Engineering application module: Personal and public transport

30 hours indicative time

Select one or more forms of transport in this module. Some examples include: bicycles, motor cars, boats, motor cycles, buses, trucks, trains and trams.

Outcomes

A student:

H1.2 differentiates between the properties and structure of materials and justifies the selection of materials in engineering applications

H2.1 determines suitable properties, uses and applications of materials, components and processes in engineering

H3.1 demonstrates proficiency in the use of mathematical, scientific and graphical methods to analyse and solve problems of engineering practice

H3.2 uses appropriate written, oral and presentation skills in the preparation of detailed engineering reports

H3.3 develops and uses specialised techniques in the application of graphics as a communication tool

H4.1 investigates the extent of technological change in engineering

H4.2 applies knowledge of history and technological change to engineering-based problems

H4.3 applies understanding of social, environmental and cultural implications of technological change in engineering to the analysis of specific engineering problems

H5.1 works individually and in teams to solve specific engineering problems and prepare engineering reports

H6.1 demonstrates skills in research and problem-solving related to engineering

H6.2 demonstrates skills in analysis, synthesis and experimentation related to engineering.

1. Historical and societal influences	
Students learn about:	*Notes:*
▪ historical developments in transport systems	▪
▪ effects of engineering innovation in transport on society	▪
▪ construction and processing materials used over time	▪
▪ environmental effects of transport systems	▪
▪ environmental implications from the use of materials in transport	▪

Students learn to:	*Notes:*
▪ investigate the history of technological change related to transport and its impact on society	▪
▪ identify design features in the engineering of transport systems	▪

▪ describe the environmental impact of energy requirements for transport systems	▪
▪ analyse the impact of developments in transport systems on the environment	▪

2. Engineering mechanics	
Students learn about:	*Notes:*
▪ simple machines	▪ Simple machines equations for its mechanical system. ▪ **Mechanical advantage (MA)** – Mechanical advantage (MA) is the measure of how useful and help a machine is to the user. – MA in mechanical machine, is the ratio of load to the effort. – The higher the MA, the lower the effort is required for the load. – If MA is below one, then it is known as mechanical disadvantage, which mean the effort is greater than the load. $$\mathrm{MA} = \frac{\mathrm{L}}{\mathrm{E}}$$ $\text{where MA} = \text{Mechanical Advantage}$ $\mathrm{L} = \text{Load}$ $\mathrm{E} = \text{Effort}$ ▪ **Velocity ratio (VR)** – VR is the ratio of the distance the effort moves to the distance of the load moves in a mechanical system. – The higher the VR the greater, the greater the distance the user must move. $$\mathrm{VR} = \frac{\mathrm{d_e}}{\mathrm{d_l}}$$ $\text{where VR} = \text{Velocity Ratio}$ $\mathrm{d_e} = \text{distance the effort moves}$ $\mathrm{d_l} = \text{distance the load moves}$ ▪ **Efficiency (η)** – An ideal machine would have 100 % efficiency. – But there is always some type of energy that is transfer into different forms of energy, and this is energy loss, which means that the machine isn't 100 % efficient.

	– MA is always less then VR – To calculate the energy efficiency percentage $$\eta = \frac{MA}{VR} \times 100$$ $\text{where } \eta = \text{percentage effieciency}$ $MA = \text{Mechanical Advanrage}$ $VR = \text{Velocity Ratio}$
▪ static friction – concept of friction and its application in engineering	▪ Static friction is friction that relates to an object that is either not moving or is at the verge of moving. ▪ If an object moves the engineers deal with kinetic friction [NOT IMPORTANT] – Concept of friction and its application in engineering ▪ Friction is a stopping force, and without it, one cannot simply brake or tighten a screw. Though it would mean all energy is converted in the machine and is 100 % efficient. [Note is will be difficult to manage the machine] ▪ Thus, friction is known as the enemy of efficiency, as a small amount of input power will convert in friction force or a stopping force and as a result, output a lower power. ▪ Frictional force always means it oppose the motion and will cause wear and maintenance. ▪ But the concept of friction is essential in life, as it provide advantages of braking and stopping situations.
▪ coefficient of friction – normal force – friction force – angle of static friction – angle of repose	▪ **Coefficient of friction is denoted as μ**, **Mu.** $$\mu = \frac{F_F}{R_N}$$ $\text{where } \mu = \text{coeffiecient of friction}$ $F_F = \text{Frictional force}$ $R_N = \text{Reaction force, Normal force}$ ▪ It can also be found by using the angle of repose $$\mu = \tan(\Theta)$$ – **Normal force** ▪ Normal force is the force that is **always acted perpendicular** to the **surface of an object.** Usual equation: $R_N = mg\cos\theta$ – **Friction force** ▪ Friction force is always **opposite in the direction of motion.** ▪ **T**wo things define a friction force; **frictional resistance** and **force resisting** the tendency toward motion between the surface.

	$$F_F = \mu R_N$$ ▪ Limiting friction is the friction resistance that exist when an object is about to move – **Angle of static friction** ▪ Angle of static friction is important upon **founding the coefficient of friction**. ▪ In normal static friction diagram, there are usually 4 forces, Weight, Reaction, Load (P) and Frictional force. If the vectors of friction force and reaction force are added, then there would be a resultant force and a total of 3 forces. This resultant will have an angle with the reaction normal force. This angle is known as angle of static friction. ▪ The angle of static friction is used to determine μ. $$\mu = \tan(\emptyset_s)$$ $$\text{where } \emptyset_s = \text{Angle of static friction}$$ ▪ When limiting friction is used or an incline, the angle of static friction is equal to the angle of incline. – **Angle of Repose** ▪ The **angle of repose is equal to angle of static friction proof**. ▪ Imagine an object on **an incline**. $$\mu = \frac{F_F}{R_N}$$ $$\mu = \frac{W\sin\theta}{W\cos\theta} = \tan\theta$$ $$\therefore \tan\theta = \tan(\emptyset_s)$$ $$\theta = \emptyset_s$$
▪ basic calculations for work, energy and power – potential energy – kinetic energy	▪ **Work** Work is the ability to move on object requiring a **force over a displacement**. $$W = F \times s \times cos\theta$$ ▪ **Energy** Energy is the **capability to undergo work**. – **Potential Energy** The energy at which allows to object to be in a **fixed position** on a planet $$GPE = mgh$$ – **Kinetic Energy** An object that is in **motion** will possess Kinetic energy. $$KE = \frac{1}{2}mv^2$$

	▪ **Conversation of Mechanical Energy** As an object **gains GPE**, it will start to **lose KE**, and conversely $$KE_i - KE_f = GPE_f - GPE_i$$ $$\frac{1}{2}m{v_i}^2 - \frac{1}{2}m{v_f}^2 = mgh_f - mgh_i$$ $$\frac{1}{2}m({v_i}^2 - {v_f}^2) = mg(h_f - h_i)$$ OR $$KE = GPE$$ $$\frac{1}{2}mv^2 = mgh$$ $$v^2 = 2gh$$ $$v = \sqrt{2gh}$$ ▪ **Strain Energy** Strain Energy is a type of **potential energy** mainly used for the expansion and contraction of **springs.** $$SE = \frac{1}{2}Fe$$ $$where\ e = extension\ (m)$$ ▪ **Power** Power is the **rate of doing work.** $$P = \frac{W}{t}$$ $$= \frac{Fs}{t}$$ $$= F\frac{s}{t}$$ $$= Fv$$

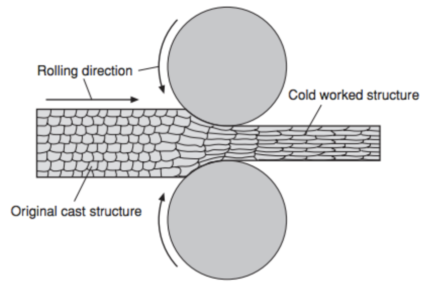
Students learn to:	*Notes:*

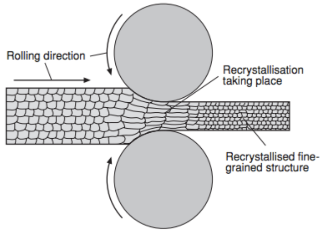
▪ apply mathematical and/or graphical methods to solve engineering problems related to transport including mechanical advantage, velocity ratio and efficiency	▪
▪ analyze problems involving static friction	▪
▪ differentiate between the concepts of energy and power and apply appropriate basic calculations	▪

3. Engineering materials	
Students learn about:	*Notes:*
▪ testing of materials – hardness – impact	▪ *The testing of material is improving the understanding of properties of that material* – *Hardness tests* ▪ *Brinell* – *A hardened steel ball is forced into an object under specified load conditions. The diameter of the ball depends on the test specimen's thickness. The hardness value is measured by the depth of the surface area of the impression.* ▪ *Vickers* – *A small square pyramid steel is forced into the test specimen under specified load conditions. It is then the calculated by using the load and the area of the indentation.* ▪ *Rockwell* – *A diamond cone or sphere is forced into the test specimen.* ▪ *Shore Scleroscope* – *Involves a striker, which is an object used for dropping. A striker will be held in a tube, and a test subject is placed on top of the tube. With the striker on the other end the tube is flipped and the strike will impact the test subject. The height of the rebound, is observed and measure to determine the hardness.* – *Soft object will absorb more energy, hence a lower rebound height.*

	– *Impact tests*
	  ▪ *Impact tests are carried out to determine the notch toughness of a material.*
	  ▪ *A material is shaped as a rectangular prism with a V notch in the centre.*
	  ▪ *The notch is subjected to a concentrated shock load to found its toughness.*
	  ▪ *Tough material will not break easily compared to brittle materials.*
	  ▪ *Izod test*
	    – *Izod test is an impacting testing method that requires a pendulum and a scale.*
	    – *The test specimen is to place vertically in the centre of while supporters. It is placed so that the V notch is facing away from the pendulum.*
	    – *The scale is calibrated and the pendulum is raised to a specific height. [Provide GPE]*
	    – *Upon release, it loses GPE and hence gains KE. When it swings, and strikes the test, the KE will be absorbed by the test into breaking it.*
	    – *After impacting and breaking of the piece, the remaining KE will act forward lifting the pendulum and gain GPE. Thus, loses KE, until all the energy is used to gain height.*
	    – *TO measure the toughness, the difference of the height is taken.*
	  ▪ *Charpy test*
	    – *Charpy test has the same procedure as Izod testing, but the position of the specimen is placed different.*
	    – *Instead of vertically, the test is held horizontally with the V notch placed facing away of the pendulum.*

▪ heat treatment of ferrous metals
  – annealing
  – normalising
  – hardening and tempering
  – changes in macrostructure and microstructure
  – changes in properties
	▪ **Heat treatment**
	  – Heat treatment of metal usually consist of heating the metal to above its recrystallization temperature and it then either air cooled, or quench at different rates to obtain the desired properties.
	▪ **Annealing**
	  – **Process annealing**
	    ▪ Process annealing is often heat treated for soft metal containing low carbon content. The metal is heated to around 550 – 650 degrees, and it air cooled. This relieve any stress from the distorted grains, whilst producing recrystallised ferrite, and leaving a small amount of pearlite in stressed/deformed state.
	  – **Full annealing**
	    ▪ Full annealing involves heating the metal to 900 degrees, before allowing too slowly cool in a furnace. This places the unstressed grains back into its equilibrium condition, providing a soft metal and unstressed grains.
	▪ **Normalising**
	  – The metal is heats to above the critical temperature and recrystallization temperature. Then is air cooled at a faster rate than full annealing, providing a finer grain structure, increasing yield strength, UTS and toughness, however decreases in ductility.

	▪ **Hardening** – Hardening steel **depends on it carbon content**. Steel with carbon content is **heated and then quenched**. This result in the steel **transforming from FCC to BCC**, leaves the **carbon trapped in the distorted lattice causing a stress state**. This is known as **Martensit**e and found in **steel with >0.03% carbon content.** ▪ **Tempering** – Tempering is **done after hardening** when the metal has obtained **Martensite (a hard structure making them brittle).** The metal is **heated to around 200-600 degrees** and is **air cooled**. This **reduces the hardness** of the metal whilst **increasing the toughness** the same. ▪ Changes in macrostructure and microstructure – Annealed ➔coarse grain structure ➔ soft with moderate strength – Normalised ➔ fine grain structure ➔ higher strength – Hardening ➔ stressed grain structure ➔ hardness + brittleness – Tempering ➔ very fine grain structure ➔ toughness + hardness.
▪ manufacturing processes for ferrous metals – forging – rolling – casting – extrusion – powder forming – welding	▪ **Hot Working ➔ Heated above recrystallization** temperature where material is **more malleable** and **easier to deform**. ▪ **Cold Working ➔ Heated below recrystallization** temperature where the material will **increase in strength and hardness**. ▪ **Forging** – Forging allows for the desired shape of a metal via undergoing **compressive impact**. The main advantage of forging is that **neat grain structure will follow the flow of the shape, achieving very high strength**. – **Drawing** ▪ Forge drawing involved hammering the **sides** to **draw out the length whilst reducing the cross section**. – **Upsetting** ▪ Forge Upsetting involved hammering the on the **face** to **increase the cross section whilst reducing the length.** – **Drop** ▪ Forge Drop involves the **hydraulic press to operate as a hammer** to shape the metal. ▪ **Rolling** – Rolling is where the metal is shaped into thin piece of metal by passing the metal through rollers. – **Hot rolling (Hot Working)** ▪ The metal is **passed through a series of rollers**, where recrystallization take place to form **unstressed fine grain structure**.  Figure 3.15 Cold rolling

	– **Cold rolling (Cold Working)** ▪ The metal will require **more force to deform into the shape**, as they are create **elongated grain structure**. This gives them **more strength and resilience**, however reducing the **malleability**.  Figure 3.14 Hot rolling ▪ Casting ▪ – Casting is the process of hot molten metal into a mould and letting it our once its cooled. – There are many varieties of casting and the biggest difference is how it is moulded. – Types – Sand Casting ▪ Involves the following steps: ▪ Sand with a binder is packed around the pattern shell of the finished product. ▪ The mould be cut into two halves where the shells can be removed. ▪ The Drag [lower box], is placed with the half of the pattern inside. The sand with the binder [known as green sand] is packed over the dump box. ▪ The inverted [flipped over] and a box with the runner and riser is placed on top of the box [cope]. ▪ The cope has two pins, and the molten metal is poured down the runner. ▪ This is done until both the runner and riser is filled. ▪ It is then left to solidify and any shrinkage caused by the contraction of the molten metal from the pins with flow into the casting. ▪ Finally, when it is cooled, the casting is removed and produce the end product. ▪ This process is the most common casting and is relatively cheap and easy to process. ▪ It will provide a neater grain structure thought the surface of the product will not be as accurate and neat. ▪ Therefore, further machinery work is done to achieve the smooth edges. – Shell Casting ▪ Involve the pattern or the shape of the object made in a shell. ▪ The shell is placed in the top half of the dump box, inside the dump box, sand and resin should fill the box. ▪ The dump box is flipped over and sand and resin should hold together due to the heat in the pattern shell. ▪ They are then both heated to around 315 degrees to ensure the hold firmly. ▪ They are then cured and ready to be ejected of using a small ejector pin. The pattern shell should come off. ▪ Do the same process with the other half of the mould. ▪ Then they placed together in a box surrounded by metal shots. ▪ Upon solidification of the casting, the mould should separate providing the end product.

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This method will provide a better product than sand casting, giving a better dimensional accuracy.
However, it is more cost effective and long to obtain.

Investment Casting
Casting

Extrusion

Extrusion where metal is forced and pressed through a die.
Direction Extrusion (Hot Working)
The metal is pushed into tubed die, and squeezed out through a hole other end.
Indirection Extrusion (Hot Working)
The metal is pushed in a mould where there no space left but to push the metal outwards. This method is very expensive.
Impact Extrusion (Cold Working)
The metal is punched by hammer, which force the metal to form around the hammer. Tubes and drink cans are made from impact extrusion.

Drawing (Cold Working)
Drawing is like extrusion; however, they are used to produce wires, tubing and thin rod. Hence, ductile material is use drawing to form thin wire, with high strength whilst keeping it light weight.
Powder Forming
Powder metallurgy involves metal taking form of powder. This can be done by through, mechanical disintegration, grinding or atomizing power
Welding
Welding allows metals to join, by heating the metals which causes a change to the grain structure.

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<tr><td>changes in macrostructure and microstructure of ferrous metals</td><td></td></tr>
<tr><td>changes in properties of ferrous metals</td><td></td></tr>
<tr><td>manufacturing processes for non-ferrous metals
alloying
annealing
solid solution hardening</td>
<td>These are the material most suitable that work exceptionally well, due their nature.
Nickel
Copper
Magnesium
Aluminium
Non-ferrous metals do not contain Iron and are usually more corrosive.</td></tr>
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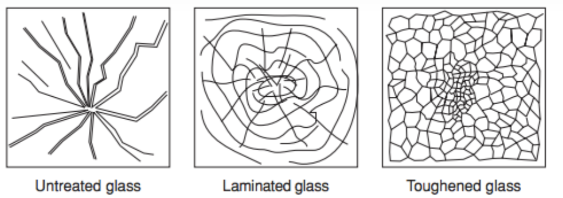
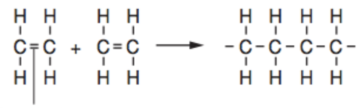
	▪ They will have less magnetic properties and are desirable due to their low weight. – Alloying ▪ Alloy is the process where there is mixing of two or more elements. ▪ This however depends on the size of atomic radius or solute elements ▪ These make the metal stronger and harder than regular pure metal. ▪
▪ changes in macrostructure and microstructure of non-ferrous metals	▪
▪ changes in properties of non-ferrous metals	▪
▪ ceramics and glasses – as an insulation material – laminating and heat treatment of glass – structure/property relationship and their application	▪ Structural ceramics: – Oxide ➔ Chemical compound consisting of one oxygen atom and other atoms. – Boride ➔ Mixture of Boron and metal properties. – Carbides ➔ Made of carbon and is usually salt-like. – Nitrides ➔ Made of nitrogen. ▪ **Ceramics** – Ceramics are made from three constituents, **Clay, Flint, Feldspar**. They have **high flexible strengt**h and are used as **insulating materials**. – Application like wear-resistant tiles, electrical insulators on power lines and heat treatment as tiles for space shuttles. ▪ **Glass** – **Anneal glass** ▪ Anneal glass is the process where glass is heated and produced by slowly cooling from there operations until they obtain the state of minimal internal stress. These glasses tend to break in large shards, posing a safety hazard. Not permitted to be used as windscreen and shower screens.  – **Tempered (Toughened)** ▪ Tempered glass is heated to increase the resistance to fracture. The glass is air quenched and cooled, which contracts the glass into internal compression (making them shatter resistance). – **Laminated**

	▪ Laminated glass consists of layers of glass being sandwiched and in between compressed with PVB (Polyvinyl butyral). The glass is heated inside a furnace making them stronger, as when they fracture, it causes a spider web effect and doesn't shatter. ▪ **Windscreens and side windows (Application)** – There has been an advancement that tempered glass is being laminated and using the two properties combined create scratch/wear and shatter resistance glass.
▪ thermos softening polymers – engineering textiles – manufacturing processes ▪ extrusion ▪ injection moulding ▪ blow moulding – structure/property relationships and application	▪ **Thermosoftening Polymers** – These polymers are based of covalent bonding of carbon (C) and Hydrogen (H) to form hydrocarbon. Multiple hydrocarbon form specific polymers.  Figure 3.24 Polymerisation of ethylene ▪ **Van Der Waal** – Van Dar Waal's is a **type of force** in polymerisation as, the thermosoftening polymers chain can have **uneven distributed electrons**, these cause some parts to be negative charge whilst other positive, **creating a force**. ▪ **Thermosetting Polymers** – ▪ Extrusion – ▪ **Engineering Textile** – **Polypropylene, polyethylene, polyester and nylon, acts as fabrication system**, known as 'shade cloth' to protect from ultraviolet rays – **Tough woven polymer fabric is used in public transport seat**, to prevent from rip and vandalism.

Students learn to:	*Notes:*
▪ differentiate between the concepts of energy and power and apply appropriate basic calculations	▪
▪ investigate the application of testing of materials	▪

▪ outline how changes in properties occur as a result of heat treatment processes	▪
▪ identify appropriate heat treatment processes	▪
▪ justify appropriate choices for ferrous materials and processes used in transportation parts and systems	▪
▪ experiment with metals to reinforce the concepts of heat treatment	▪
▪ explain the method and applications of various ferrous metal forming processes	▪
▪ justify the use of non-ferrous metals in transportation parts and systems based on relevant structure/property relationships	▪
▪ justify appropriate choices of ceramics and glasses used in transportation parts and systems	▪
▪ justify appropriate choices of polymers used in transportation parts and systems	▪
▪ explain the properties, uses, testing and appropriateness of materials used in transportation	▪

4. Engineering electricity/electronics	
Students learn about:	*Notes:*
▪ Power generation/distribution – electrical energy and power – simple circuits	▪ Electrical energy and power – Coal – Burning coal is the most common method of electrical generation. – Power station burn coal, because coal is always readily available as a resource. – Uses coal and water as fuel. – The coal is first set to boil. – The heating of the coal, produces steams which flows and drives the steam turbines. – The turbines are connected to a generator which the spun turbine produces electrical energy. – This pose the increase in high volumes of carbon dioxide affecting the greenhouse effect. – Hydroelectricity – These hydroelectric systems offer electricity without atmospheric pollution. – Uses the energy of water as fuel. – As the gravitational potential energy of water is converted to kinetic flowing water, the water is flowing down into the power station. – These rushing water drive the turbines connected to a generator. – As the generators produces electricity, the flowing of the water is fed back into the water system for irrigation. This offers little waste to water and less atmospheric pollution. – However, this form of system requires mountainous regions and large land for water flow control and channels to provide proper dams. – Wind power – Another source of alternate energy power source to generate energy. – Wind is driven through large turbines, which are like windmills. – The momentum of the turbines drives the generators to produce electricity. – This method may be the cleanest but will require a lot of turbines to power a large city. Hence vast mass of land must be devoted. – Nuclear power – This method may be very effective in both the production of electrical energy, and harmful effects on Earth.

	– Nuclear power uses nuclear reaction to heat power station. Just like coal power station, coal is the source of heat and steam. In nuclear power station, Uranium atoms are splits causing a nuclear reaction and producing immense heat. – This causes steam and heats up the turbines to produce electricity. – This method is very non-atmospheric polluted and requires very little fuel. – But, other issues arises, like the waste of nuclear power due to radioactivity can be very contaminated for thousands of years. Wrong human errors can lead to devastating situation like, Three Mile Island, Chernobyl and Fukushima.
▪ electric motors used in transport systems – principles – applications	▪ **Electric Motors** – **Principles** All Electric motors **convert electrical energy into mechanical energy**. Using the **Motor Effects, Faraday's Law of Electromagnetism** and **Lenz's Law**. – **Applications** They are used as 3 phases synchronous motors, AC induction motors, universal motors and DC motors ▪ **3 Phases Synchronous Motors** – **3 Phases** have **3 pairs of electromagnets** that are provided by current carrying conductors. With this, it induced a **rotating magnetic field** which induced currents on the rotor. The rotor is connected to a **slip ring commutator** for electrical contact and supply current. ▪ **AC Induction Motor** – Induction Motors, also uses a **3 Phase system**, however, the rotors do not have any contact with the circuit, they are poles of coils connected like a cage **(squirrel cage).** A **rotating magnetic field**, will induce current onto the squirrel cage, and hence provide torque for mechanical energy. ▪ **Universal Motors** – Universal Motors are in form of a DC motors; however, they allow the **suitability for both AC and DC inputs.** ▪ **DC Motors** – They have **a pair of permanent magnets** and a **coiled rotor**, that is connected to a **split commutator**. Mechanical energy is provided by a current entering the rotor to produce torque via the Motor Effect and hence generate a rotating force on the rotor.
▪ control technology	▪

▪ electrical safety	▪

Students learn to:	*Notes:*
▪ identify the electrical systems used in the transport industry	▪ Bicycles – Lighting for vision at night, – **Speedometer** used as a unit for displaying the distance travel, speed, and maximum speed. ▪ Motorcycle – Alternator to generate electrical power. – **Battery** to store energy. – **Rectifier** to convert AC to DC. – Horn to signal presence on the road. – **Motor** to allow mechanical movement. – Light for illumination at night. ▪ Electrical Powered Trains
▪ describe current transmission and simple circuit diagrams	▪
▪ investigate the principles and application of electric motors used in the transport industry, including motor speed control	
▪ analyze the basic principles of control technology as applied to the transport industry	▪
▪ appreciate the safe use of electricity and electrical equipment	▪

Students learn about:	*Notes:*
▪ freehand sketching, design and orthogonal drawings	▪
▪ sectional views	▪
▪ Australian Standard (AS 1100)	▪
▪ computer graphics, computer aided drawing for orthographic projection	▪
▪ collaborative work practices	▪
▪ Engineering Report writing	▪

Students learn to:	*Notes:*
▪ produce dimensioned, sectioned orthogonal drawings applying appropriate Australian Standard (AS 1100)	▪
▪ use appropriate software to produce orthogonal drawings	▪
▪ work with others and identify the benefits of working as a team	▪
▪ complete an Engineering Report based on the analysis and synthesis of an aspect of personal and public transport using appropriate computer software	▪

Peter Tran