Good conductor of heat & electricity Easy to machine & solder	Hinges Decorative artefacts Musical instruments Barrel bolts
Pewter (+tin + antimony)	Silvery (colour) Soft Malleable	Ornaments (e.g. Plaques, vases, mugs, souvenirs)
Duralumin (+ aluminium + manganese)	Greyish-white Light but strong	Portable ladders, door and window frames, aircraft & vehicle parts

<u>Non-ferrous</u> metals	Properties	Uses
Aluminium	Greyish-white Light Good conductor of heat & electricity	Drink cans Cooking foil Road signs Engine parts
Copper	Reddish-brown Excellent conductor of heat & electricity	Electrical fittings & cables Water pipes Cooking utensils
Zinc	Silvery-blue Ductile Good corrosion resistance	Batteries Manufacture of galvanised iron Rust-proof paints

<u>Non-ferrous</u> metals	Properties	Uses
Tin	Silvery-white Soft Non-toxic	Coating or printed circuit boards Tinplate of food cans
Lead	Bluish-grey Heavy but soft Toxic Resistant to corrosion	Core of batteries Solders Fishing weights Protection against x-rays & radiation

Plastic

Aesthetics	Properties	Types of Plastics	
		Thermoplastic (TP)	Thermosets (TS)
• available in many different colours • good surface finish	• many able to withstand sudden shock without breaking	• can be reheated/softened/formed many times	• can be heated/softened/formed only once
		• nylon • polythene / polyethylene (PE): low/high density • polyvinyl chloride (pvc): flexible/rigid • polypropylene (pp) • acrylic • polystyrene: sheet/expanded	• polyester resin / glass reinforced polyester (grp) • melamine • urea formaldehyde • phenol formaldehyde

side note: “TS” does not mean “TS PMO” unless you feel that way for d&t and/or this topic...

TP	Aesthetics	Properties	Uses
Nylon	variety of colours	Tough Durable Highly resistant to chemicals & high temperatures	Gears Bristles Rope
Low density Polythene / PE	variety of colours from waxy and milky	Soft Very tough & flexible electricity & chemical resistant	Garbage / carrier bags Squeeze bottles
High density Polythene / PE		Fairly stiff / hard Resistant to impact & chemicals	Buckets Pails Bleaching bottles Toys structure
Flexible PVC	variety of colours with gloss or matt finish	Soft Flexible Good electrical insulation	Waterproof clothing Swimming floats Garden hose
Rigid PVC		Light Stiff Hard Strong with good abrasive resistance	Water pipes Electrical trunking

TP	Aesthetics	Properties	Uses
Polypropylene (PP)	variety of colours from waxy and milky	Flexible High impact strength Good electrical resistance	Crates Chairs
Acrylic	variety of colours from clear to opaque	Hard Tough & durable	Display signs Lenses Jewellery Furniture
Polystyrene sheet	variety of colours	Cheap Hard Brittle	Disposable cutlery Plates and cups Modelling kits
Expanded Polystyrene		Light Shock absorbant Good sound & heat insulation	Packaging Buoyancy aids

TS	Appearance	Properties	Uses
Polyester resin / Glass reinforced polyester (GRP)	?	Use catalyst to speed up hardening process Use with fibreglass to create GRP (strong, rigid)	Hard surface coat for protection or repair
Melamine	Clear Variety of colours	Very durable & strong Resistant to heat & scratches	Non-breakable tableware Buttons
Urea Formaldehyde	White and cream colors	Stiff & hard Resistant to heat & electricity	Toilet seat Electrical casing
Phenol Formaldehyde	Black and brown colours	Strong Hard & rigid Resistant to heat & electricity	Knobs Pan handles Electric meter casing Billiard balls

Questions, all in terms of **sustainability** (*extracted from DMN Materials in Design Slides*):

- When will **natural wood** be considered **unsustainable**?
 - when **deforestation** is considered
- When will **wood** be considered more sustainable than metal?
 - wood is a renewable material and can grow back on trees, but metal on Earth is limited
- When will **metal** be considered more sustainable than plastic?
 - metal can **almost always be recycled** and is **more commonly recycled** than plastics
 - however, some **toxic heavy metals** (like cadmium, lead, nickel, mercury found in handphoned) may also cause **pollution** to the Earth when **not disposed properly**

yay end of materials



Structure

D&T Structure Notes

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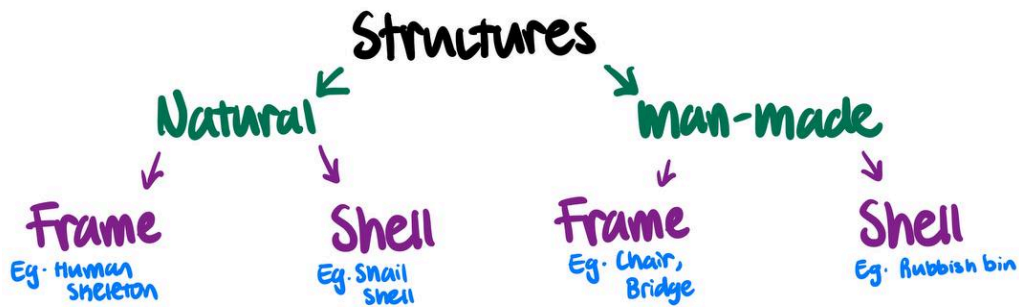
What is Structure?

- An object that supports its **self-weight** and **external loads without collapsing**.

Purposes	Functions
• resist forces • hold different parts together • not collapse during usage	• support • span • contain • protect

Types of Structure

Note: Focus on man-made (usually tested)

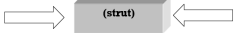
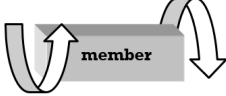
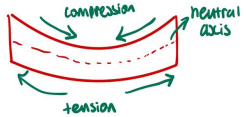


- **Frame** (support/span) – Consists of a Framework, strong with minimal materials used
 - made of members **with joints**
- **Shell** (contain/protect) – Outer layer provide strength
 - usually curved, **no joints**

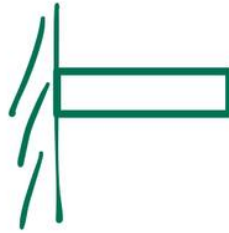
Types of Forces

Static (stationary) constant size / direction / position e.g. plates drying on rack	Dynamic (moving) changing size / direction / position e.g. wind blowing on building	External forces acting on structure from outside e.g. book resting on table	Internal forces act within structure to resist external forces e.g. ball being squeezed
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Internal Forces

Compression squeezed e.g. sitting on chair also known as a strut 	Tension stretched e.g. rope also known as a tie 	Torsion rotary/twisted e.g. fan 	Shear slide past e/o e.g. scissors 	Bending deflected compression, tension, and neutral axis also known as a beam 
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Types of Beams

1. Simply Supported Beam 	2. Cantilever Beam a. supported at one end only 
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Structure in Equilibrium

Uses concept of Turning Effects of Forces (Moments) – Physics students have advantage Lol

- Equilibrium when all forces and moments acting upon it are **balanced**
 - **Total upward forces = Total downward forces**
 - **Total clockwise moments = Total anti-clockwise moments**
- The moment of a force is the tendency to cause a body to rotate about a specific point or fulcrum
 - Moment (Nm) = Force (J) × Perpendicular distance from fulcrum (m)
 - calculations shouldn't be tested but good to know
 - apply more of this inside the mechanism topic!

Structural Failure

- **Unable to resist** the forces acting on/within it.
- **Unstable / deformed / break apart.**

Possible reasons:

- wrong design calculation
- excessive loads
- joint failure
- defective construction (poor workmanship)
- wrong choice in the use of materials

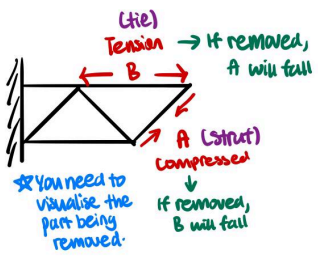
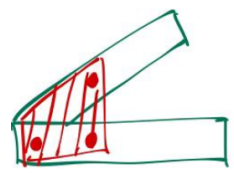
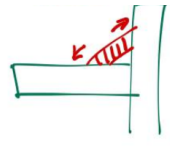
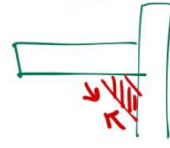
How to prevent it? Reinforce structures!

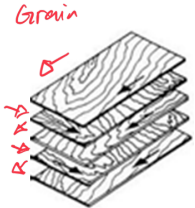
Reinforcing Structures

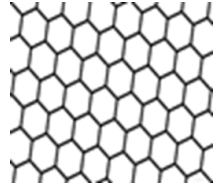
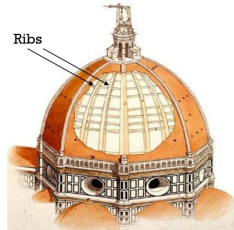
- for **rigidity** so that it can withstand deformation / bending

Types of reinforced structures

Triangulation, Stiffened Folds, Lamination, Honeycomb, Ribs, Gusset Plate, Braces & Webs

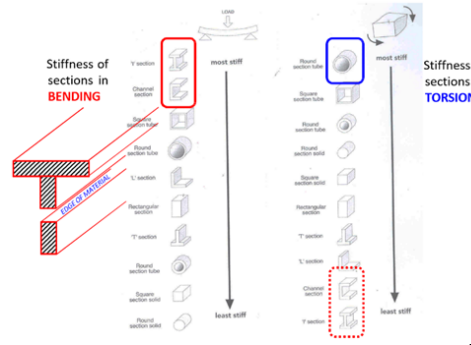
Triangulation		Joint	
Triangulation (Strut & Tie) 	triangle → strong/rigid → does not deform/bend easily e.g. Truss	Gusset plates 	add strength/support to joints increase in contact area of joint & distribute stress more evenly plates secured by bolts & nuts e.g. joints in frame structure → bridge, roof
		Braces / Webs tie  strut 	add strength to joint add support to structure e.g. wall shelves, street lamps, tripod stand legs note: need to show methods to install the brace e.g. nut & bolt, nails, welding (metals)

Body	
Stiffened folds 	weak thin sheets, stiffened by folds/rolls e.g. trays, disposable plates
Lamination 	thin sheets of wood glued one over the other with the grains of each layer at 90° to the other. strengthen soft material using outer hard material e.g. plywood advantage: - good strength to weight ratio - greater flexibility in shape design over solid timber - stable, less prone to bending/warping

Body	
Honeycomb 	strong compression very light air → poor heat/sound conductor e.g. door, carton boxes
Ribs 	strong & light add strength to walls → prevent walls from caving in stiffeners e.g. aircraft wing, sheltered walkway, bus stop shelter, roof dome

Structural Properties

Strength, Hardness, Toughness, Elasticity, Ductility, Malleable, Stiffness
Refer to specific materials [here](#).

Strength	Hardness	Toughness	Elasticity
resist forces without breaking	resist cutting / scratching / wearing off	resist/withstand impact without breaking brittle material → breaks easily upon impact	return to its original length after being deformed
Ductility	Malleability	Stiffness	
pulled apart without breaking	shaped/bent without breaking	ability to resist deformation by an applied force depends on the cross-sectional shape of a material picture below shows stiffness in bending & torsion (should roughly know)	 The diagram illustrates the relative stiffness of various cross-sections under two conditions: bending and torsion. On the left, a chart titled 'Stiffness of sections in BENDING' shows that an I-section is the most stiff, followed by a channel section, square hollow section, round hollow tube, C-section, rectangular hollow section, T-section, round section tube, square section solid, round section solid, and I-section as the least stiff. On the right, a chart titled 'Stiffness sections TORSION' shows that a round section solid is the most stiff, followed by round hollow tube, square hollow section, rectangular hollow section, T-section, C-section, square section solid, round section solid, and I-section as the least stiff. A red box highlights the I-section in the bending chart, and a blue box highlights the round section solid in the torsion chart. A red arrow points to the I-section in the bending chart with the text 'axis of rotation'.

yay end of structure



Mechanism

D&T Mechanism Notes

Made by Javier (@javierererie)

Sources: Dunman Secondary School Notes

View this document in PRINT VIEW for best experience.

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What are Mechanisms?

- used to change one kind of motion into another
- simplifies our tasks by making use of our effort more effectively
- function: transform input motion by transferring, converting or controlling the motion in order to get the work done (Ref. [Motions](#))

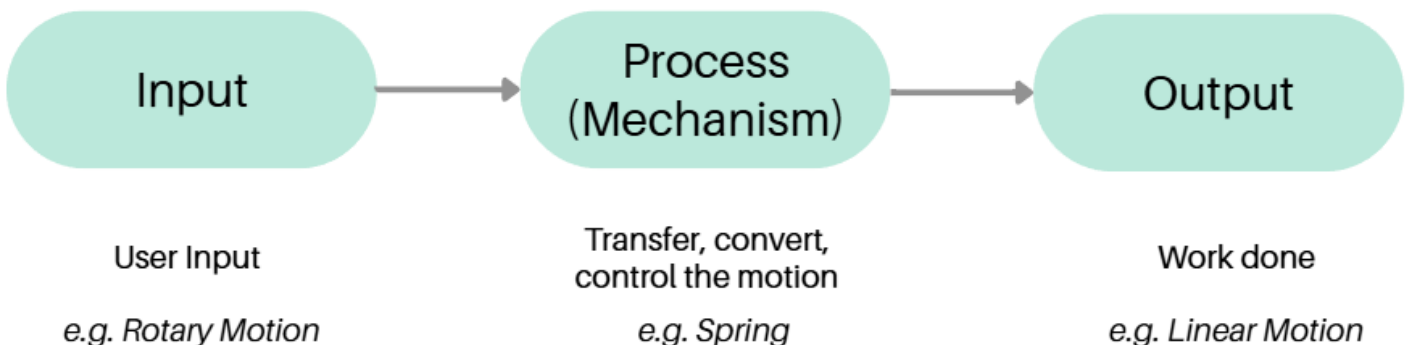
Basic Principle of Mechanisms

- energy change in terms of **motion**
 - e.g. Pedalling action by user → movement of bicycle over distance

Motions

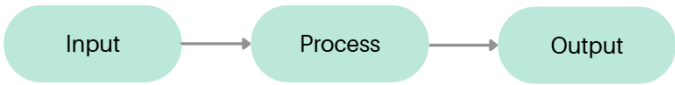
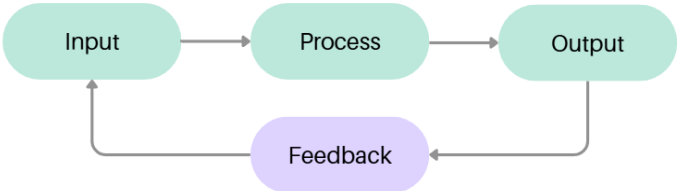
One-directional		Two-directional	
Linear	Rotary	Oscillating	Reciprocating
motion in a straight line does not change direction e.g. MRT moving on a straight track Symbol: 	circular motion about a fixed point e.g. fan Symbol: 	back and forth motion in an arc about a pivot e.g. Gears, Metronome, pendulum Symbol: 	back and forth or up and down linear motion Symbol: 

Application in Mechanism (Input/Output)



Note: understand how the product is used first before writing down the process flowchart / determining the motion conversion at the input/output.

Control Systems

Open-loop Control System	Closed-loop Control System
 <pre> graph LR Input([Input]) --> Process([Process]) Process --> Output([Output]) </pre> - Input unaffected by output (no feedback loop) - accuracy of the system depends on user experience Example (just understand the idea): Toaster Example:  <pre> graph LR Input([Input]) --> Process([Process]) Process --> Output([Output]) </pre> Input: User set timing for toaster Process: Toaster will heat up the bread according to the set timing Output: Bread is toasted <i>How well the bread is toasted depends on the user experience i.e. it is not affected by environmental changes</i>	 <pre> graph LR Input([Input]) --> Process([Process]) Process --> Output([Output]) Output --> Feedback([Feedback]) Feedback --> Input </pre> - output is fed back to the input using a feedback loop - input is adjusted based on the desired output required Example (its electronics but it will do): Air Conditioning Unit Example:  <pre> graph LR Input([Input]) --> Process([Process]) Process --> Output([Output]) Output --> Feedback([Feedback]) Feedback --> Input </pre> Input: When temperature reaches above setting, compressor unit turns on Process: Air Conditioner blows cold air out of the unit Output: Room Temperature is measured continuously Feedback: Temperature of the room <i>Input will adjust accordingly to the environmental changes based on the feedback loop</i>

Cable Control System

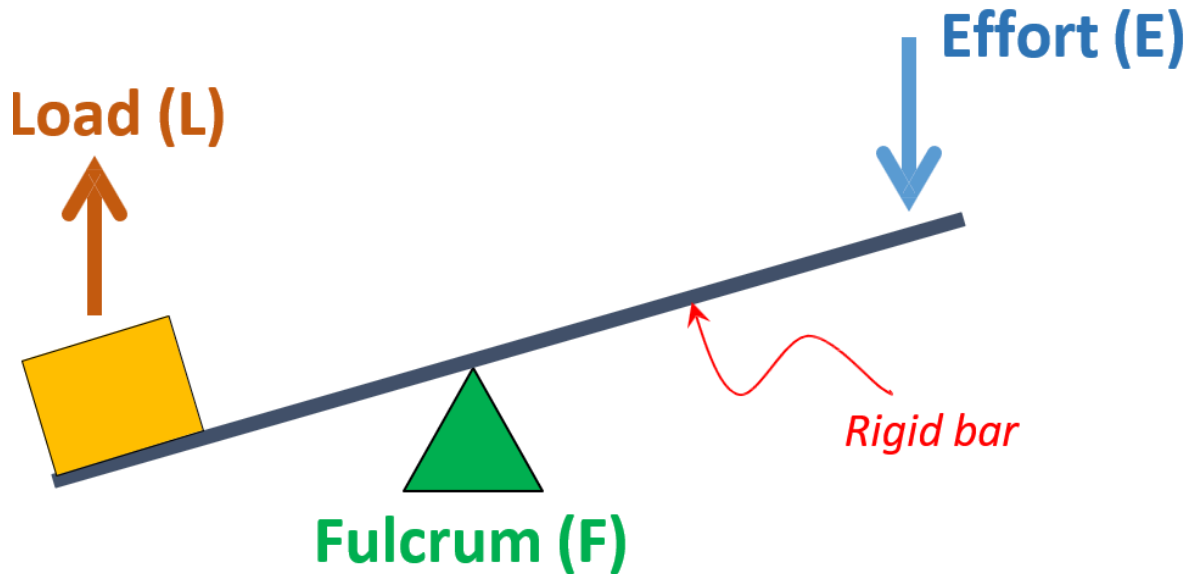
- used in bicycle brakes & car hand brakes

Advantages	Disadvantages
- flexible - take up less space & are lighter than rods and levers	- flexible – offers limited precision - produces only tension forces, cannot be used to push a load

Levers

Uses concept of Turning Effects of Forces (Moments) – Physics students have advantage Lol

- a rigid bar resting on a pivot called the fulcrum, and arranged such that effort is used to move a load
- A lever is a mechanism when it has an **Effort (E)**, **Fulcrum (F)**, and **Load (L)**.



Classes of Levers: FLE

Numbered class lever dependent on position of letter. i.e. F – 1st Letter of FLE, 1st class, etc.

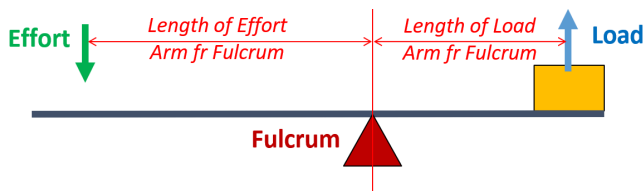
Classes of Levers: FLE		
Class 1: F Between L & E	Class 2: L Between F & E	Class 3: E Between F & L
Diagram showing a horizontal bar with a red triangle fulcrum in the center. A blue trapezoid load is on the left end, and a purple arrow effort is on the right end.	Diagram showing a horizontal bar with a red triangle fulcrum at the left end. A blue trapezoid load is in the middle, and a purple arrow effort is at the right end.	Diagram showing a horizontal bar with a red triangle fulcrum at the left end. A purple arrow effort is in the middle, and a blue trapezoid load is at the right end.

Mechanical Advantage

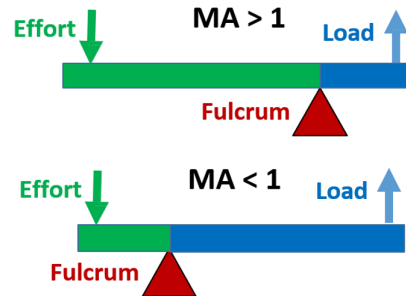
- measure of how a simple machine multiply a force
- larger MA = lesser effort needed to lift a load
- note: need to understand the concept of it, calculations unlikely to be tested

$$\text{Mechanical Advantage (MA)} = \frac{\text{Length of Effort arm}}{\text{Length of Load arm}} = \frac{\text{Load (Output Force)}}{\text{Effort (Input Force)}}$$

↑ Length of Effort arm = ↑ MA

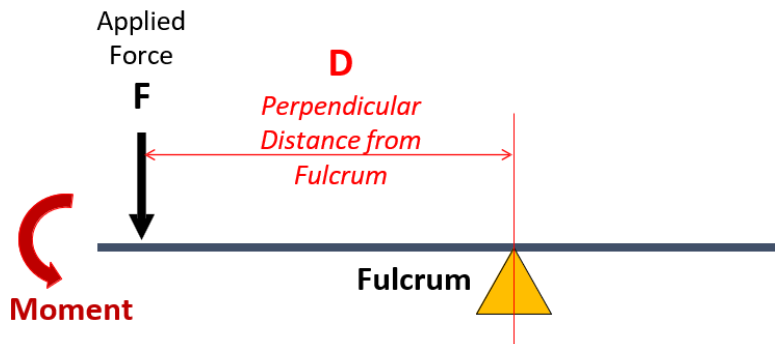


When Effort > Load, MA > 1.
When Effort < Load, MA < 1.



Moment (Turning Force)

- When force (aka the moment/torque) applied to a lever, it causes lever to turn
- Moments = Force × Perpendicular distance
 - note: calculations unlikely to be tested



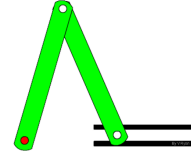
Velocity Ratio

- ratio of distance moved by effort over distance moved by load
 - note: calculations unlikely to be tested

$$\text{Velocity Ratio (VR)} = \frac{\text{Distance moved by Effort}}{\text{Distance moved by Load}}$$

Linkages

- two or more levers joined together
- application
 - scissors platform
 - foot-operated bin
 - car park barrier

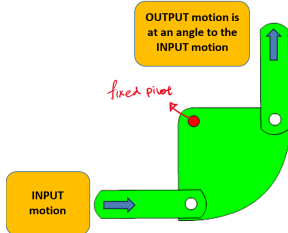


Functions

- change direction of a motion

Example: Bell Crank

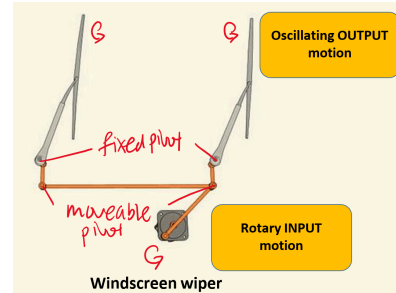
- Transmits motion through an angle
- Can be in an L-shape



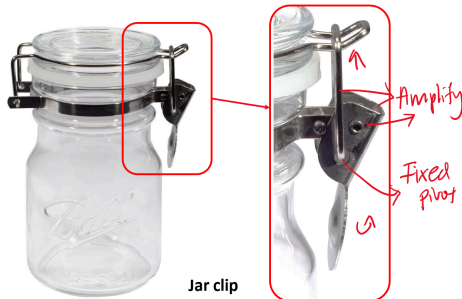
- change type of motion

Example: Rotary → Oscillating motion

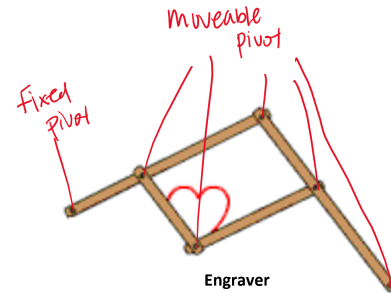
- take note of fixed/moving pivots



- increase size of force

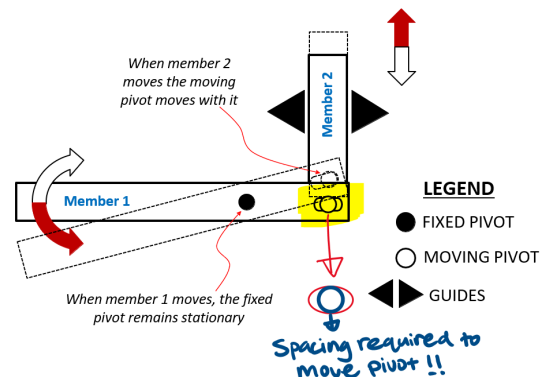


- amplify movement

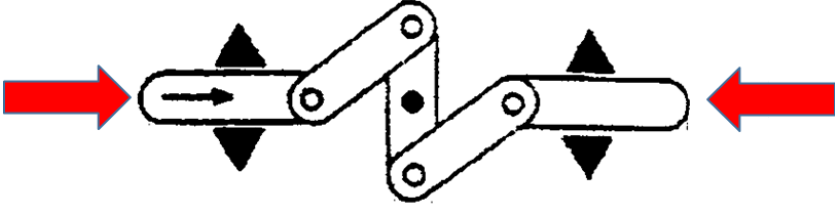
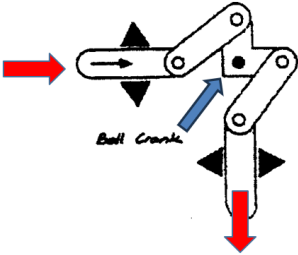
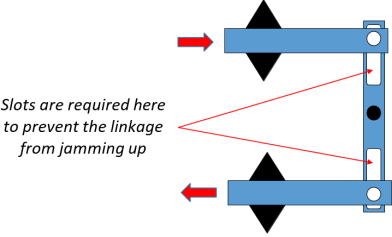


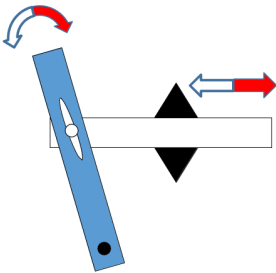
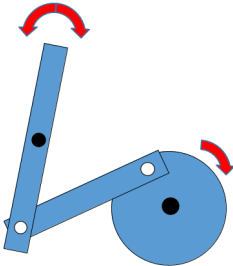
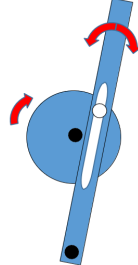
Parts of a Linkage

- fixed pivot (solid dot)
- moving pivot (hollow dot)
- guides – force member to be linear (triangles in between member 2)



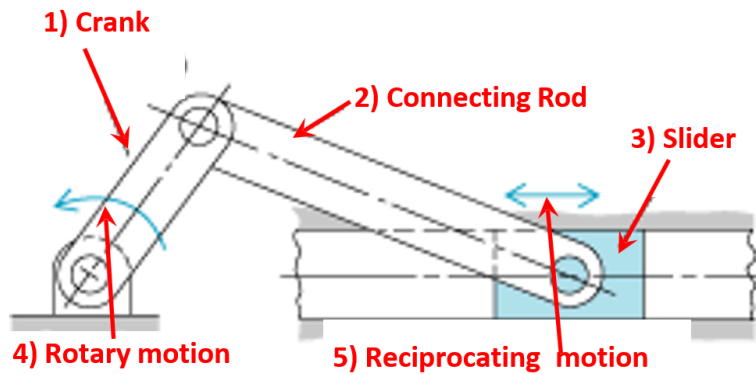
Types of Linkages

No	Diagram Representation	
1		
2		Bell Crank is L-Shaped
3		slots required for the linkage to move

No	Diagram Representation	
4		Since input movement can be forward or backwards , need to differentiate input/output arrows (Ref. White/Red Arrows)
5a		Movement is continuous , no need to differentiate the arrow diagram (Ref. Red Arrows)
5b		

Crank & Slider

- crank attached to a slider by a connecting rod
 - crank – lever attached perpendicular to a rotating shaft



Application

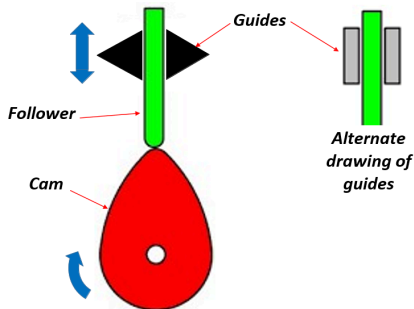
Power Hack Saw	Water Pumps
POWER HACK SAW The diagram shows a power hack saw. A crank is connected to a connecting rod, which is attached to a slider. The slider moves vertically along a guide. Two pulley wheels are shown on the left, connected by a belt. The mechanism is labeled with 'crank', 'Connecting rod', 'slider', and 'TWO PULLEY WHEELS'. The signature 'By V.Ryan' is visible at the bottom right of the diagram.	WATER PUMPS The diagram shows a water pump mechanism. A crank is connected to a connecting rod, which is attached to a slider. The slider moves vertically within a cylinder. A pulley wheel is connected to a motor and pulley via a pulley belt. The mechanism is labeled with 'crank', 'PULLEY WHEEL', 'PULLEY BELT', 'MOTOR AND PULLEY', 'CONNECTING ROD', 'slider', 'CYLINDER', 'WATER SPOUT', and 'WATER IN'.

Cams

- specially shaped piece of material fitted to a rotating shaft
- used with a **follower**
- application
 - toys
 - combustion engine
 - cam lock on bicycle (quick adjustment of seat & handle bar height)
 - cam lock on work piece during drilling (quick & secure)

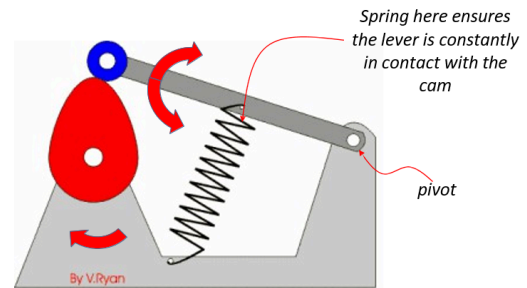
Rotary → Reciprocating

- as the cam rotates (rotary), the follower moves up and down (reciprocating)



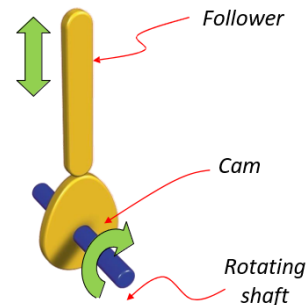
Rotary → Oscillating

- follower pivoted at one end

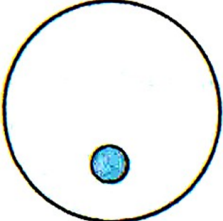
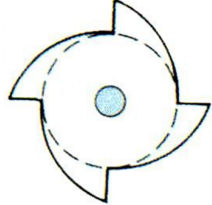
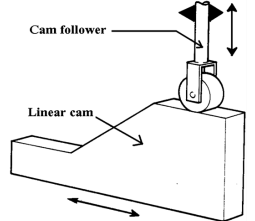


Parts of a Cam

- Cam
- Follower
- Guides (in between follower)

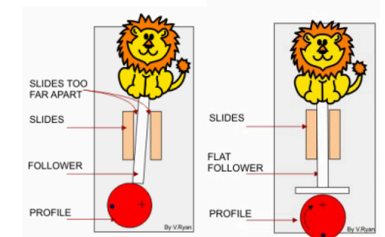


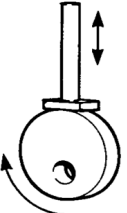
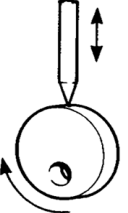
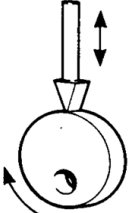
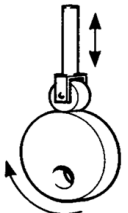
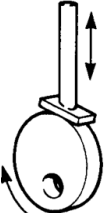
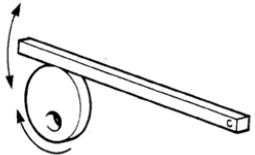
Cam Shapes

Pear	Ecentric	Snail	Multi-ratchet	Heart	Linear Cam
					
	Unconventional as midpoint not at center.	Cam can only turn clockwise, otherwise flat drop with crash into follower.		Require Point/Knife follower to follow profile of cam accurately	Application: Rack & Pinion Mechanism

Follower Shape

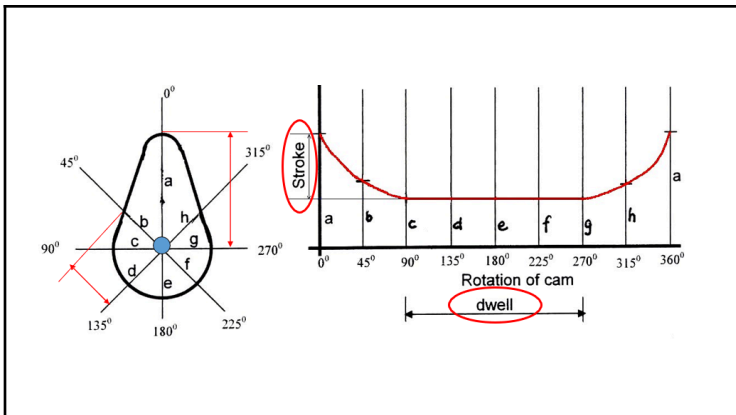
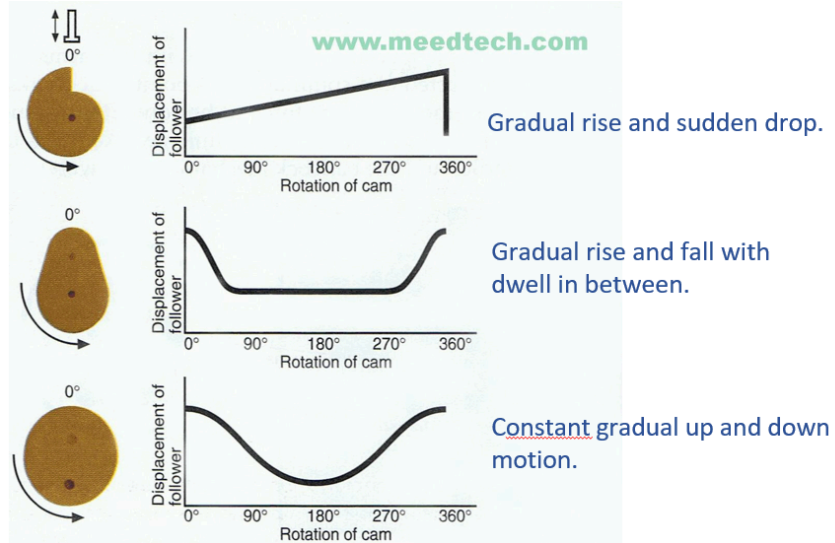
- Key consideration when selecting:
 - Follow profile of cam accurately while minimising wear.
 - Should allow smoother motion by ensuring that profile does not cause a jam between follower and guides. (Ref. to the image on the right)



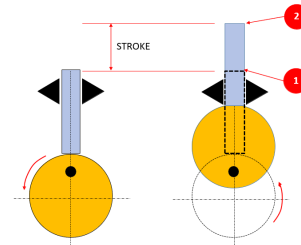
Flat	Point	Knife	Roller	Sloping	Radial Arm
					

Distance-Rotation Graph

- shows distance travelled against rotation of cam
 - Example below shows Snail, Pear & Eccentric Cams

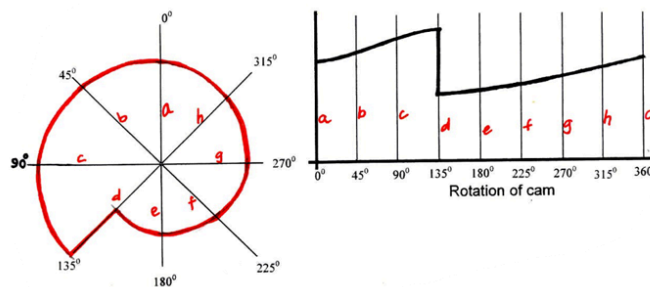


Stroke: distance between **highest (2)** and **lowest (1)** points of cam (Ref. below)



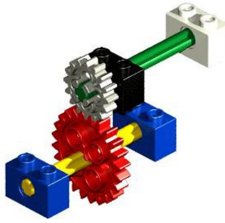
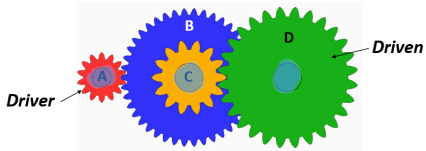
Dwell: period when follower does not move

Example of distance-rotation graph based on snail cam



Gears

- wheel with teeth around its edge
- combined in different ways for:
 - **controlling** speed
 - **transmitting** turning force
 - **changing direction** of rotations of motion

Simple Gear	Compound Gear
• gear fixed to a shaft 	• two or more gears fixed to a shaft 
Simple Gear Train • simple gears in mesh 	Compound Gear Train • compound gears in mesh • Used when: ○ high speed reduction required ○ space limited between driver and driven shaft 

Gears in mesh

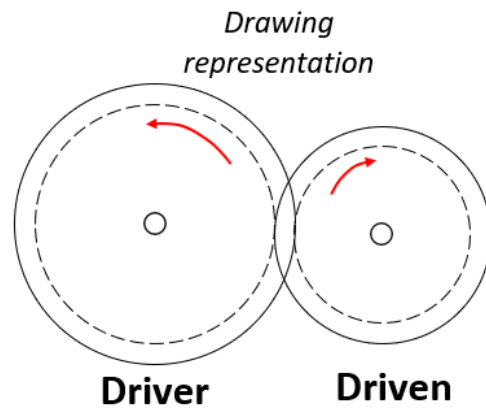
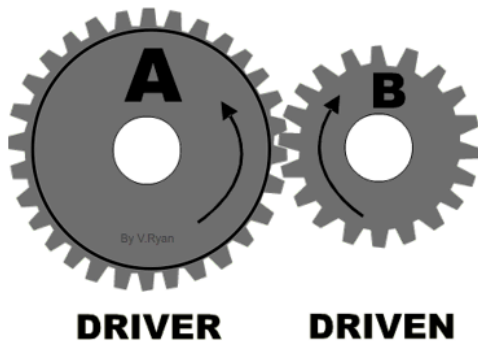
- gears transmit power (motion & force) → initiated by a power source (motor)

Refer to gear diagram on the right

- Driver (**DR**) (green gear) – **powered**
- Driven (**DN**) (yellow gear) – **moved**
 - Rotate in opposite directions
 - Use an **idle gear** (orange gear) to rotate in the same direction
 - does not affect output speed



Drawing Representations



- Dotted lines (in drawing representation on the right) represent the teeth of the gear
- Show:
 - direction of rotations (represent with arrows)
 - identification of driver (**DR**) & driven (**DN**) gears (label)

Speed & Turning Force

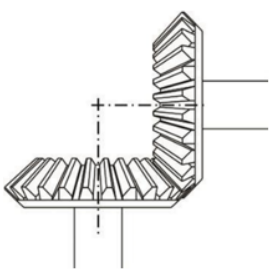
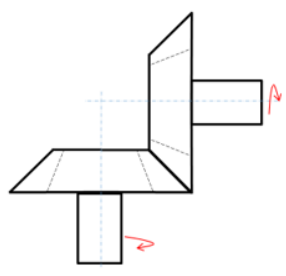
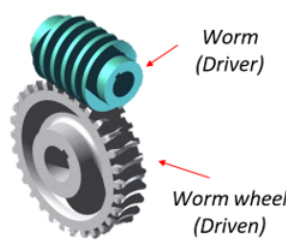
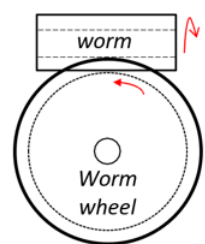
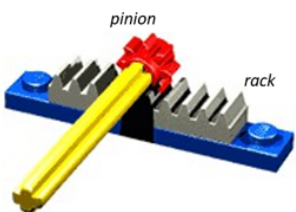
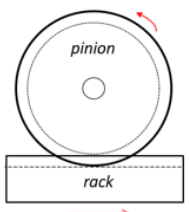
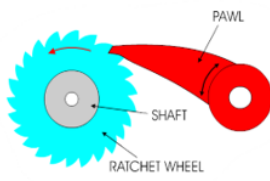
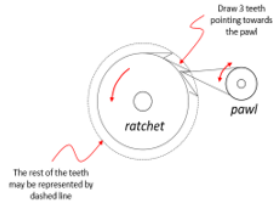
Low speed, High turning force	High speed, Low turning force
Driver smaller than driven • Speed lower at output • Turning force higher at output	Driver larger than driven • Speed higher at output • Turning force lower at output

Gear Ratio / Velocity Ratio

- Gear Ratio or Velocity Ratio = No. of rotations of the driver (**DR**) to the driven (**DN**)

$$\text{Velocity Ratio} = \text{Gear Ratio} = \frac{\text{No. of rotations of DR}}{\text{No. of rotations of DN}} = \frac{\text{No. of teeth of DN}}{\text{No. of teeth of DR}}$$

Special Gears

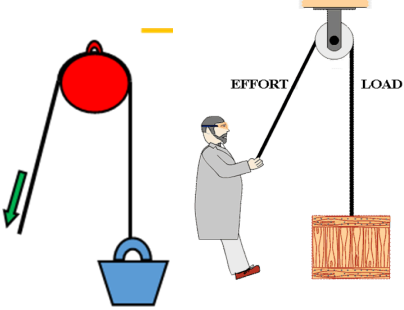
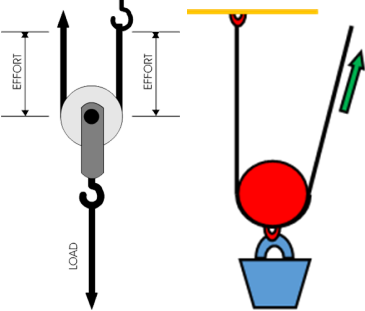
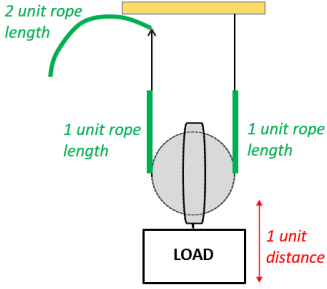
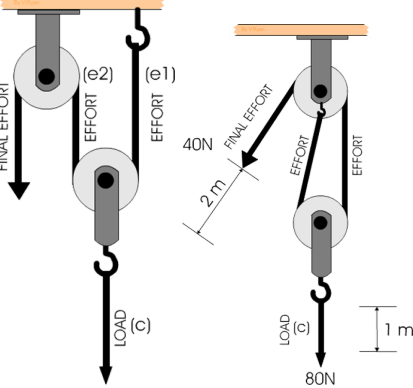
Bevel Gears	Worm and Worm Wheel
• driver shaft at 90° of driven shaft • different sized gears provide different output speeds Application: • hand drill • chuck and chuck key in drilling chuck Actual  Drawing Representation 	• driver shaft at 90° of driven shaft • large speed reduction between driver and driven shaft ◦ worm is a one tooth driver • only worm can be driver, not the other way round Application: • guitar strings tensioner mechanism • blinds • winch Actual  Drawing Representation 
Rack and Pinion	Ratchet and Pawl
• rotary motion → linear motion Application: • steering wheel mechanism in vehicle • raising and lowering drill table • door lock in public table Actual  Drawing Representation 	• ratchet wheel ◦ only rotate in direction away from pawl • pawl ◦ prevents ratchet from turning in direction of pawl Application: • winch Actual  Drawing Representation 

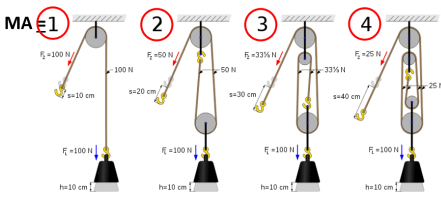
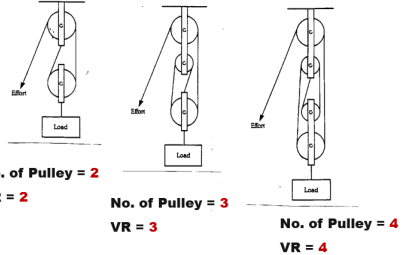
Pulley

- wheel that rotates about an axel
- two functions – lifting system & driving system

Lifting System

- make it easier to lift a load

Fixed Pulley	Moveable Pulley	Compound Pulley
• fixed (onto ceiling/wall) • allows load to be pulled up (<i>directional advantage</i>) • effort needed to lift load = weight of load ($M.A. = 1$)  Application: Raise Flag • Directional Adv. as effort directed downwards to move flag up	• free to move together with load • one end of rope fixed and supports half the weight of load • Effort needed to lift load is half the load ($M.A. = 2$)  Disadvantage: • Need to pull on twice the amount of rope for each unit distance moved • Effort needs to be directed upwards instead of downwards 	• combination of fixed and moveable pulley • both directional and mechanical advantage  Application: Cranes • Lift heavy loads

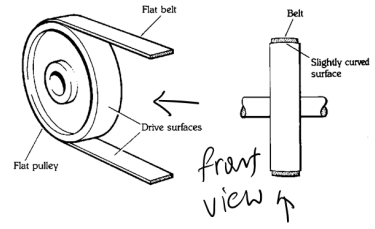
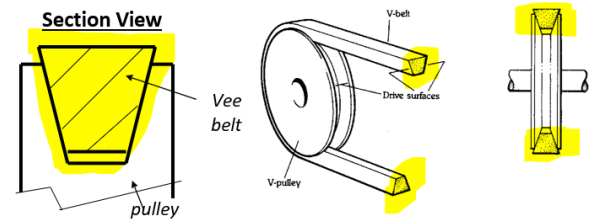
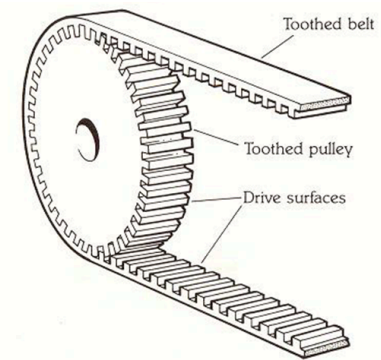
Mechanical Advantage	Velocity Ratio	Efficiency
calculated by the ratio of load over effort based on 100% machine efficiency (no friction)  MA,  No. of pulleys Mechanical Advantage = $\frac{\text{Force required at Load}}{\text{Force required at Effort}} = \text{No. of Pulleys (at 100\% efficiency)}$ 	key disadvantage of pulley  MA =  distance the effort must travel Velocity Ratio = $\frac{\text{Distance moved by Effort}}{\text{Distance moved by Load}} = \text{No. of Pulleys}$ 	percent of work put into a machine by the user that becomes work done by the machine Efficiency = $\frac{\text{Mechanical Advantage}}{\text{Velocity Ratio}} \times 100\%$ machine cannot be at 100% efficiency due to loss of efficiency through friction, heat & sound additional effort needed to overcome: - weight of pulley - weight of rope - friction at axel

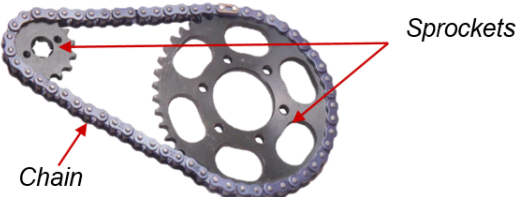
Driving System

- flexible rubber belt in tension used to transmit power between driver & driven pulleys
- done via friction between belt & pulley

Advantages	Disadvantages
1. economical when driver and driven shafts separated by long distances	1. belt slippage
2. lubrication free, low maintenance	
3. driver and driven shafts do not need to be parallel	
4. rotation between driver and driven can be reversed by connecting the belt in a cross drive without the need for additional components	

Types of belts

Flat belt		
Advantages • transfer power over long distances • low cost to manufacture	Disadvantages • not suitable for short distances • low efficiency due to ease of belt slippage	
Application: conveyor in manufacturing / food industries		
Vee Belt		
Advantages • better grip on pulley than flat belt due to 'wedge effect' • transfer higher power at higher speeds	Disadvantages • higher manufacturing cost as compared to flat belt	
Application: drilling machine with step/cone pulleys		
Toothed / Timing Belt		
Advantages • no belt slippage • can be used in high load application	Disadvantages • higher manufacturing cost	
Application: used in place of sprocket and chain (quiet operation, no lubrication required) vehicle engine drive system		

Sprocket and Chain		
• sprocket – sturdy wheels with teeth that lock onto a chain • chain – transmits power between driving and driven shafts as sprocket spins		
Advantages • no slippage • can be used in high load application	Disadvantages • high manufacturing cost • higher maintenance as mating parts between sprockets and chain require lubrications to prevent wear	
Application: forklift (carry loads) bicycle drive system		

Velocity Ratio

- Diameter used in place of teeth

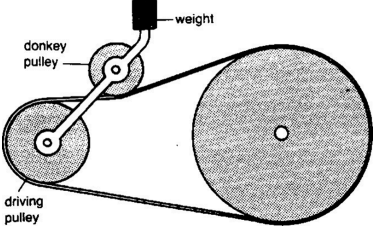
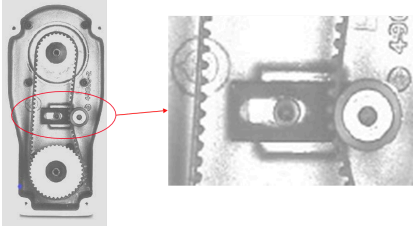
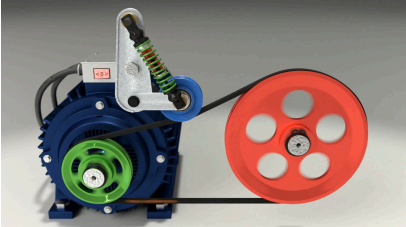
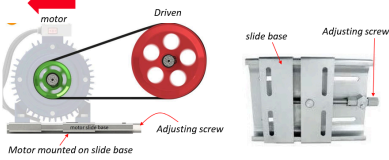
$$\text{Velocity Ratio} = \frac{\text{No. of rotations of Driver (DR)}}{\text{No. of rotations of Driven (DN)}} = \frac{\text{Diameter of Driven (DN)}}{\text{Diameter of Driver (DR)}}$$

Belt slack

- belt made of rubber and stretches overtime
- causes belt to slack → reduce tension between driving and driven shaft
- results in belt slippage → loss of efficiency in drive system

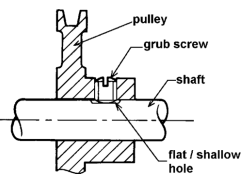
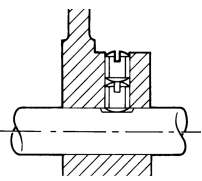
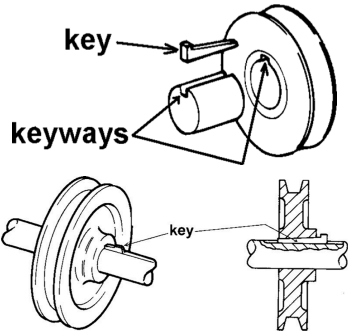
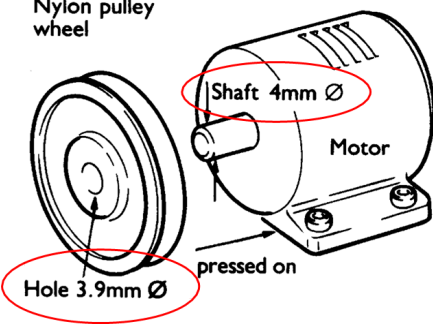
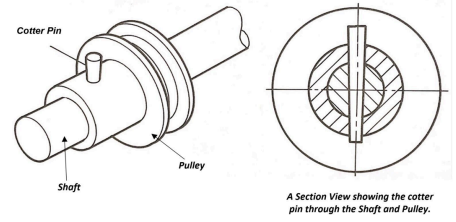
Tensioning belt

- tensioner pulley
- moving the motor way from driven shaft

Tensioner Pulley (weight)	Tensioner Pulley (screw)
use tensioner pulley with weight attached, constantly tensions belt 	tensioner pulley incorporated with slot and locking screw, adjust to tension belt 
Tensioner Pulley (spring)	Moving the motor
spring-loaded tensioner pulley 	move motor away from driven shaft by mounting motor on slide base, adjusting screw controls the distance the motor moves 

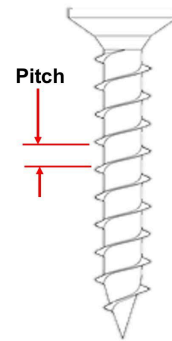
Fixing Shaft to Gears, Pulleys & Cranks

- driving shaft used to transmit motion
- if not secured tightly, slippage will occur → damage to equipments

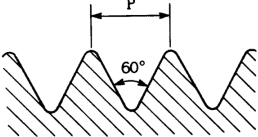
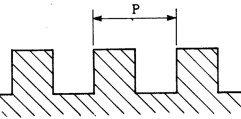
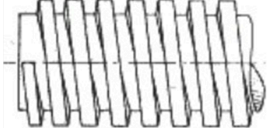
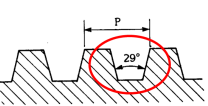
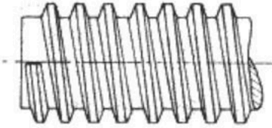
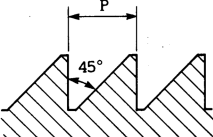
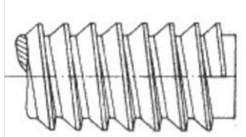
Grub Screw	Key and Key Way	Interference Fit	Cotter Pins
• secure gear to shaft • hexagonal-shaped head used with allen key → apply more torque • used to press on the side of shaft • cheaper and easier than key & key way  • use 2nd grub screw to prevent 1st from coming loose during operations 	• fit rectangular pin (key) into a rectangular slot on the shaft and component • very secure • used for high load operations • more expensive to manufacture (disadv.) 	• cheap and easy by using friction • making hole of component slightly smaller than mating shaft • suitable for low torque operations (disadv.) 	• tapered pins • pushed into holes on component and shaft • compresses as it is driven into the hole → friction, prevent from working loose • easy to install • used for high load operations 

Screw

- screw thread – shaft with helical grooves cut around it
- rotary motion → linear motion
- pitch – linear distance moved in one rotation of the screw
- Main uses
 - hold objects in place
 - position parts accurately
 - transmit power
 - transmit motion

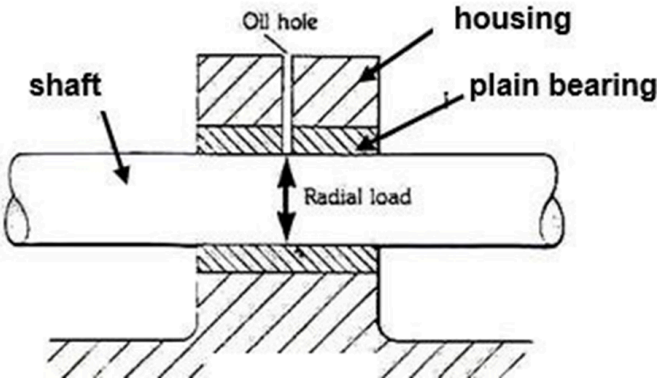
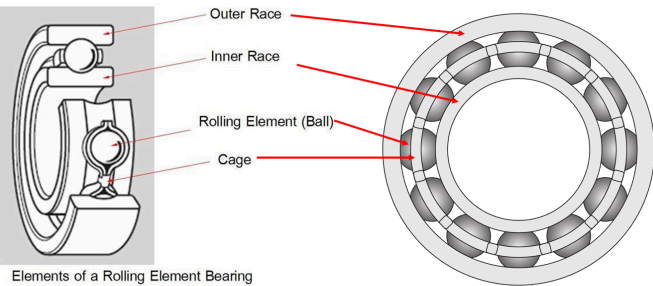


Types of screw threads

Vee Thread	Square Thread
- hold parts together and for fine adjustment - vee-shaped thread profile does not come loose easily → ideal for holding objects in place Application: - adjust focus in binoculars - adjust seat height of stool  	- power transmission - most efficient in having least friction - most expensive to produce Application: - screw lock - holding vice - G-clamp  
Acme Thread	Buttress Thread
- power transmission - not as efficient as square threads - less costly to produce than square threads Application: - leadscrew and carriage  	- take heavy load in one direction only - as efficient as square threads - less costly to produce than square threads Application: - woodworker's vice - closed and opened quickly by releasing a half nut  

Bearings

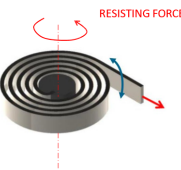
- component used to reduce friction between a stationary and a rotating component of a machine

Plain Bearing	Ball Bearing
• simplest form of bearing • cylindrical in shape, no moving parts • less costly to produce • suitable for low rotational speed applications only  • inserted into a housing to provide bearing surface for rotating shaft • easily replaced when worn • oil hole in housing provides a means to supply lubricant to bearing to further reduce friction • made from soft metals (e.g. brass, bronze) • some made from nylon • ensures that plain bearing wears instead of shaft → replace at regular intervals Brass  Bronze  Nylon 	• consists of four main parts ○ outer race ○ inner race ○ rolling element (ball) ○ cage • costly to produce • long bearing life • can be used for both low and high rotational speed applications  Elements of a Rolling Element Bearing

Springs

- store elastic energy
 - released suddenly or gradually
- used to provide return movement in mechanism

Types of Springs

Compression spring	Tension Spring
• resist squashing (compressive) force • when squashed, it tries to push back to original length Application: • spring mattress • bicycle suspension 	• resist a stretching (tensile) force • when stretched, it tries to pull back to original length Application: • table lamp • chest pull 
Torsion spring	Flat spring
• resist turning force (torque) • when twisted, it tries to twist back to original shape Application: • clothes peg • clips • door handle returning to original position 	• also known as leaf spring • slender length of spring steel • when compressed, it tries to return to original position 
Clock spring	Application: • vehicle suspension
• prepared from flat wires • when pulled at outer end from coil, it tries to uncoil to original position Application: • tape measure • wind-up toys 	
Radial spring	
• when ends compressed together, it tries to expand itself to original position Application: • cloth peg • tube benders → prevent lateral movement of pivot pin 	

yay end of mechanism



Electronics

D&T Electronics Notes

Made by Javier (@javierererie)

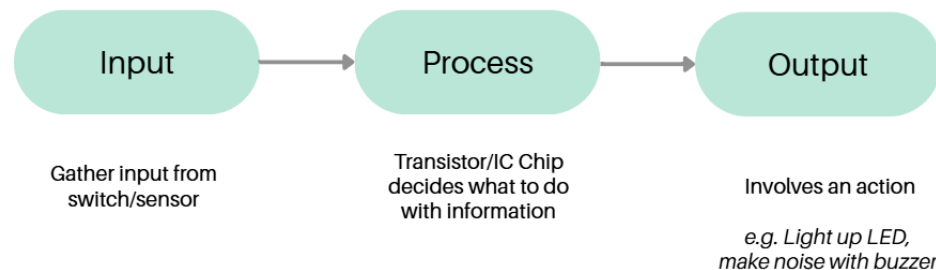
Sources: Dunman Secondary School Notes

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Electronics in Everyday Life

- Electronics plays a crucial role in our daily lives
 - allows specific devices to produce heat & sound
 - allows light bulbs to light up
 - helps trains move and makes travelling to work / school easier
 - enables cooling system of a refrigerator to work

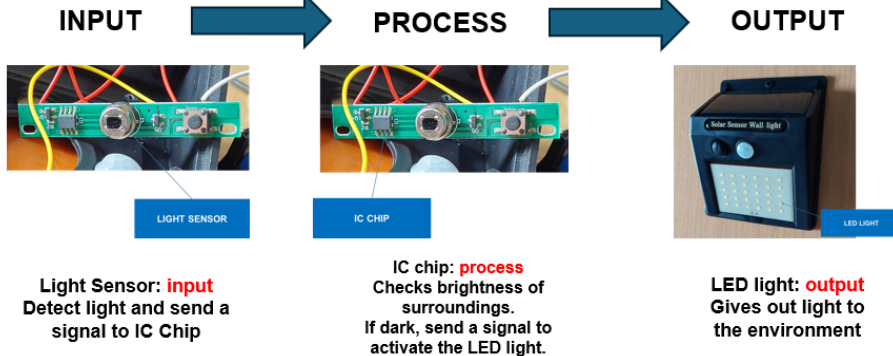
Electronic System



Open-loop electronic system

- Input unaffected by environment since no feedback loop

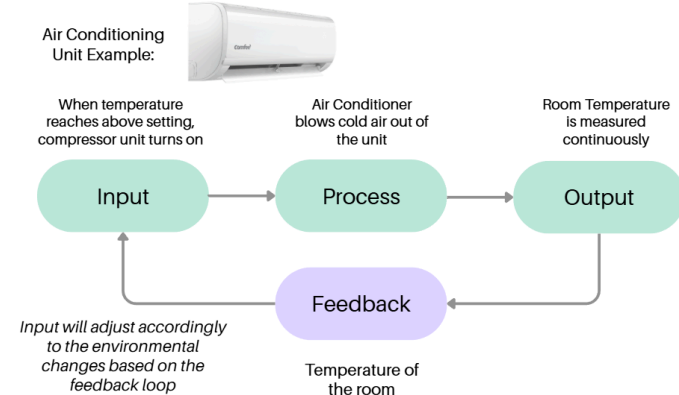
Example: Wall light with LDR



Closed-loop electronics system

- Input directly affected by feedback loop

Example: Air Conditioner



Power Supplies

- comes mainly from burning of fossil fuels & renewable energy sources

Nuclear Power	Renewable Energy
<u>Advantages</u> • No burning of fossil fuels → low carbon footprint • More efficient & reliable energy than fossil fuels <u>Disadvantages</u> • High cost for designing and building factory • High radioactive waste produced → severe pollution if leaked / treated improperly	Wind-powered, solar panels, hydro <u>Advantages</u> • No harmful gases released into environment • Sustainable sources • Readily available <u>Disadvantages</u> • Only works when source of energy available • High setup costs • Not suitable for all locations Alternating Current (AC) wire  The diagram shows a horizontal cylinder representing a wire. Inside the cylinder, there are two thick red arrows. One arrow points to the right and the other points to the left, indicating that the current flows in alternating directions. • current flows in alternating directions ◦ In Singapore: 50Hz, 220/240V • sent to houses/factories by thick underground cables • need to convert to direct current (D.C.) for use in electronic products ◦ A.C. (220V) → D.C. (5V) for electronic devices

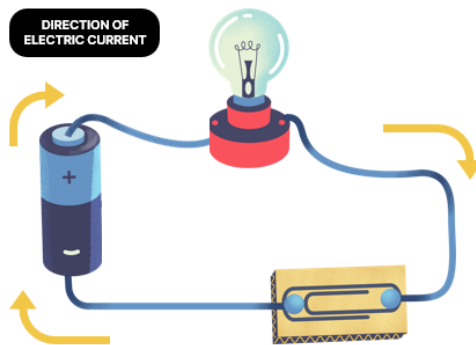
Batteries

rechargeable, non-rechargeable, different voltage rating / sizes

Dry cell batteries • 1.5V – AAA, AA, C, D • 9V – PP3	Lithium batteries • store more energy • non-rechargeable
Wet cell batteries • 12V – Car battery	Lithium ion batteries • rechargeable – less wastage

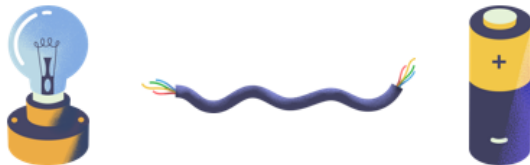
Electric Circuit

- **complete path through which electric current flows**
- constructed in an unbroken loop



What “completes” a circuit?

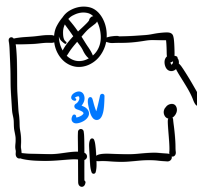
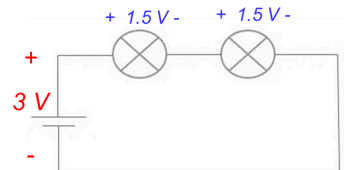
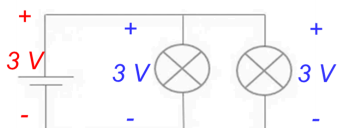
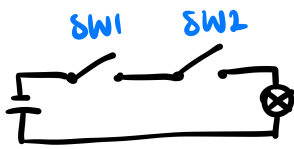
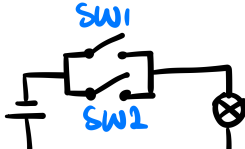
- Circuit consists of:
 - Battery (source)
 - light bulb
 - conducting wires
- Represented using:
 - components



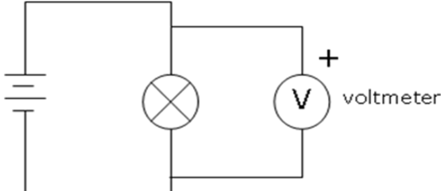
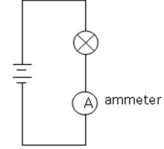
- **circuit symbol**



Series & Parallel Circuits

Series	Parallel
Power Supplies	
batteries operate at 3V each 	batteries operate at 1.5V each (halved) 
Output Voltages	
shared voltage between 2 bulbs - more bulbs → dimmer 1 damaged bulb → whole circuit fail 	same voltage for each bulb - more bulb → same brightness - damaged bulbs do not affect other bulbs 
Switches	
close both switch to activate bulb 	close any switch to activate bulb 

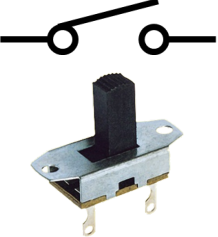
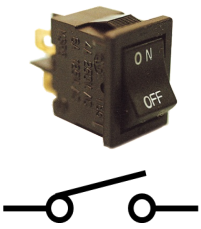
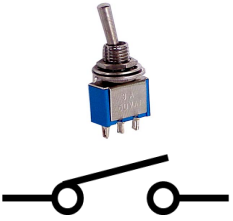
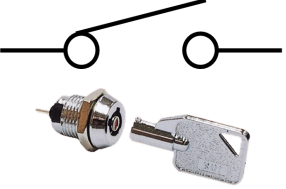
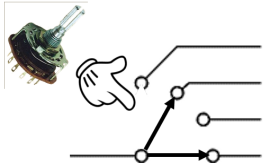
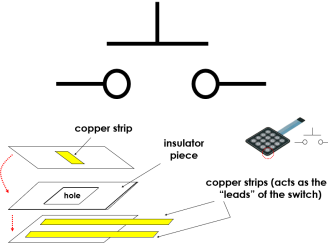
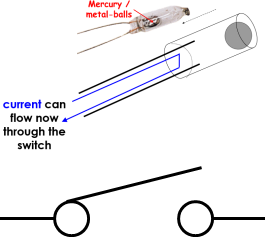
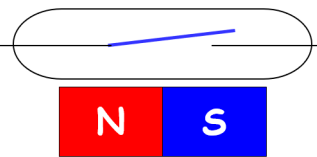
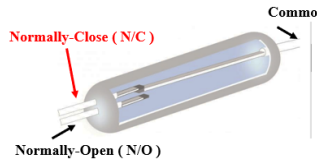
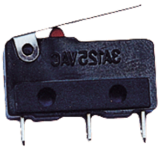
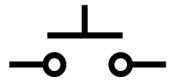
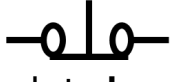
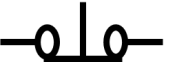
Measuring Voltage & Current

Voltage (Voltmeter)	Current (Ammeter)
Voltmeter in parallel to bulb 	Ammeter in series to bulb 

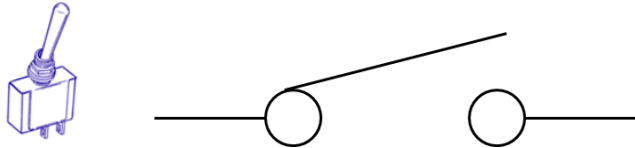
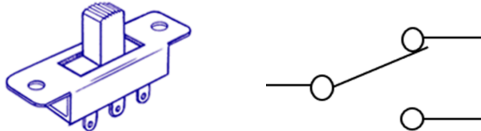
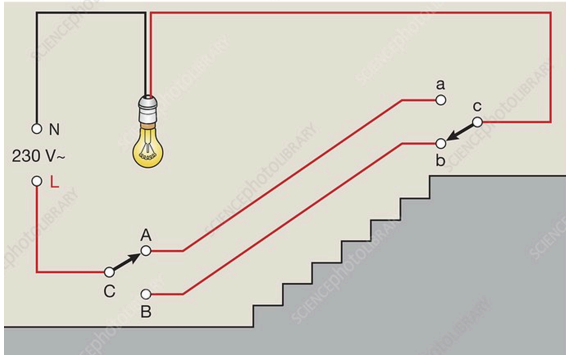
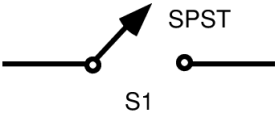
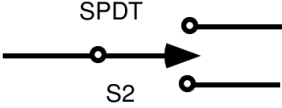
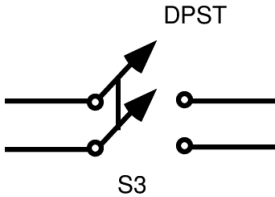
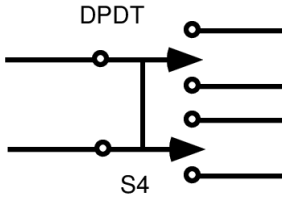
Switches & Application

- Components (physical connection) & Circuit connection

Types of switches

1. Slide switch  used in toys / torch	2. Rocker switch  used in lights / electric kettle	3. Toggle switch  used in control panels	4. Key switch  used in security alarm	5. Rotary switch  used in knobs (vol. knob, fan speed knob etc.)
6. Membrane panel switch  used in computer keyboard / control panel button	7. Tilt switch  mercury / metal-balls with metal leads/contacts used to detect tilt (angle-activated) used in robotics arm angle sensing, changing phone screen orientation, forklift level sensing	8. Reed switch magnetism-activated a. normally-open (n/o)  b. normally-close (n/c) used in burglar alarm at door/window 	9. Micro switch  push-to-make  push-to-break  used in limit switch / alarm sensor	10. Push switch Momentary (using spring under button)  Push-to-make  Push-to-break  Latched used in doorbell, emergency stop button

Classification of switch

Single Pole Single Throw (SPST)	Single Pole Double Throw (SPDT)
	
	used in 2-way lighting switch on staircase 
Double Pole Single Throw (DPST)	Double Pole Double Throw (DPDT)
	   Image source (NEED TO KNOW ROUGHLY)

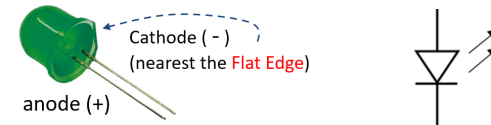
Output components

1. Light bulb (produce light)



2. LED light (produce light) – Light Emitting Diode (LED)

- operate at 2V, 10mA depends on colour
- less current needed than light bulb
- low heat produced
- longer lifespan
- less fragile



3. Buzzer (produce sound)



4. DC Motor (produce rotary motion)

- runs continuously
- reverse voltage polarity (+ and -) to turn other direction



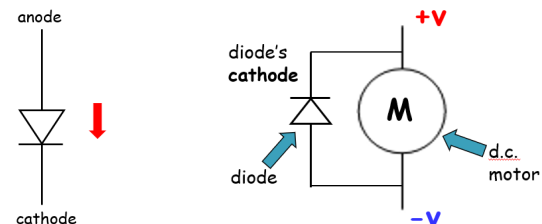
5. Push switch (**Solenoid** w. plunger)

- when current flows through the inside coil, it creates a magnetic field, causing plunger to move inwards.
- used in electronic locks for cabinets, safe etc.



6. Diode (*ref. left picture*)

- allow current to flow in one direction only
- used to protect inductive components (e.g. dc motor, relay switch etc.)
- use as **transient protector** (*ref. right picture*)
 - i. protect solenoid, motor etc. in a circuit
 - ii. connect **cathode** towards **+ve** of voltage in parallel



Resistance

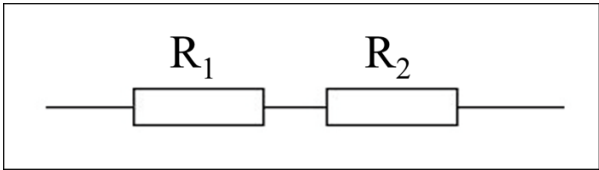
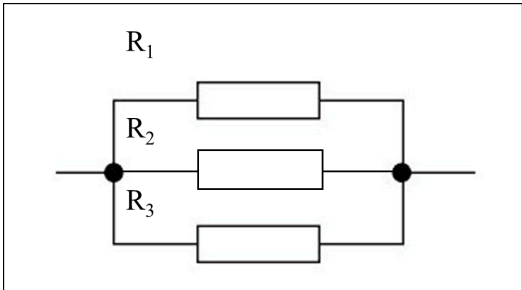
Ohm's Law

- current through a conductor is directly proportional to the voltage (potential difference) across it.
- Formula
 - Name / Representation / SI Unit
 - Current / I / A
 - Voltage / V / V
 - Resistance / R / Ω (ohm)
 - $V = IR$ or $I = \frac{V}{R}$

Resistors

- Control the amount of current flow in a circuit
- **Limit current to prevent damage to components**

Arrangement in Series & Parallel Circuits

Series Arrangement	Parallel Arrangement
Calculating Total Resistance (R): • $R = R_1 + R_2$ • Total Resistance is higher than each resistor 	Calculating Total Resistance (R) • $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$ ○ Afterwards, Invert R (i.e. $\frac{R}{1}$) to find resistance. • Total resistance is lower than each resistor 

Resistance Value

- measured in Ohms – Ω
- Large values, hence to use prefixes (Physics Topic 1 // 3EM Topic 3)
 - Kilo (k) – 10^3 – Kilo-ohms $K\Omega$
 - Mega (M) – 10^6 – Mega-ohms $M\Omega$
 - Giga (G) – 10^9 – Giga-ohms $G\Omega$

Measuring Resistance Value

1. Multimeter
 - a. If resistor is connected to circuit, need to cut any one end off
2. Reading resistor colour code

Reading of Resistor Colour Code Tables

1. Place resistor with silver/gold end on your right
2. Identify each of the 4 colour bands (with the colour code table provided) to derive its resistance and tolerance (the manufacturer guaranteed accuracy of physical resistor made)

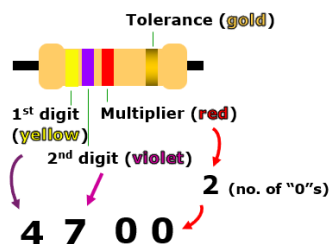
Calculating Resistance
Colour 1 & 2: First & Second Digits of resistance
Colour 3: Multiplier of resistance (ie. number of zeroes at the back of the number)

Number	Colour
0	black
1	brown
2	red
3	orange
4	yellow
5	green
6	blue
7	violet
8	grey
9	white

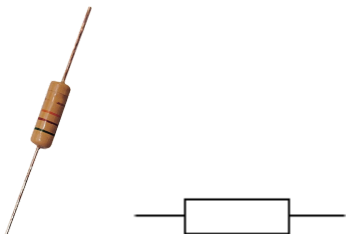
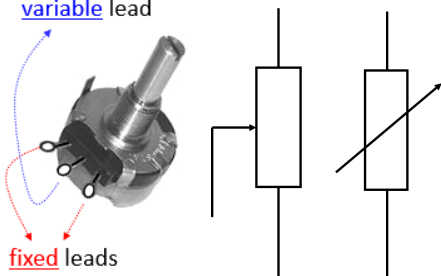
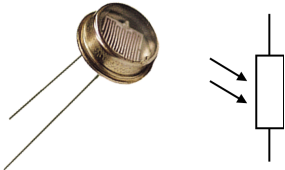
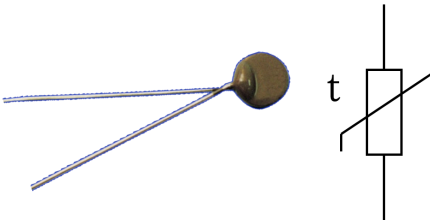
Calculating Tolerance
(how accurate the resistor will follow the resistance stated)
Colour 4: Tolerance of resistor

Tolerance	Colour
$\pm 1\%$	brown
$\pm 2\%$	red
$\pm 5\%$	gold
$\pm 10\%$	silver

Example of resistor reading



Types of Resistors

Fixed Value	Varying Value
Fixed Value Resistor Fixed resistance 	Hand Change - Potentiometer  - Connect one variable + 1 fixed lead to use as a variable resistor - Connect two fixed leads to give fixed (max) resistance value
	Condition Change 1. Light Dependent Resistor (LDR)  2. Thermistor (Temperature) 

Transistors

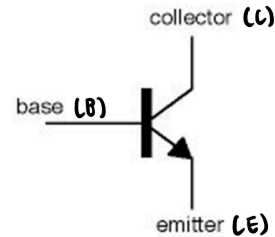
- use: automatic switch



- used in Basic & Modified Sensing Circuits

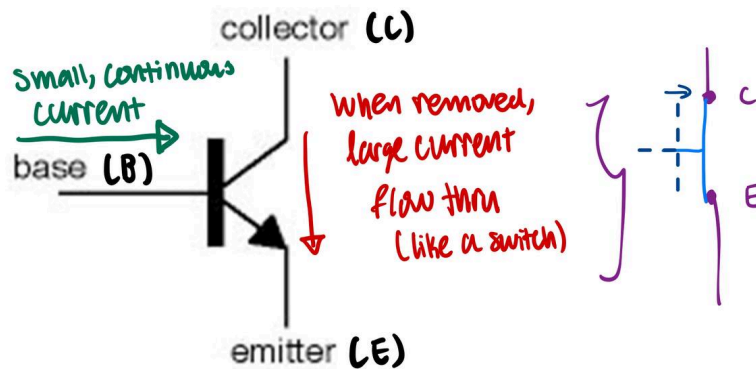
- Circuit Symbol:

- B - Base
- C - Collector
- E - Emitter



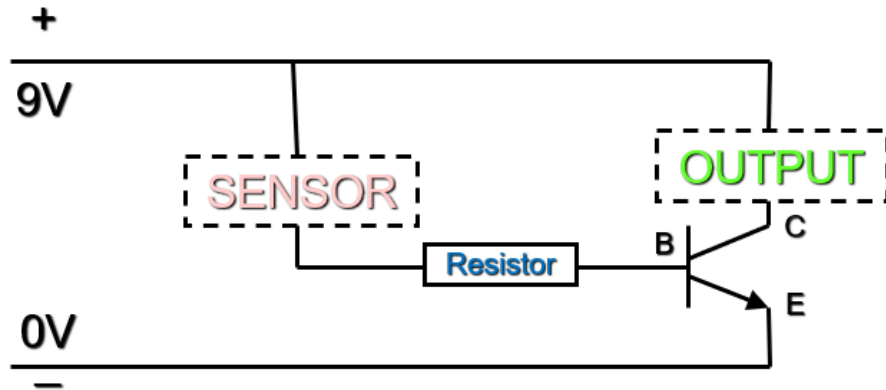
How does it act as a switch?

- When small, continuous current to B is removed, large current will flow from C to E, thus the transistor acts like a closed switch



- You can think of the **base** like it's an “on/off” switch.
- When you **send current** into the base, it is in its “off” position
- However, when you **remove that current**, it is in its “on” position, allowing current between the two wires to flow through.

Basic Sensing Circuit



- **Purpose of resistor:**

- prevents too much current from flowing into base (B) and damaging transistor

Types of conditions, sensors & outputs

Condition	Sensor	Output
Moisture	Moisture Probes	Lamp, Buzzer, LED, Motor, Relay etc.
Light	Light Dependent Resistor (LDR)	
Heat	Thermistor	

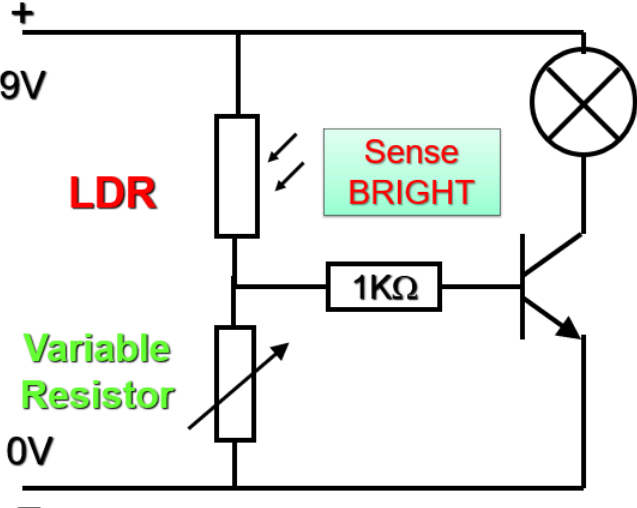
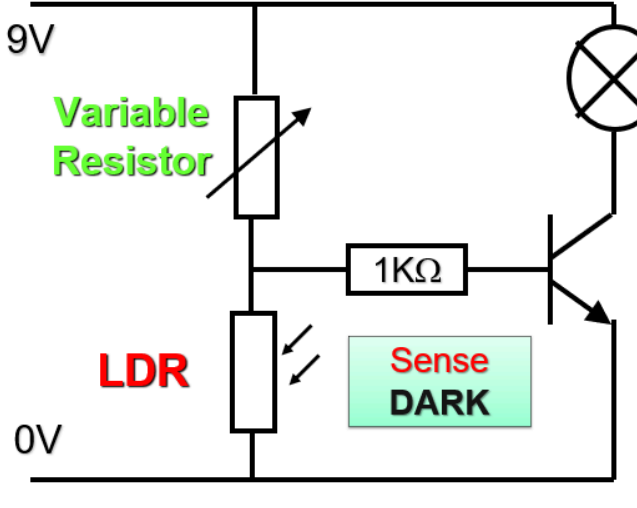
To activate transistor, sensor must have **low resistance** when moisture/light/heat detected.

Resistance Value	Current Flow
High (i.e. ✗ moisture/light/heat)	No
Low (i.e. ✓ moisture/light/heat)	Yes

Type of Sensing Circuit	Moisture Sensing Circuit	Light Sensing Circuit	Heat Sensing Circuit
Circuit Diagram with Sensor			
Sensor & Physical Sensor	Moisture Probes 	Light Dependent Resistor (LDR) 	Thermistor
Type of control system	Open-loop control system		
Process (Steps)	1. dry → no current flow through sensor (due to high resistance) 2. contact moisture → current flow through probes into base of transistor (due to low resistance) 3. transistor activates and acts like a closed switch 4. current flow through LED via collector & emitter of transistor to light up LED	1. dark → no current flow through sensor (due to high resistance) 2. bright → decreased resistance, current flow through LDR into base of transistor 3. transistor activates and acts like a closed switch 4. current flow through bulb via collector & emitter of transistor to light up bulb	1. low temp → no current flow through sensor (due to high resistance) 2. high temp. → decreased resistance, current flow through thermistor into base of transistor 3. transistor activates and acts like a closed switch 4. current flow through buzzer via collector & emitter of transistor to activate buzzer
Process (Control System)	Input: Probe & presence of moisture allows current to flow through	Input: LDR senses brightness and allows current to flow through	Input: Thermistor senses heat and allows current to flow through
	Process: Small but large enough current flows through base of transistor to activate it		
	Output: LED lights up indicating the presence of moisture	Output: Bulb lights up indicating the presence of light	Output: Buzzer produces sound indicating the increase in temperature

Modified Sensing Circuit

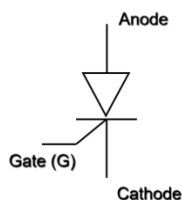
- Sensitivity – how much moisture, light or heat is needed to be sensed by the sensor to activate the transistor.
 - less sensitive = sense more heat/moisture/light to activate

Adjustable Sensing Circuit	Reverse Sensing Circuit
senses brightness  When Variable Resistor value decreased, lower sensitivity of circuit = need more light to activate	senses darkness  Difference is the position of the VR & LDR (swap with each other).

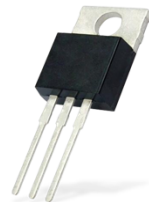
Thyristor

- another common type of component for automatic sensing switch

Circuit Diagram

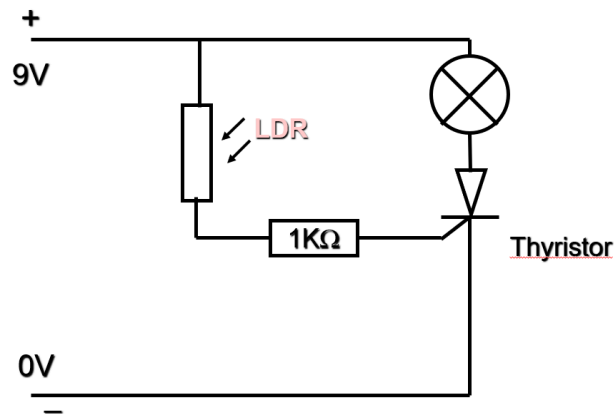


Physical Thyristor



Transistor	vs	Thyristor
switch off when current to base (B) is removed		remains switched on (latched) even when current to gate (G) is removed
use when output needs to change based on the input (e.g. sensing circuits)		use when designing switching applications (e.g. alarm system)

Basic Thyristor Circuit

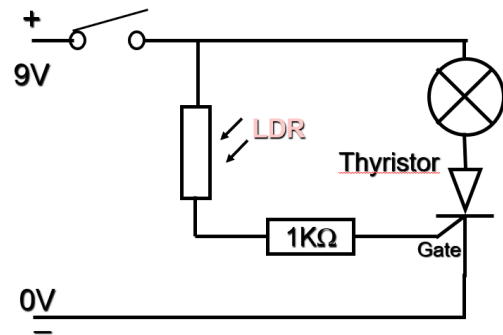


- Works similarly to [basic sensing circuit](#) with **one key difference**
 - when sensor stops detecting (e.g. LDR stops detecting light), the thyristor will **remain on** even after **current stops flowing into the gate** of the thyristor
 - how to turn it off? refer to the next section below!

Switching OFF a Basic Thyristor Sensing Circuit

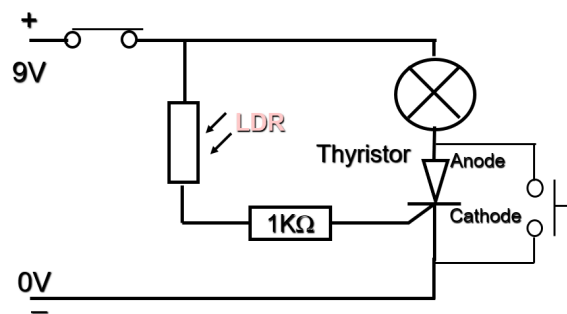
Method 1: Add a switch to the circuit to cut off power supply

When the switch is opened, current flow to the thyristor is cut off, thus turning it off.



Method 2: Add a push-to-make switch from the Anode to Cathode

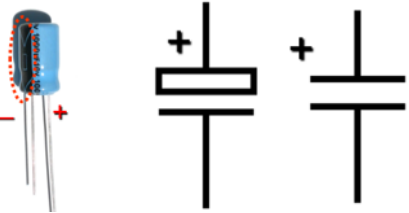
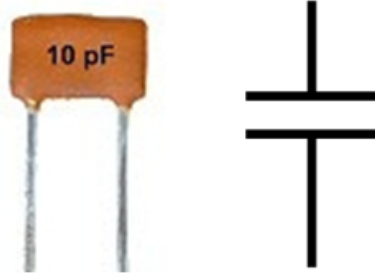
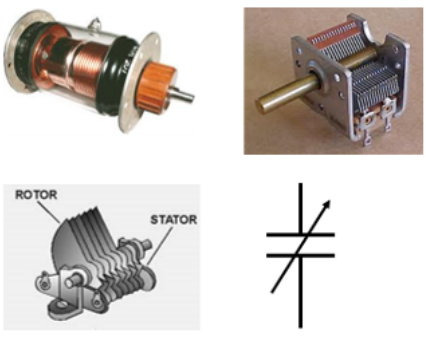
When the switch is pushed down and released, current will flow through the switch instead of the thyristor since it has lower resistance, thus turning the thyristor off.



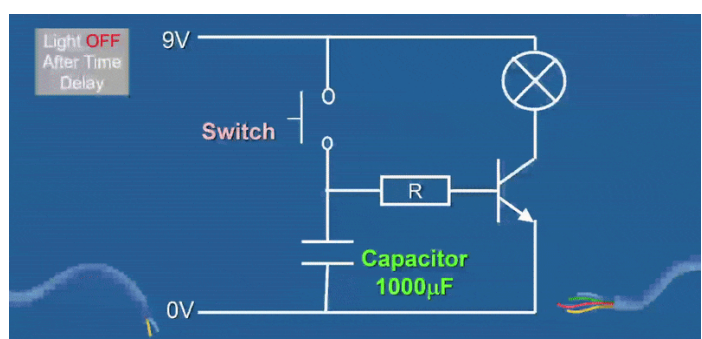
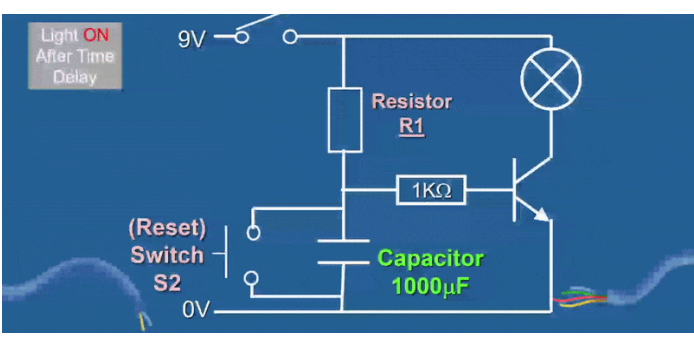
Capacitor

- stores electricity (electrical charge)
 - Capacitance – amount of charges that can be stored
 - Measured in Farads (F)
 - Usually of very small value
 - Micro-Farads (μF)
 - Nano-Farads (nF)
 - Pico-Farads (pF)

Types of Capacitors

Electrolytic	Non-Electrolytic	Variable Capacitor
Polarised (+/- terminal) 	Non-polarised 	Vary amount stored in capacitor 

Timing and Counting Circuit

Light OFF after time delay  Application: Traffic Light	Light ON after time delay  Light bulb turns on after capacitor is fully charged.
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Integrated IC

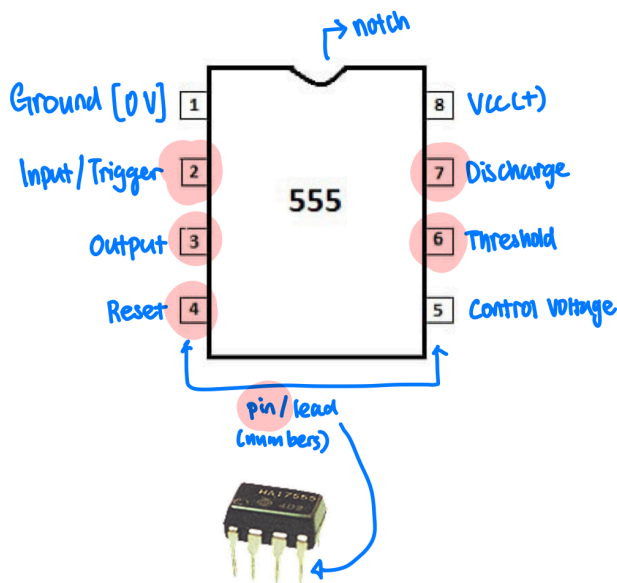
- made of semiconductor material
- contains many transistors and other components joined together
- performs specific tasks

555 Timer IC

- used for timing events in a circuit
- popular due to its ease of use, versatility, low price, and stability

Parts of the IC Chip (with help from ChatGPT)

"describe the purpose of each section of the 555 timer from 1 to 8 in terms that a secondary school student would understand"



Notch – find the **correct orientation**
Pin/Lead – **numbered legs** of the IC (1-8)

Need to KNOW: Pins 2, 3, 4, 6, 7

1. 0V Ground

- Connects the IC to the **negative** side of the battery

2. Input/Trigger

- **Starts the timer** when it detects a low voltage (similar to a “start” button).

3. Output

- Turns the connected LED/speaker **ON** (close to pin 8) or **OFF** (0V, close to pin 1)

4. Reset

- Forces the timer to **reset** by sending an **OFF output**, regardless of what it was doing.

5. Control Voltage

- Used to change timing. Usually not needed — just connect a capacitor to ground here.

6. Threshold

- **Stops the timing** when the when voltage reaches a set level (2/3 of battery) – turns output “off”

7. Discharge

- Connects to a capacitor in timing circuits and acts like a switch to help it to empty its charge when needed.

8. + VCC (Power)

- Connects to the positive side of the battery

Operating Modes

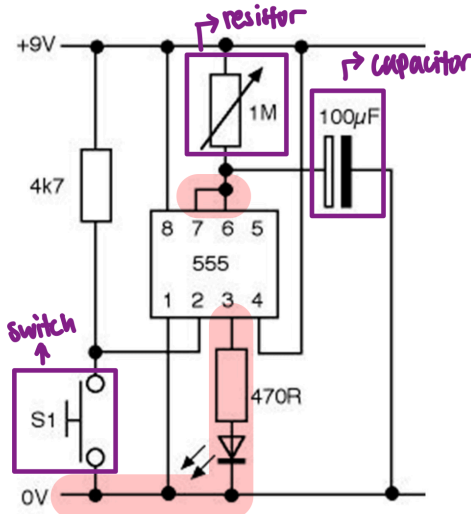
Time Delay (Monostable)

Type 1: Output turn **OFF** after a delay

Refer to the diagram below.

Note on pin connection:

- *pin 6 directly connected to pin 7*
- *pin 3 connects to 0V wire*



When the circuit is **connected to power**, the **LED** will **remain off**.

- When Switch (S1) is pressed, the **LED (under pin 3) will light up.**
- At the same time, the **capacitor will also start to charge up.**
- After some time, when the **capacitor is fully charged**, the **LED will turn off.**

The time delay is dependent on your **resistor and capacitor** (as labelled in the diagram...)

You can use an analogy like a bucket filling up with water to visualise this process happening.

When the bucket (your capacitor) is filling, the tap (your LED) will remain **ON**. However, when the bucket is full, your tap (LED) will automatically turn **OFF** (otherwise it will overflow).

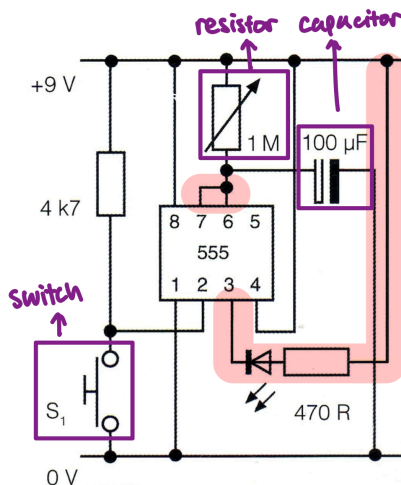
It's similar to this circuit, as when the capacitor is fully charged, the LED will turn off by itself (since no more voltage can be sent through to charge the capacitor).

Type 2: Output turn **ON** after a delay

Refer to the diagram below.

Note on pin connection:

- *pin 6 directly connected to pin 7*
- *pin 3 connects to (+) wire*



When the circuit is **connected to power**, the **LED** will **turn on**.

- When Switch (S1) is pressed, the **LED (under pin 3) will turn off.**
- At the same time, the **capacitor will also start to charge up.**
- After some time, when the **capacitor is fully charged**, the **LED will turn on.**

The time delay is dependent on your **resistor and capacitor** (as labelled in the diagram...)

You can use the same bucket-filling analogy here.

The LED acts like a tap attached to a valve on the bucket (your capacitor). When another tap is filling up the bucket, it will remain closed (off) . However, when the bucket is full, the valve attached to the bucket will automatically open (turn on) to activate the tap (LED).

From the two types above, the **time delay** is affected by your **variable resistor** and the **capacitor** that you use.

Variable Capacitors are **not normally used** since their capacitance is usually too small for practical use and its range is also limited.

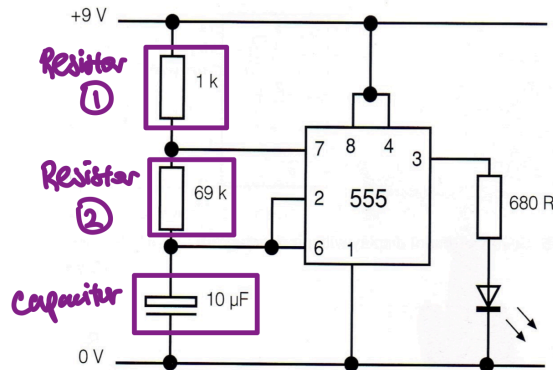
Pulse Generator (Astable)

Output turns **ON and OFF** repeatedly

Refer to the diagram below.

Note on pin connection:

- pin 6 directly connected to pin 2



- When power is supplied, the LED will blink continuously.
- When power is removed, the LED will turn off.

How fast the LED blinks (turn on/off) is dependent on your Resistor 1, Resistor 2, and Capacitor.

4026 Decade Counter IC

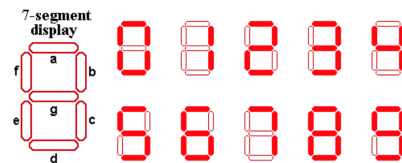
- used to display numbers on a 7-segment LED, counting from 0-9 in an ascending order continuously



Picture of the physical IC

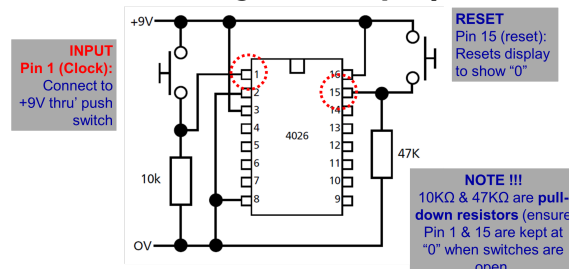
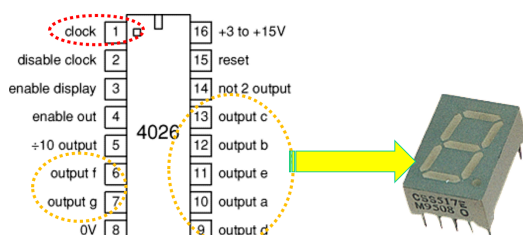
7-segment LED

- used to display numbers
- consists of 7 LEDs that are connected onto the 4026 Decade Counter IC to form the display (check)



How are these two used together?

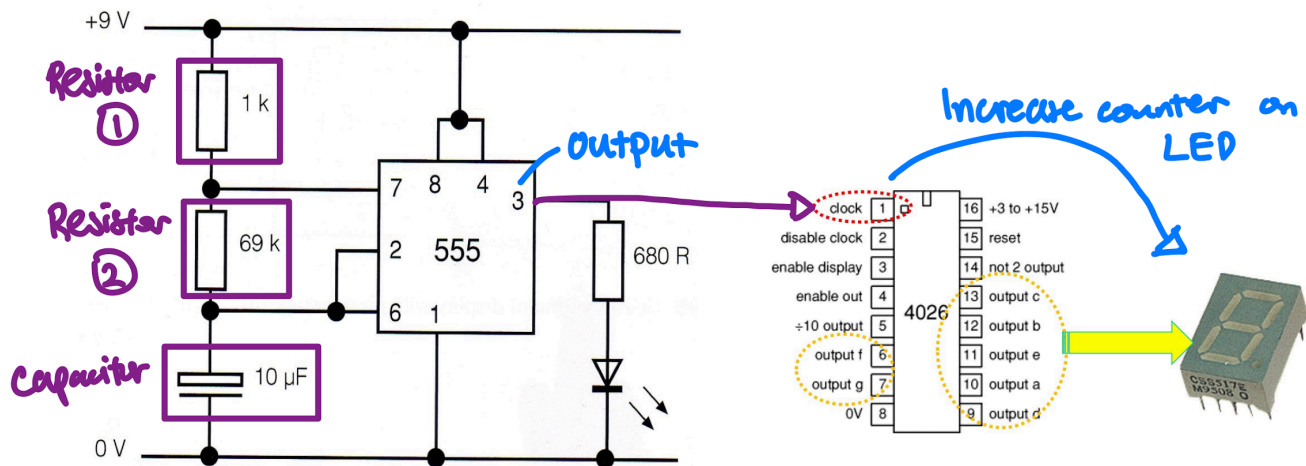
- the “clock” input (pin 1) is connected to the (+)ve power through a push switch
 - it **increases the count** every time it receives a pulse
- the “reset” pin (pin 15) resets the counter to “0”
- the **resistors at pin 1 and 15** ensure that when the switches are open, the pins 1 and 15 are **OFF** when the push switches are left open
- the **output pins (pin 6, 7, 9-13)** are connected to the **7-segment display**



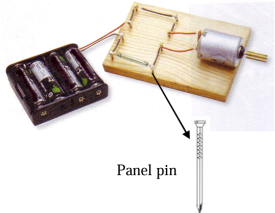
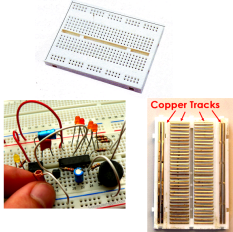
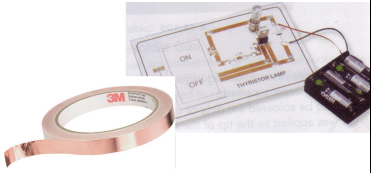
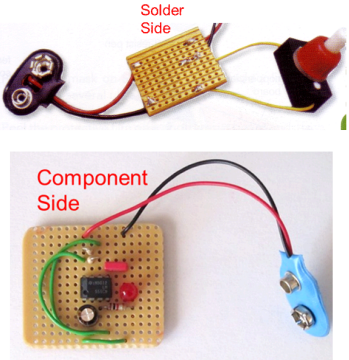
How is the 555 Timer IC and 4026 Decade Counter IC with 7-segment LED used together?

- the **555 Timer IC** can be used as a **pulse generator (astable)**, where its output pin, **pin 3**, is connected to the clock input pin, **pin 1**, of the 4026 Decade Counter IC
- this allows **each pulse generated from the 555 Timer IC to be counted** by the 4026 Decade Counter IC, increasing the displayed digit on the 7-segment LED

Pin 3 of Astable 555 Timer IC connected to Pin 1 of 4026 Decade Counter IC

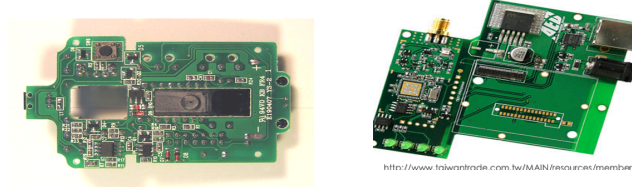


Circuit Construction Methods

Terminal Blocks	Wooden Block	Breadboard	Copper Tape	Stripboard
join wires and components easily with screwdriver (tighten/loosen) Advantages - no need to solder (quick assembly) Disadvantages - circuit quite bulky 	panel pins hammered onto wooden block wires & components' leads wrap around the pins / soldered Advantages - easy to design (similar to circuit diagrams) - circuits can be rearranged and modified to some degree Disadvantages - circuit are bulky - very difficult to use with ICs 	components' leads pushed into holes metal tracks hidden underneath holes to connect components used for circuit testing Advantages - components easily inserted/removed - circuits are compact Disadvantages - circuits more difficult to design as assembled unlike circuit diagrams 	self-adhesive copper tape stick to cardboard easily, like wires in circuit diagram wires & components' leads need to be soldered onto copper tape for better contact Advantages - easy to design – similar to circuit diagrams - relatively easy to construct Disadvantages - difficult to change position of components once circuit is set - difficult to use with ICs as tape is too wide 	rows of copper (with holes) on one side to let components' leads to insert through and solder Advantages - construction compact and firmly fixed - components can be neatly placed on one side Disadvantages - circuits cannot be modified without de-soldering components - circuits difficult to design as unlike circuit diagrams 

Printed Circuit Board (PCB)

- manufactured circuit boards widely used in industrial and commercial purposes



Advantages	Disadvantages
neatest way of constructing circuit - can be made extremely precise and compact with proper placement of components - able to be mass-manufactured for efficiency and lower cost	- preparation for making takes up a lot of time and specialized resources, esp. for individual project - during manufacturing, toxic solutions and materials likely to be used - once manufactured, circuit impossible to modify

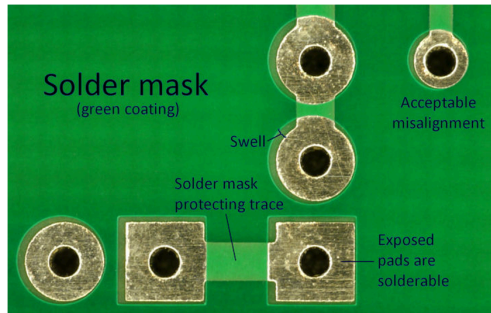
Mounting PCBs using screws	Commercial DIY Electronics Kits	Programmable Devices
- spacer normally used to raise PCB to avoid soldered side from directly touching metal casing - spacer used for ventilation (heat dissipation)	- for different applications to be assembled and soldered by oneself - e.g. warning lights, counting, timer etc.	- allows complicated functions like fingerprint scanning, robot control etc. - Software is free (open-source) - e.g. Arduino, Raspberry Pi, Microbit Arduino Raspberry Pi

Soldering

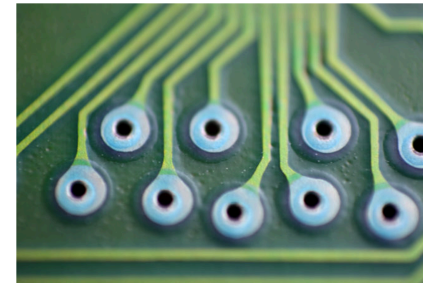
- a process to join 2 metal items together by melting and flowing a filler metal solder into the joint

Parts of Soldering

exposed **copper pad** (link to diff. electric paths in the **circuit**) allows soldering

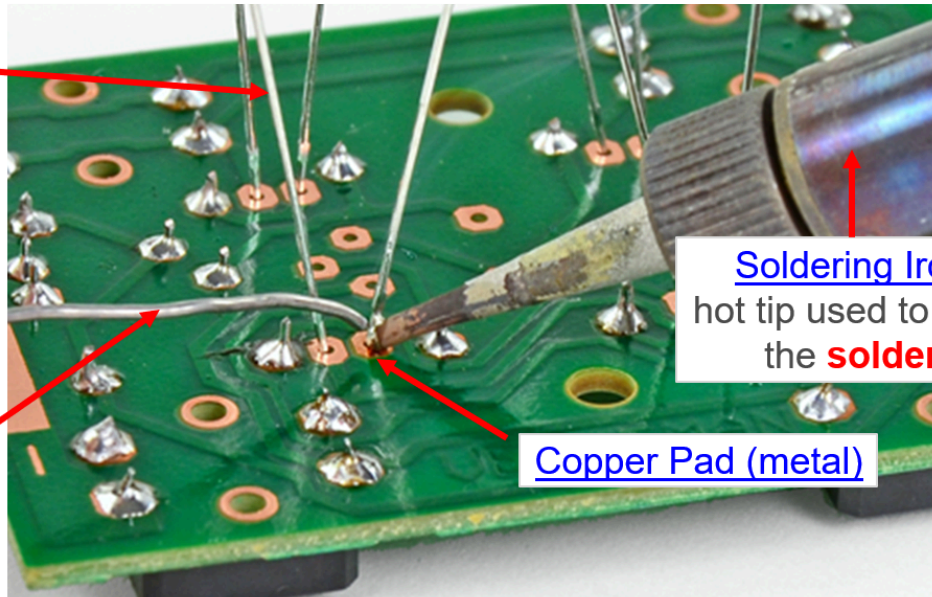


circuit paths → covered with coating to protect solder from oxidation/corrosion



Metal (Lead)
of electronics
component

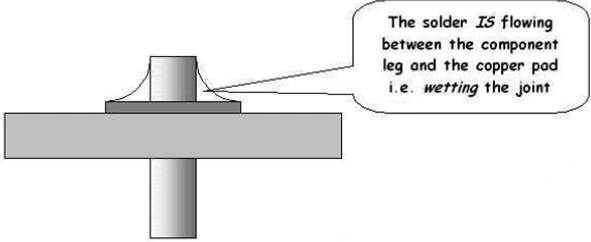
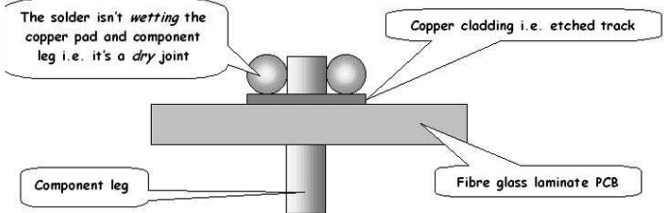
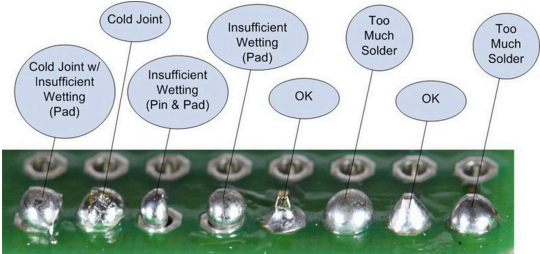
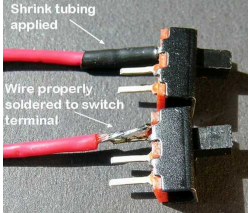
Solder
filler metal, lower
melting point



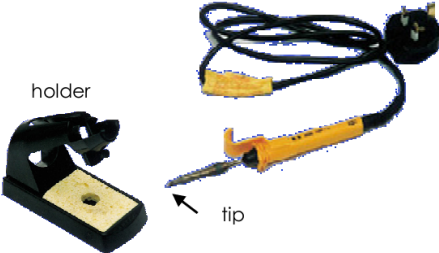
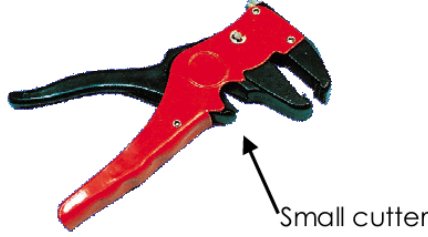
Soldering Iron
hot tip used to melt
the **solder**

Copper Pad (metal)

Good vs Bad Solder Joint

Good Solder Joint	Bad Solder Joint
solder flows between component leg and copper pad (wetting the joint)  The solder <i>IS</i> flowing between the component leg and the copper pad i.e. <i>wetting</i> the joint	- solder isn't wetting component leg and copper pad (dry joint) - copper cladding (etched track) - not enough heat - surface is dirty/oxidised - solder was not applied to joint, applied to the tip of iron instead  The solder isn't <i>wetting</i> the copper pad and component leg i.e. it's a <i>dry</i> joint Copper cladding i.e. etched track Component leg Fibre glass laminate PCB
Examples of good/bad solder joints on a PCB  Cold Joint Cold Joint w/ Insufficient Wetting (Pad) Insufficient Wetting (Pin & Pad) Insufficient Wetting (Pad) OK Too Much Solder OK Too Much Solder	Heat Shrink Sleeve protect exposed wires & pins  Shrink tubing applied Wire properly soldered to switch terminal

Soldering Tools

Soldering Iron	Solder	Wire Stripper	Desolder Gun
- melts the solder using the tip - always store in holder when not in use - be careful of hot tip and not to burn hands or wires of soldering iron when using - good practice to “tin” the tip before using the first time to prevent from oxidation and increase lifespan 	- solder to joint 2 metal contacts electrically and physically - flux (in solder) helps to: - clean away oxide on joint surface - let melted solder flow smoothly to form a good joint - solder melts at 180°C  http://img02.shop-pro.jp/PA01007494/product/2775401.jpg	- remove plastic insulation off wire - small cutter used to cut wires 	remove unwanted solder / melted solder that is jointed wrongly 

yay end of electronics

yay end of notes