First edition

Systems Engineering

Units 3 and 4

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SE26-31 U3/4

Systems Engineering
Units 3 and 4

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UNIT 3: ETHICAL SYSTEMS DESIGN

UNIT 4: SYSTEMS PRODUCTION AND INNOVATIVE TECHNOLOGIES

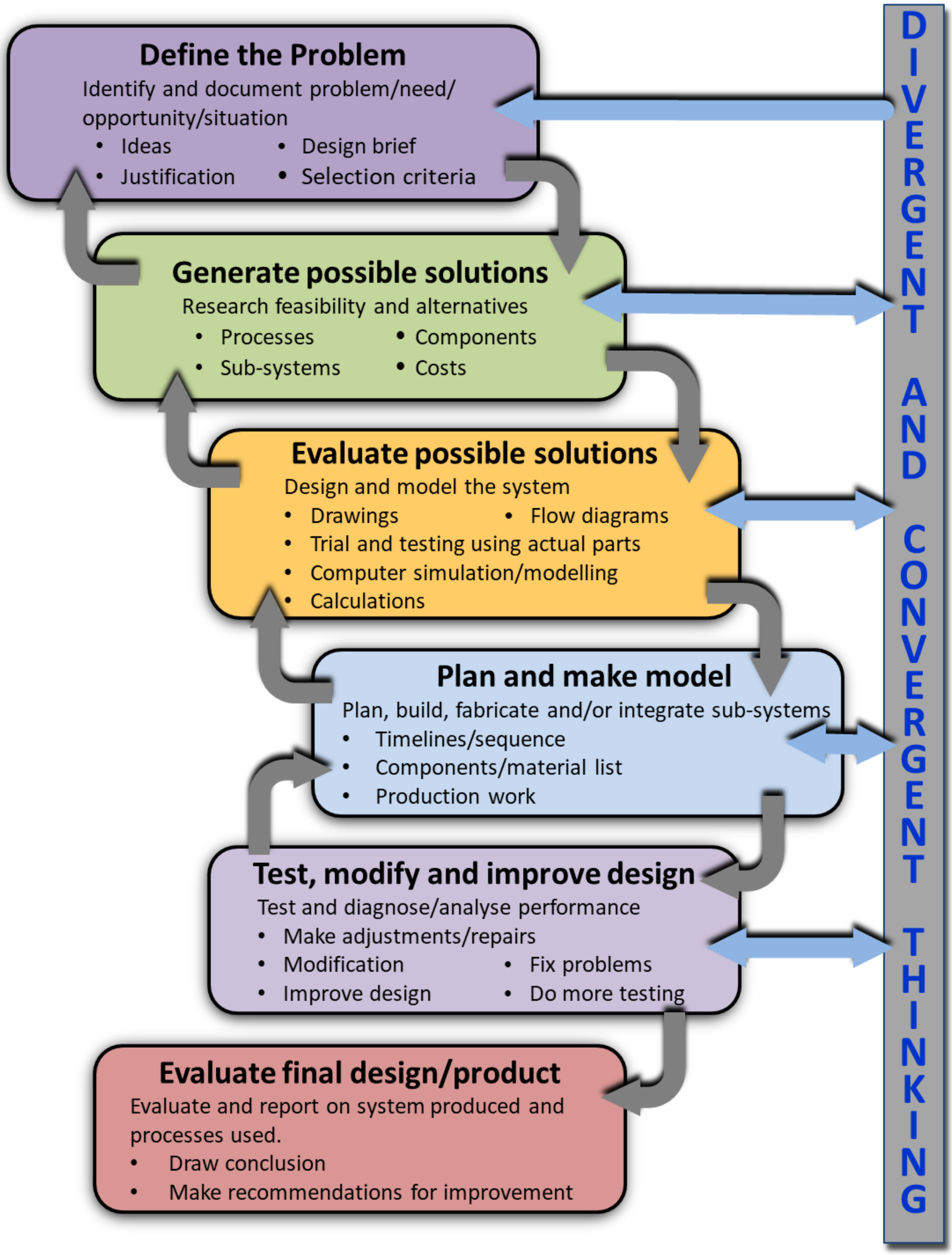
Student Learning Guide & Record

TASK	PAGE	TASK TITLE	ACHIEVED	
			YES	NO
Task 1	10	Identify an ethical problem of your choosing	☐	☐
Task 2	12	Explanation of the' law of conversation of energy'	☐	☐
Task 3	14	Description of energy	☐	☐
Task 4	16	The lever	☐	☐
Task 5	17	The inclined plane	☐	☐
Task 6	18	Screws	☐	☐
Task 7	19	Wheel and axle	☐	☐
Task 8	20	The pulley	☐	☐
Task 9	22	Belt drive and velocity ratio calculations	☐	☐
Task 10	22	Belt drive configurations	☐	☐
Task 11	23	Speed calculation	☐	☐
Task 12	25	Gears and gearing	☐	☐
Task 13	29	Physics of gears	☐	☐
Task 14	30	Velocity ratio table	☐	☐
Task 15	31	Types of motion	☐	☐
Task 16	33	Changing the direction of motion	☐	☐
Task 17	39	Moments	☐	☐
Task 18	39	Mechanical advantage	☐	☐
Task 19	40	Velocity ratio of levers	☐	☐
Task 20	47	Summary questions	☐	☐
Task 21	54	Review questions – Laws of motion	☐	☐
Task 22	56	Friction	☐	☐
Task 23	62	Hydraulic systems	☐	☐
Task 24	66	Complete the following exercises to display your understanding of pascal's principle	☐	☐
Task 25	68	Determine mechanical advantage	☐	☐
Task 26	77	Simple system	☐	☐
Task 27	77	Extension questions – Simple systems	☐	☐
Task 28	78	Pneumatic 'and' control	☐	☐
Task 29	78	Extension questions – AND control	☐	☐
Task 30	79	'OR' control	☐	☐
Task 31	79	Extension questions – OR control	☐	☐
Task 32	80	Speed control	☐	☐
Task 33	80	Extension questions – Speed control81	☐	☐
Task 34	81	Double acting cylinder	☐	☐
Task 35	81	Extension questions – Speed control	☐	☐
Task 36	82	Five port valve	☐	☐
Task 37	82	Extension questions – Five port valve	☐	☐
Task 38	83	5/2 Valve combination	☐	☐
Task 39	86	Determine the pull and thrust of a cylinder	☐	☐

TASK	PAGE	TASK TITLE	ACHIEVED	
			YES	NO
Task 40	89	Types of forces acting on a structure	☐	☐
Task 41	92	Review questions	☐	☐
Task 42	98	Summarise electron theory and the structure of the atom	☐	☐
Task 43	103	Review questions on resistors	☐	☐
Task 44	103	Use a multimeter to determine resistor values	☐	☐
Task 45	105	Review questions – Light Dependent Resistors	☐	☐
Task 46	109	Capacitors – Review questions	☐	☐
Task 47	116	Review questions on semi-conductors	☐	☐
Task 48	120	Make your PCB (optional)	☐	☐
Task 49	120	Check all components (optional)	☐	☐
Task 50	122	Mount and solder components (optional)	☐	☐
Task 51	123	Test your circuit	☐	☐
Task 52	124	Record data sheets used and information gained	☐	☐
Task 53	128	Review questions and explanations for voltage, amperage and resistance	☐	☐
Task 54	133	Batteries	☐	☐
Task 55	135	Summarise photovoltaric cells	☐	☐
Task 56	138	Review questions – Buzzers and piezo transducers	☐	☐
Task 57	148	Types of switches	☐	☐
Task 58	150	Review questions – Analogue and digital signals	☐	☐
Task 59	151	Research data storage	☐	☐
Task 60	151	Identify component circuit symbols	☐	☐
Task 61	154	Explain the terms, volts, amps and ohms and their relationship to each other	☐	☐
Task 62	161	Ohms law and resistance calculations	☐	☐
Task 63	164	Calculate capacitance	☐	☐
Task 64	170	Review questions for power and energy	☐	☐
Task 65	172	Electrical energy conversion and efficiency	☐	☐
Task 66	177	Producing alternating current and sine wave form	☐	☐
Task 67	180	Producing direct current	☐	☐
Task 68	182	Solenoid and relays	☐	☐
Task 69	185	Transformers	☐	☐
Task 70	189	Demonstrate your understanding of rectifiers to your teacher	☐	☐
Task 71	191	Fixed and variable voltage controllers	☐	☐
Task 72	200	Explain how a magnetic field creates movement	☐	☐
Task 73	202	Identify uses for microcontrollers	☐	☐
Task 74	203	Draw a system block diagram of your selected integrated system	☐	☐
Task 75	205	Draw a flow chart of your selected integrated and controlled system	☐	☐
Task 76	207	Record factors that influence your design	☐	☐
Task 77	208	Complete fish bone diagram	☐	☐

TASK	PAGE	TASK TITLE	ACHIEVED	
			YES	NO
Task 78	209	Additional factors to consider	☐	☐
Task 79	211	Decide on an integrated and controlled system that considers ethical design to plan, design and produce	☐	☐
Task 80	212	Carry out primary and secondary research	☐	☐
Task 81	216	Review the research data	☐	☐
Task 82	218	Write a clear and defined 'design brief'	☐	☐
Task 83	220	Concept drawings	☐	☐
Task 84	223	Design options	☐	☐
Task 85	226	Draw preferred design option	☐	☐
Task 86	228	Justification of preferred option	☐	☐
Task 87	229	Evaluation criteria	☐	☐
Task 88	230	Make a prototype model of your preferred design option	☐	☐
Task 89	231	List of materials, components and sub-systems	☐	☐
Task 90	232	Identify tools, equipment and machines	☐	☐
Task 91	233	Identify range of processes required	☐	☐
Task 92	236	Carry out risk assessment	☐	☐
Task 93	244	Risk assessment for the workplace	☐	☐
Task 94	245	Make a production plan	☐	☐
Task 95	247	Commence making your system	☐	☐
Task 96	247	Use measuring and/or test equipment	☐	☐
Task 97	251	Carry out the measuring and testing	☐	☐
Task 98	252	Perform basic calculations	☐	☐
Task 99	253	Reflections	☐	☐
Task 100	254	Design review/evaluation	☐	☐
Task 101	256	Maintain a record of the production work (50+ words)	☐	☐
Task 102	264	Investigate clean energy technologies	☐	☐
Task 103	268	Risk assessment	☐	☐
Task 104	273	Identify range of production processes for unit 4	☐	☐
Task 105	274	Identify tools, equipment and machines	☐	☐
Task 106	275	Performance characteristics	☐	☐
Task 107	280	Investigate Australian standards related to your product		
Task 108	281	Investigate and list data sheets and technical information related to your product		
Task 109	282	Maintain a weekly record of the processes used and decisions made during the production of your system		
Task 110	288	Write an evaluation report		
Task 111	295	Prepare your folio for Unit's 3 and 4 Outcome 1, for presentation		
Task 112	295	Evaluate your mechanical, electromechanical system		
Task 113	300	Investigate new and emerging technologies		

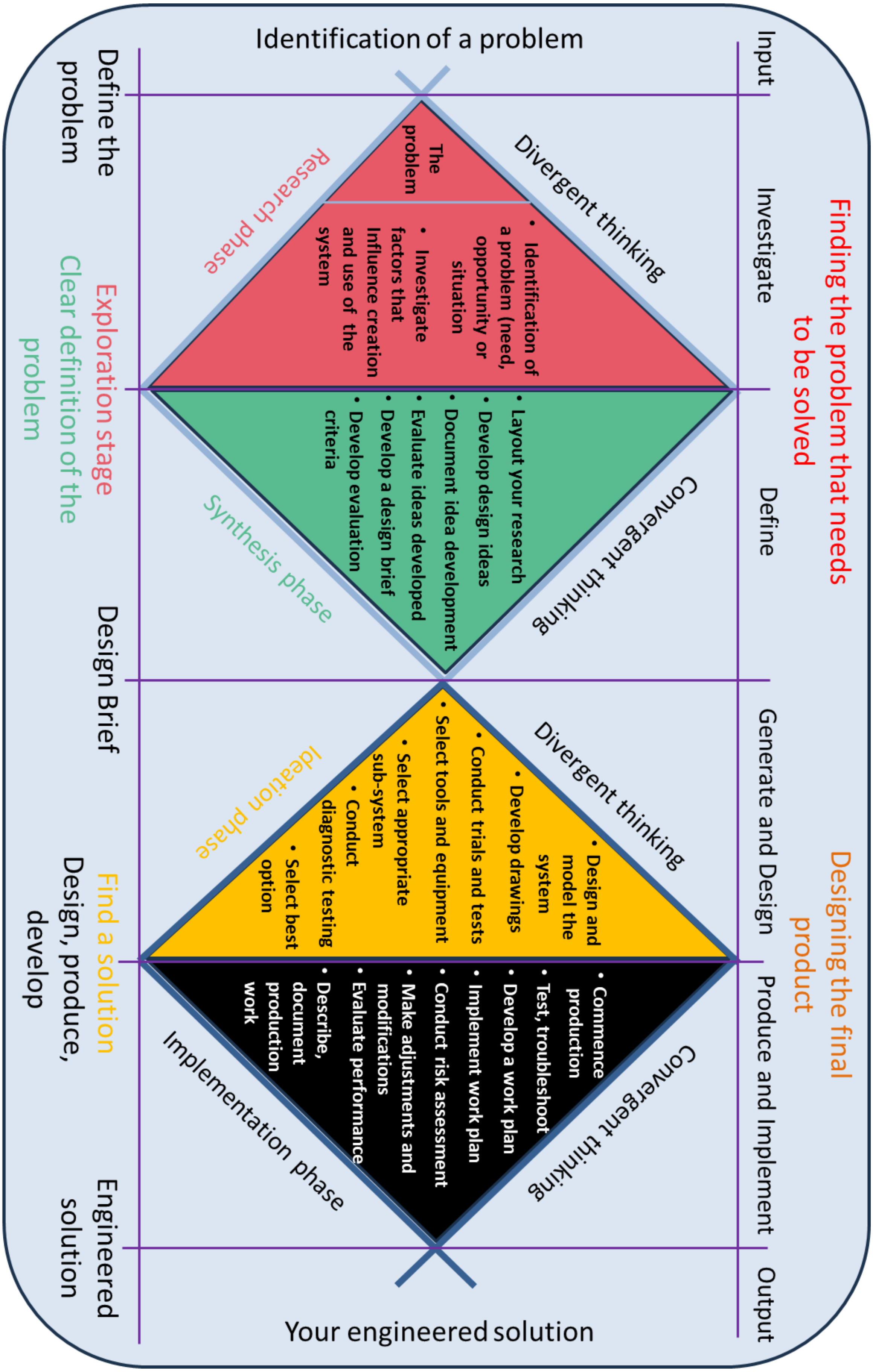
SYSTEMS ENGINEERING AGILE PROCESS



AGILE DESIGN PRINCIPLES

The Agile Design Framework is an iterative process that you will use to design, build, refine and improve your integrated and controlled system that addresses an ethical issue. The iterative approach is a method of problem solving or development that uses repeated cycles of planning, implementation, testing and evaluating, with adjustments made based on feedback and results. During the iterative process, you will continually improve your design and product until you are satisfied with your final project.

DOUBLE DIAMOND SYSTEMS ENGINEERING PROCESS



Adapted Double Diamond Approach from the British Design Council

HYDRAULIC SYSTEMS

Hydraulics deals with the properties of liquids and how they can be used to do work. The type of hydraulics applied to earth moving equipment, hydraulic equipment, aircraft system etc. is called power hydraulics, because it involves the application of power through the medium of hydraulics.

Development of power through hydraulics

'Power' is the product of force and distance divided by time. 'Work' is force times distance; hence, power can be defined as work divided by time taken.

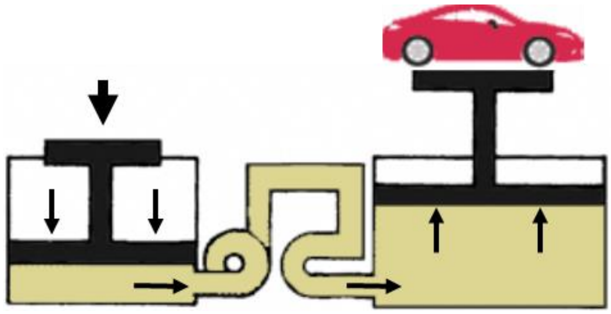
$$\text{Power} = \frac{\text{work}}{\text{time taken}}$$

'Force' may be considered as a push or pull or any cause which tends to produce or change motion. Force is measured in grams or kilograms. To measure the force of hydraulics, we must be able to determine 'force per unit area' (Pa/m^2). This is called 'pressure' and is measured in kilopascals (Kpa).

$$\text{Pressure} = \text{force x unit area}$$

Characteristics of liquids

Liquids are composed of tiny particles that move about easily. Liquids always take the shape of their container. For all practical purposes, liquids are incompressible. This characteristic makes them particularly suitable for transferring power from one place to another through tubing.



Applied hydraulics

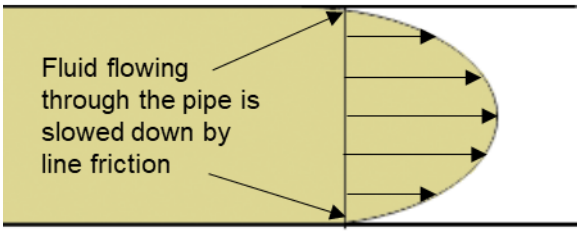
NOTE: Hydraulic fluids and other liquids expand as temperature increases; hence, safeguard must be provided in hydraulic systems to allow for the expansion and contraction of fluid as temperature changes. Devices to provide the necessary protection are called "thermal relief valves'.

FLUID FLOW

When a fluid flows through a tube, contact is made against the tube's walls. This holds some of the liquid back by resistance. As the velocity of a moving liquid increases, the resistance also increases. There are two kinds of fluid flow: laminar and turbulent.

Laminar Flow

When a liquid is forced through a constant-diameter tube at low velocity the flow is smooth and even and the fluid's particles tend to move in a parallel stream. The portion of liquid that touches the tube's walls is slowed down because of friction. This means the liquid near the centre of the tube moves at a higher velocity than does the liquid near the wall of the tube. However, as long as the velocity remains low, the flow will continue to be smooth because of the low resistance.



Laminar flow

TASK 24: COMPLETE THE FOLLOWING EXERCISES TO DISPLAY YOUR UNDERSTANDING OF PASCAL'S PRINCIPLE

How: Complete the following.

1. State Pascal's law.

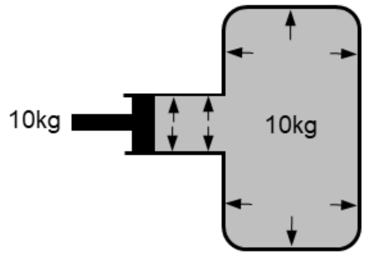
....

....

....

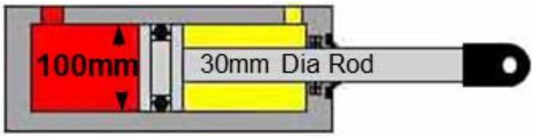
....

....



Fluid pressure is the same in all directions

2. The pressure in the cylinder is 2000Pa. Calculate the forces that act on the out stroke and the in stroke for the cylinder on the right.



Out stroke

F = PA on the full area of the piston

In stroke

F = P(A-a) on the rod side

....

....

....

MECHANICAL ADVANTAGE (MA)

One of the most important tools that you as the designer can use, is mechanical advantage. Mechanical advantage lets you accurately determine the size of actuating cylinders and pistons and the distance the pistons must move to operate a mechanism.

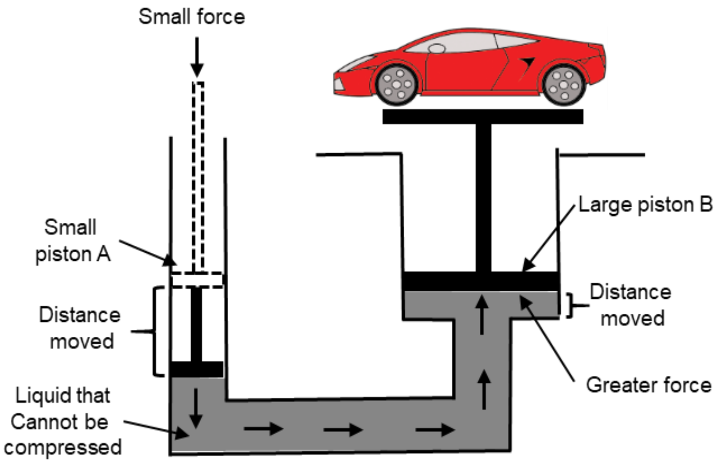
Vehicle hoist

The vehicle hoist on the right has a mechanical advantage of both power input and distance output.

The small input force on the small piston A results in a greater output force on the large piston B so there is a mechanical advantage.

The input force is called the **effort** and the output force is called the **load**.

The pressure at small piston A is equal to the pressure at large piston B (Pascal's principle).



Mechanical advantage

RESISTORS

Resistors are components used to control the size of the current that flows in an electrical/electronic circuit. The size of the current that flows depends on the property of the component called its resistance. The greater the resistance the smaller the current.

The higher the current draw from a battery, the faster the battery will be discharged. Resistance limits the amount of current drawn. It can also reduce the voltage in certain portions of a circuit.

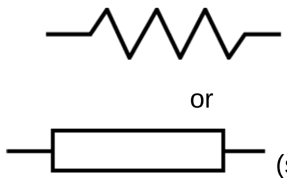
Resistors may be made from carbon, metal oxide or a coil of wire. Resistors are probably the most used class of components in electronics.

The resistors most used in electronic circuits include the fixed value resistor, the variable resistor, the temperature-dependent resistor (Thermistor) and the light-dependent resistor.

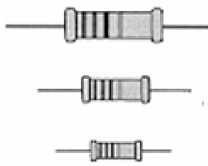
1. Fixed value resistors

Resistors are neither insulators nor conductors; they are somewhere in between, allowing some current to flow. The lower the resistance, the more current can flow.

Resistance is measured in **ohms**. Resistors are used to limit current to values that can be used by the various components; too much current and the components may be damaged.


(B2)
or
(standard)

Circuit symbol



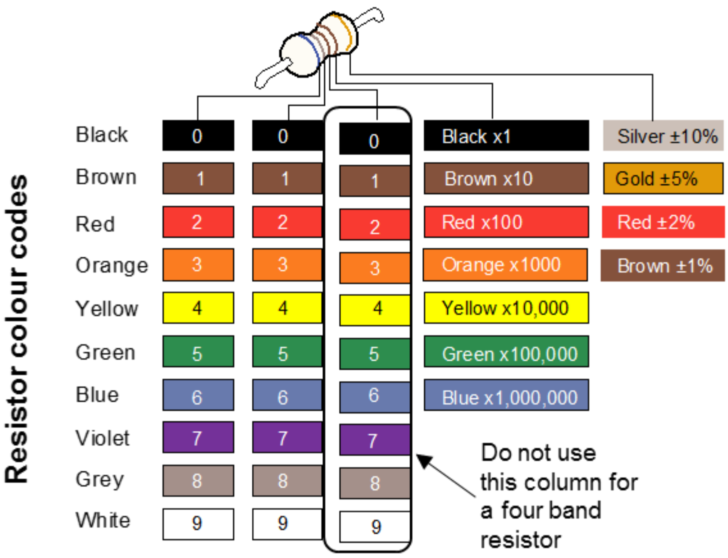
Fixed value resistors (W – Watt)

Fixed value resistors are made in sizes to suit the power rating of the resistor. Those shown on the previous picture are typical low power resistors with a power rating of one watt or less. Because these resistors are so small, it is not possible to print their resistance value on the body of the resistor. Instead, a series of coloured bands are printed around the body of the resistor. Each colour represents a number and the resistance value is therefore determined by reading the colour code.

The colours used in the resistor colour code are shown below.

Multiplication factors and symbols

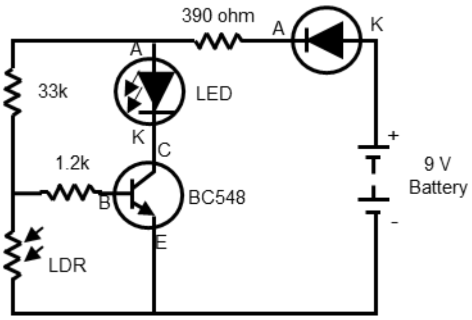
M	mega	1,000,000	(10^6)
k	kilo	1,000	(10^3)
m	milli	0.001	(10^{-3})
µ	micro	0.000,001	(10^{-6})
n	nano	0.000,000,001	(10^{-9})
P	Pico	0.000,000,000,001	(10^{-12})



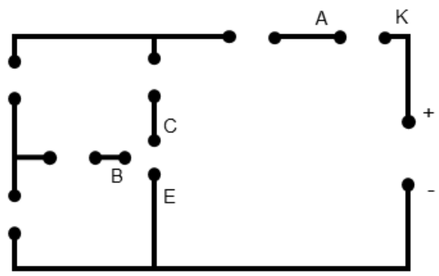
Four and five band resistor colour code

MAKING YOUR OWN PRINTED CIRCUIT BOARD (PCB)

Making a PCB for an electronic circuit is not a difficult task and it is a very handy skill to have for when you want to venture off and make new circuits.



Circuit diagram



PCB artwork

TOOLS/EQUIPMENT REQUIRED

- Single sided PCB 40mm x 60mm (1 off)
- Ferric Chloride (in powder form)
- Dalo pen
- Steel wool

PROCEDURES

1. Clean the copper surface of the PCB's by scrubbing with steel wool.
2. Obtain a copy of the PCB artwork.
3. Using a dalo pen draw an exact copy of the PCB artwork onto your PCB's.
4. Let the artwork dry for at least 30 minutes.
5. Drill mounting holes of a suitable size in the corners of the PCB.
6. Drill the centre of each pad using a 0.8mm high speed drill bit for mounting the components.

NOTE: ***Take care, make sure that you drill in the exact centre of each pad. This will ensure that soldering in your components is easier.***

7. Place the PCB's in an etching tank until the etching process is complete.

NOTE: ***If you don't have an etching tank, pour ½ litre of warm water into a plastic tray, add 30-50 gms of ferric chloride to it. Place in the PCB with the copper side facing up into the solution ensuring that it is fully immersed. The etching process should be completed in 30-60 minutes.***

CAUTION: ***Ferric Chloride is a very harmful chemical. It is hygroscopic in nature (it absorbs water) so it should be kept in an airtight container at all times. Gloves should be used to handle it. Safety goggles must be worn at all times. It should not be allowed to contact metal, because it eats the metal away.***

After the etching process is complete, remove the PCB and clean under running water.

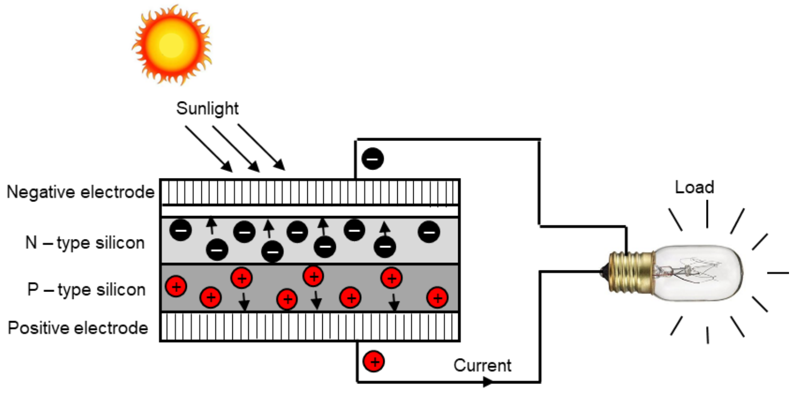
8. Remove the remaining dalo pen from the surface of each track by scrubbing with steel wool.
9. Mount all components.
10. Solder in the components.
11. Apply a coat of varnish to prevent oxidation.

PHOTOVOLTAIC CELL

Photovoltaic cells (PV) are used to convert the sun's rays into electricity. The light we can see has a medium amount of energy and is made up of tiny bits of energy called photons. Photons shoot out of atoms whenever their electrons change position in a particular way. This is electromagnetic radiation.

How Photovoltaic Cells Work

The diagram on the right illustrates the operation of a basic photovoltaic cell. The PV cell contains two layers of semiconducting material, one with a negative charge and the other with a positive charge. When sunlight strikes the cell, some photons are absorbed by semiconductor atoms, freeing electrons that travel from the negative layer of the cell back to the positive layer, in the process creating a voltage. The flow of electrons through an external circuit produces electricity.



The sunlight striking the cell is converted into electricity

Photovoltaic cell

Individual solar cells vary in size from about 1 cm to about 10 cm across. A cell of this size can only produce 1 or 2 watts, which isn't enough power for most applications. To increase power output, cells are electrically connected into a module.


Cell

Photovoltaic module

A number of photovoltaic cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module.

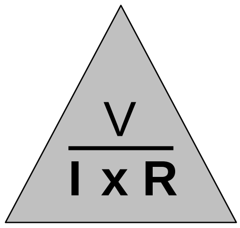

Module

Solar array

Modules are connected to form an array. The term "array" refers to the entire generating plant, whether it is made up of one or several thousand modules. The larger the area of a module or array, the more electricity that will be produced. Photovoltaic modules and arrays produce direct-current (dc) electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination.


Solar array

3. State the equation you would use to determine the following values:



a) Voltage **(V)**

. ...

b) Current **(I)**

....

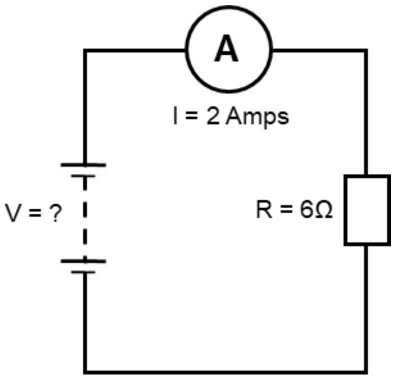
c) Resistance **(R)**

....

HOW TO USE OHM'S LAW

If you know any two of the volts amps or resistance in a circuit you can use Ohm's Law to calculate the third. The following examples show you how to calculate voltage, amperage and resistance

To Calculate Voltage

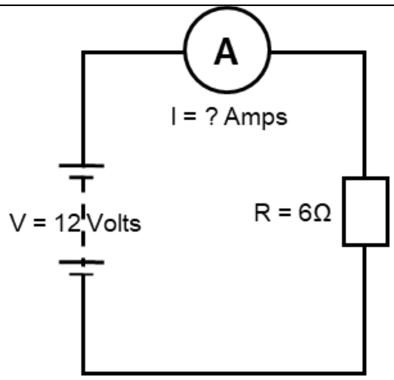


From Ohm's Law $V = I \times R$

$= 2 \times 6$

$= 12$ Volts

To Calculate Ampere

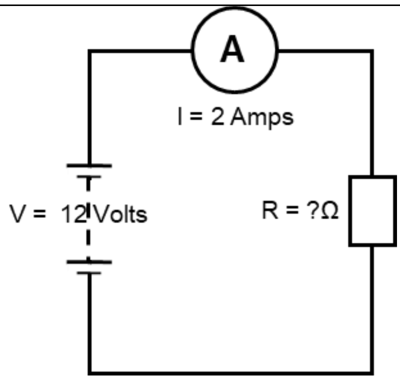


From Ohm's Law $I = \frac{V}{R}$

$= \frac{12}{6}$

$= 2$ Amp

To Calculate Resistance

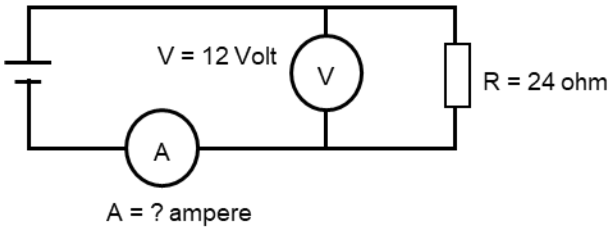


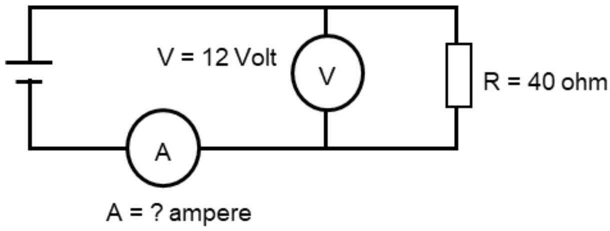
From Ohm's Law $R = \frac{V}{I}$

$= \frac{12}{2}$

$= 6$ Ohm

4. Complete the following practical applications of Ohm's Law.





a) I =

=

=

b) I =

=

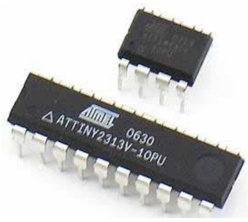
=

MICROCONTROLLERS

Having a basic understanding of microcontrollers could help you to select a control system for your integrated system.

WHAT IS A MICROCONTROLLER?

A microcontroller is often described as a "computer-on-a-chip". It is an integrated circuit that contains memory, processing units, and input/output circuitry.



Microcontroller

Microcontrollers are purchased "blank" and then programmed with a specific control program. Once programmed the microcontroller is built into a product to make the product more intelligent and easier to use.

WHERE ARE MICROCONTROLLERS USED?

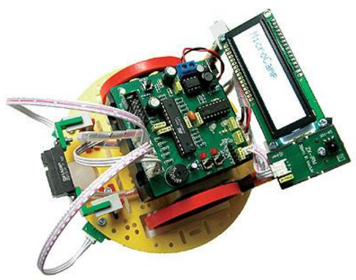
Applications that use microcontrollers include household appliances, alarm systems, medical equipment, vehicle subsystems, and electronic instrumentation. Some modern cars contain over 150 microcontrollers – used in a range of subsystems from engine management to remote locking!

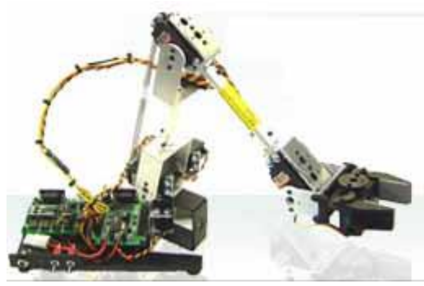
As an example, a microwave oven may use a single microcontroller to process information from the keypad, display user information, and control the output devices (turntable motor, light, bell and magnetron).

Microwave Oven

One microcontroller can often replace a number of separate parts, or even a complete electronic circuit. In industry, microcontrollers are usually programmed using the assembler or ‘C’ programming languages. Advantages of using microcontrollers:

- Increased reliability by using a smaller number of components.
- Reduced stock levels, as one microcontroller replaces several parts.
- Simplified product assembly and smaller end products.
- Greater product flexibility and adaptability since features are programmed into the microcontroller and not built into the electronic hardware.
- Rapid product changes or development by changing the program and not the electronic hardware.





Microcontroller models from www.robot.com

TASK 77: COMPLETE FISH BONE DIAGRAM

How: Complete the following fishbone diagram to assist you to further consider the influencing factors that need to be considered with the design, planning, production and use of your integrated and controlled system.

	Function	Safety	Cost	User needs requirements	
					Use
					Production
					Planning
Name of product					**Design**
....					**Design**
					Planning
					Production
					Use
	Materials	**Components**	**Environment of Use**	**Minimising Waste and Energy Use**	

RISK MANAGEMENT

Risk assessments are a crucial part of displaying compliance with OHS laws and regulations. Without risk assessment forms there is no way for the relevant workplace health and safety officers to determine if you have even attempted to maintain compliant OHS standards.

A risk assessment builds your knowledge and helps you to understanding about hazards and risks that have been identified in your workplace and in your prototype model. This knowledge helps you to make informed decisions to effectively control the risk.

A Risk assessment involves:

1. Determining what levels of harm can occur.
2. Determining how harm can occur.
3. Determining the likelihood that harm will occur.

EVALUATE THE RISK

As mentioned earlier, a risk is defined as the likelihood that a hazard will cause harm and to help you assess the risk you can use the following tables and formula.

How likely is it that the hazard may result in harm? (Likelihood)	If the hazard does result in harm, how severe would the injury be? (Severity)
1. Highly Unlikely	1. Scratch (trivial)
2. Unlikely	2. Minor injury (Cut)
3. Possible	3. Major injury (Fracture - Over 3 day injury)
4. Probable	4. Major injury (Amputation)
5. Certain	5. Death (Death)

To carry out a risk ranking simply multiply the Likelihood x Severity.

Example:

It is **Probable (4)** that the hazard may result in harm and could cause a M**ajor injury (4)**.

Likelihood x Severity = Priority. 4 x 3 = 12

Likelihood	Severity				
	Trivial	Minor injury	Over 3 day injury	Major injury	Incapacity or death
Highly unlikely	**1**	**2**	**3**	**4**	**5**
Unlikely	**2**	**4**	**6**	**8**	**10**
Possible	**3**	**6**	**9**	**12**	**15**
Probable	**4**	**8**	**12**	**16**	**20**
Certain	**5**	**10**	**15**	**20**	**25**

UNIT 3 ETHICAL SYSTEMS DESIGN

OUTCOME 2 – CLEAN ENERGY TECHNOLOGIES

This area of study examines various energy sources and the application of technologies to convert these energy sources into work for engineered systems.

The outcome focuses on your ability to discuss the advantages and disadvantages of renewable and non-renewable energy sources, and analyse and critique technologies used to harness, generate and store non-renewable and renewable energy. (Systems Engineering Study Design Page 40 - 41).

Form of Non-renewable energy sources

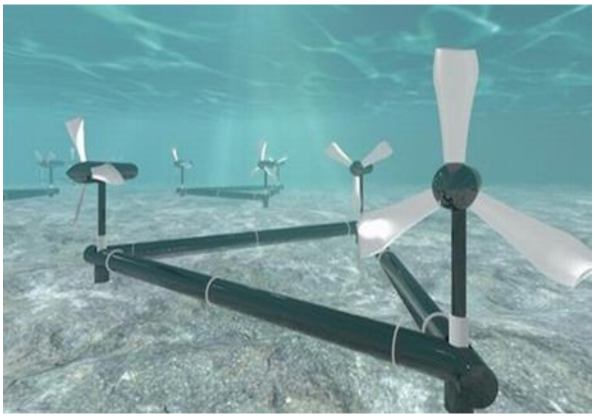
- Fossil fuels Current dependence on this energy form for industry and society.

Form of Renewable energy sources

- Wind
- Solar
- Tidal
- Wave
- Hydro
- Geothermal
- Biomass

Coal fired power station (non-renewable)

Wind energy (renewable)



Tidal energy (renewable)

Geothermal energy (renewable)

AUSTRALIAN STANDARDS

Australian Standards have been developed to ensure that all work carried out, is to a suitable level of quality and safety and to maintain the high standards that are part of everyday Australian life.

Australian Standards are of public benefit and national interest and promotes and supports Australian design and innovation. It is recognised as the peak, non-government standards development body in Australia.

Standards Australia develops and maintains around 7000 Australian Standards and related publications which are prepared by over 1500 committees involving more than 8000 committee members. These documents, used in countless daily business transactions, facilitate trade between individuals, corporations and nations. More information visit *www.standards.org.au*.

TASK 107: INVESTIGATE AUSTRALIAN STANDARDS RELATED TO YOUR PRODUCT

How: Identify and explain the Australian Standards that relate to your integrated and controlled system that considers ethical design, using the systems engineering process.

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DATA SHEETS AND TECHNICAL DATA MANUALS

The role of data sheets and technical manuals is to provide detailed information on the physical and operational characteristics of a product for the user. The product data sheets and technical manuals are available from the manufacturer.

TASK 108: INVESTIGATE AND LIST DATA SHEETS AND TECHNICAL INFORMATION RELATED TO YOUR PRODUCT

1. Investigate and list the data sheets and technical information that you required for the design and construction of your integrated and controlled system.

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UNIT 4 SYSTEMS PRODUCTION AND INNOVATIVE TECHNOLOGIES

OUTCOME 2 – NEW AND EMERGING TECHNOLOGIES

This area of study focuses on new and emerging systems, engineering technologies and processes that have been developed within the last eight years preceding the year of study, or that are in the developmental stages and may not yet be commercially available. You consider scientific, technological, environmental, economic, and societal and human factors that led to the development of these new and emerging technologies and develop an understanding of how they operate and are used.

The component/s, system or innovation must not be the same as that studied in Unit 3, Area of Study 2. (Systems Engineering Study Design Pages 43 – 44)

On completion of this unit the student should be able to evaluate a range of new and emerging systems engineering technologies and analyse and critique likely impacts of these selected technologies.

New and emerging technologies

You should gain an understanding of:

- New and emerging developments in systems engineering products and components, how they work and their applications.
- New and emerging developments in systems engineering processes improve economic and environmental sustainability, efficiency and risk management.
- Reasons for and drivers of the development of new and emerging technologies, including discoveries, new materials, technology convergence and new manufacturing methods and processes.
- Positive and negative impacts and the future potential of the new and emerging developments.

You can be required to carry out the following:

- Research and evaluate the operations and applications of new and emerging developments in systems engineering processes and products.
- Explain reasons for and drivers of the development of new and emerging technologies.
- Analyse and critique impacts and the potential of the new and emerging developments.
- Analyse and present information about new and emerging systems engineering innovation.

New and emerging technologies may be exhibited in, or intended for use in

- Defense operations
- Aerospace
- Health
- Sports, and enhancement of human physical capabilities
- Security and intelligence gathering
- Robotics and automation
- Metrology
- Transportation
- Education