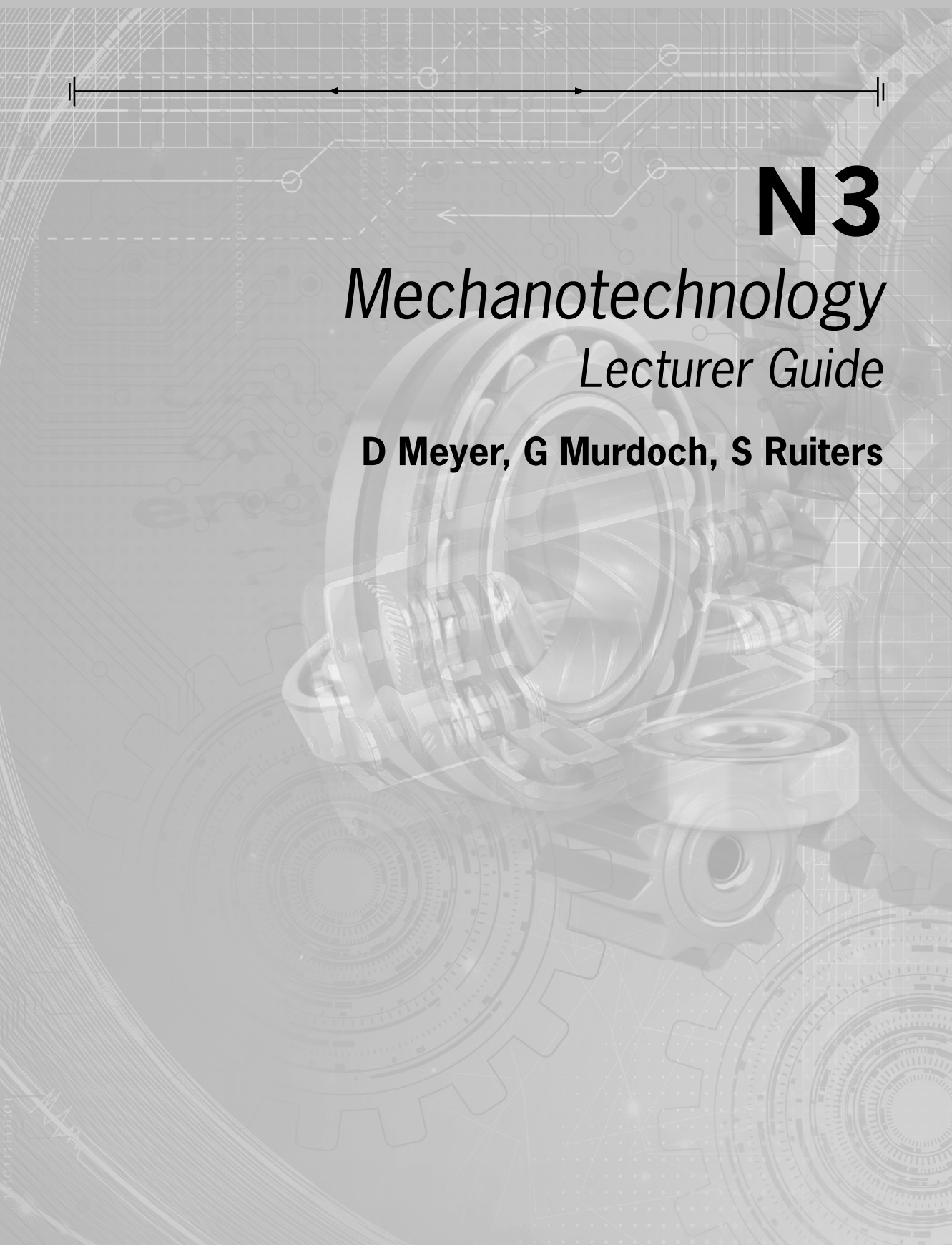

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Mechanotechnology

Lecturer Guide

D Meyer, G Murdoch, S Ruiters

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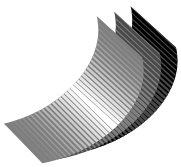

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1 *Power transmission*

Learning objectives

On completion of this module you should be able to:

- Belts and chain drives
  - Explain the differences between a V (vee) and wedge belt (endless and segment type) in terms of power transmission and construction of the belt.
  - Discuss the difference between a wedge belt and chain drives with respect to pulleys, sprocket, slip, tension, maintenance, lubrication and centre distance.
  - Select wedge belts by means of (a) basic calculations and (b) using a catalogue in terms of the following:
    - Speed ratio
    - Safety factor (service factor)
    - Design power
    - Belt section
    - Minimum pulley diameter
    - Pulley pitch diameter
    - Belt length
    - Centre distance between pulleys
    - Correction factor
    - Basic power per belt
    - Number of belts.
  - Explain the installation procedure of wedge belt drives and chain drives.
- Gear drives
  - Explain the following terms:
    - Pitch circle diameter (effective diameter)
    - Addendum
    - Dedendum
    - Module
    - Circular pitch
    - Circular tooth thickness.
  - Identify and name from given drawings the following gear types:
    - Spur
    - Helical
    - Double helical (herringbone)

    - Worm and wheel
    - Bevel
    - Rack and pinion.
  - Distinguish between the gear drives in terms of constructional features and applications.
  - Differentiate between simple, compound and planetary epicyclic trains from given drawings.
  - Explain the relationship between speed reduction and torque multiplication.
- Coupling of shafts
  - Identify from given drawings and list the following categories and types of couplings:
    - Permanent (fast) couplings
    - Flexible couplings
    - Self-aligning couplings.
  - Describe the features of the type of couplings mentioned above.
  - Identify and label the basic parts of the given couplings mentioned above.
- Clutches
  - Identify, name and list from given drawings the following categories and types of clutches:
    - Positive
    - Friction
    - Centrifugal
    - Hydraulic.
  - Briefly describe the basic working principle of the following categories of clutch:
    - Positive
    - Hydraulic
    - Friction
    - Centrifugal.
  - Compare the features of the two positive types of clutches.
  - Compare the features of the three friction types of clutches.
  - Label (from a given drawing) the basic parts of all the types of clutches.
  - State the advantages and disadvantages of all the types of clutches.
- Discuss and compare the factors that will be taken into consideration in the application of each of the transmission methods.

SB page 32

Exercise 1.1

1. No.
   Reasons: A muff coupling is solid, there is no allowance for misalignment at all. If not perfectly aligned, teriffic vibrations will occur. The coupling is fixed to the shaft with a key in a keyway. The key will work loose shortly after starting up, if the coupling is not perfectly aligned.

2. Absolutely not.
   If the two shafts are not on exactly the same plane, the connecting bolts will not line up with the holes in the two flanges. If you adapted the connection by, for example, enlarging the holes, this would put unnecessary load on both bolts and flanges. This would create excessive wear that would very soon destroy the bolts and flanges as well as the bearings in the attached motor or pump.

3. No, not the best choice.
   Flexible pin-type couplings could handle the situation of the two shafts being slightly out of alignment, but not the case quoted here, where we have much dust and dampness, especially acid dampness. The material used to give the pins their flexibility will absorb the dust and dampness that turns into grinding paste which will grind away the very pins that support them.

4. Rubber tyre type (page 26, Fig. 1.30). This particular coupling is designed especially for the situation and can handle quite bad alignment.

   Self aligning coupling, such as the Oldham coupling, (page 24, Fig. 1.26). Again we have a coupling designed for the out-of-alignment situation.

5. The conditions for using a claw type clutch:
   - the driving and driven system is stationary when being engaged or disengaged.
   - no slip is required or allowed.
   - enormous amounts of torque are being transmitted.

6. Two, one on each side of the single plate.

7. Firstly, space: As in the case of a powerful motor cycle, (page 29, Fig. 1.38) we have a large amount of torque to transmit but with limited space. The gearbox and differential are usually incorporated in the engine unit. This unit is mounted between the legs of the rider of the motor cycle. This does not allow for one big clutch plate as in the case of a motor car.

   Secondly, practicality: As in the case of an automatic gearbox, multi-disc clutches are more suitable. More slip can take place when required, and the clutch can be wet, in oil to reduce wear on the plates.

8. A centrifugal clutch would be found on a scooter, where we want to have the same effect as a torque converter with an automatic gearbox but without the extra weight and expense. The effect is similar on pull away, there is just no changing of gears.

9.
- The driver does not have to decide when to change gears. Many drivers over rev the engine, while others change too soon and make the engine labour when the revs are too low.
- With this type of clutch there is no shock transmitted to the engine by the clutch being dropped or by the driver changing down too fast causing the engine to be forced to increase speed unnaturally quickly.
- The driver can concentrate on driving, not changing gears, and his eyes on the road. The peripheral vision of most drivers is used without knowing or doing it on purpose when changing gears manually.
- The engine lasts longer as the gears are always changed at exactly the right moment and engine revs-level with the engine welfare as the main concern.
- Fuel consumption is improved as the gearbox control unit (computer) changes gears to let the engine always run at revs that ensure the best fuel consumption.
- More efficient and quicker pull away is obtained as the drive train is always engaged unlike a manual motor vehicle.

These last two reasons may be disputed by some but can be checked by comparing car tests of the same model vehicle, one with a manual gearbox and one with an automatic box. This applies only to modern vehicles manufactured post-2000.

(*Any FOUR*)

10. Cone clutches are used on over-drive units. An extension of a gearbox giving the driver of the vehicle a wider choice of gears.

On drilling machines, to engage the drive after changing gears.

Between a pump and the motor driving it. Very many similar cases where the driver (motor) and driven machine need simply to be separated for a time.

2 *Brakes*

Learning objectives

On completion of this module you should be able to:

- Describe the purpose of a brake.
- Describe the activating and the de-activating action with respect to the following brake operating principles:
  - Electromagnetic
  - Hydraulic
  - Air (spring)
  - Mechanical.
- Describe the advantages and disadvantages of each of the braking systems mentioned above.
- Compare the advantages and disadvantages of the following braking units:
  - Disc brake
  - Internal drum and shoe brake
  - External drum and shoe brake
  - Cone brake.

SB page 42

Exercise 2.1

1. Brake systems are designed to suit a particular vehicle, machine or device that has momentum and could require stopping in a hurry, Brake systems are firstly safety devices and must always be in perfect working condition.

   Modern vehicles are equipped with an anti-skid system that improves the efficiency of the system (ABS) by preventing wheel lockup.

   Secondly, a brake system is used to adjust the rate of movement.

   Thirdly, the brake system should control the vehicle or machine to get work done efficiently.

   A brake system must be able to stop a vehicle within a given time and distance. It should also be able to keep a vehicle stationary on an incline.

   Emergency brakes are needed for machines such as lifts and cranes.

2. I would fit a hydraulic, disc-brake system, with ceramic discs as they can take much more heat than metal discs. Ceramic discs also do not warp when heated to 1 000 °C from 20 °C and back to 20 °C within a few seconds. Anti-lock braking system (ABS) is also a big help as is electronic brakeforce distribution (EBD) when allowed in certain classes of racing cars. This system is the most reliable and gives the least problems. It is also the lighter weight system.

3. The electro-magnetic brake unit as seen on page 34 would be most suitable as it activates instantly should there be a power failure. It is in the locked position at rest.

   It requires electric current to flow to the solenoid which will then release the drum and allow it to rotate in whichever direction required.

4. When a vehicle brakes the momentum of the vehicle plus its load are projected forward placing the majority of the braking work on the front wheels.

   The front wheels are therefore fitted with the biggest possible brake discs of the double disc type separated by ventilation fins for cooling. The rear wheels must however be slowed at the same rate, just less viciously. Drum brakes will be adequate for this purpose. If we had the same discs at the rear as at the front the rear wheels would slow too quickly and start skidding. Bakkies are often used off-road with the wheels getting submerged momentarily, the drums prevent the braking surface from being swamped.

5. Drum brakes on all the wheels. They will supply more than enough stopping power and are much cheaper than hydraulic disc-brakes. They can also be cable operated with a lever.

6.
   - Compressor
   - Air receiver
   - Air pressure gauge
   - Air pressure regulator
   - Brake pedal, valve that controls the amount of pressure demanded by the pedal movement and the pipe system that might include snap-on couplings if there is a horse and removable trailer.

7. The disc brake system is so effective because: The disc is open and can be cooled very quickly thus reducing the chance of brake fade.

   The disc has two sides giving it twice the friction area of a drum.

   Discs can take all the brake pressure you can give them as the disc is pinched between the two sets of pads, unlike a drum that can burst open if too much pressure is applied.

8. **Anti brake-skid system (ABS)**: This system consists of a sensor at each wheel that feeds back the rotational speed to the CPU which compares the revolutions of all the wheels and ensures that during braking all the wheels slow at the same rate and especially that no wheel stops rotating during braking, prematurely. Should one wheel slow more quickly than the others the system will reduce the hydraulic pressure to that wheel cylinder thus allowing it to catch up with the others.

   Electronic stability control (ESC): Dynamic stability program (DSP). All surface progress control (ASPC), autonomous emergency braking (AEB). Each manufacturer fits a similar stability program that does basically the same thing, namely: bringing the vehicle back under control once the driver starts losing it. In these systems the ABS system is used by the system to apply braking at a particular wheel or wheels to re-align the vehicle and reduce velocity back to the vehicles ability.

9. Firstly it is not designed to work on cars as it does not have the fine adjustability of a hydraulic system. Cars do not normally have the high voltage required by such a system. The system mentioned is designed to stop a single rotating drum, not a set of wheels in harmony.

10. Air brakes. There are hoses that can bend through 90° fitted with snap-on connections that take only seconds to connect or disconnect. The system is safety based where the braking power is obtained from the compressed air in the receivers and not the drivers strength only. When the air pressure drops the vehicle is slowed by the system.

3 *Bearings*

Learning objectives

On completion of this module you should be able to:

- Explain the difference between friction bearings (bush type) and ant-friction bearings (rolling bearings).
- Identify and name the following anti-friction bearings from a given drawing:
  - Single and double row radial ball bearing
  - Single and double row radial cylindrical roller bearing
  - Thrust ball and thrust roller bearing (single and double direction)
  - Single row angular contact bearing
  - Tapered roller bearing
  - Needle roller bearing
  - Spherical roller bearing.
- Describe bearing failures and preventions thereof.
- Name the three main types of loads and the specific type of load applicable to anti-friction bearings.
- State the factors that have a detrimental effect on anti-friction bearings.
- Select the correct type and size bearing with the aid of a manufacturer's catalogue (no calculations).

SB page 62

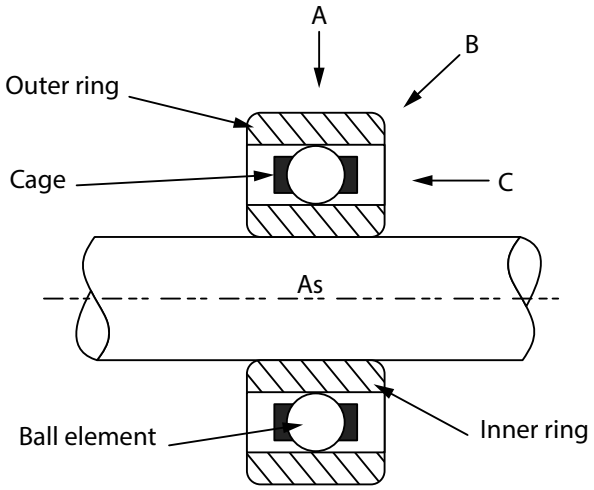
Exercise 3.1

1. 1.1 First number indicates the type of bearing
   1.2 Second number refers to the width series of the bearing
   1.3 Third number refers to the diameter series of the bearing

2.
   - The amount of heat which can be transported away from the bearing
   - Bearing type and size
   - Magnitude of the load
   - Lubrication and cooling conditions
   - Design of the cage
   - Internal clearance
   - Installation accuracy

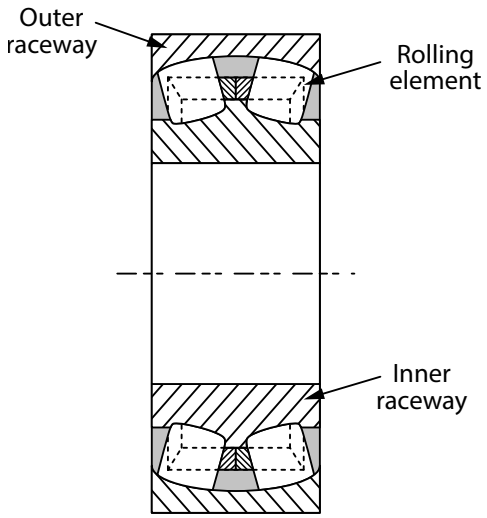
   (*Any FOUR*)

3.



A: Radial load
B: Angular or combine load
C: Axial or thrust load

4.



4.1 Spherical roller bearing
4.2 Very high radial loads, but can also accommodate axial loads.
4.3 Because the rollers are thicker in the middle and thinner at the ends, this bearing can accommodate both static and dynamic misalignment and are insensitive to error of alignment of the shaft relative to the housing or shaft.

5.
- Solid (radial) bearings
- Part bearings
- Split bearings
- Thrust bearings
- Guide bearings

6. The first number indicates the type of bearing
   The second number refer to the width series of the bearing
   The third number refers to the diameter series of the bearing

7. Bearing number 2219

8.
   - The presence of foreign matter in the bearing and its shaft housing.
   - Incorrect bearing clearances between inner raceway and shaft; and outer raceway and housing causing raceways to turn on shaft or in housing.
   - Raceways may have indents due to improper handling or assembly.
   - The shaft and housing are not round or true.
   - Variation in the sizes of the rollers or balls.
   - Excessive clearance between the shaft and the bearing or between the housing and the bearing.

   (*Any FIVE*)

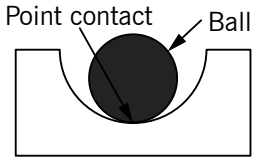
9. False

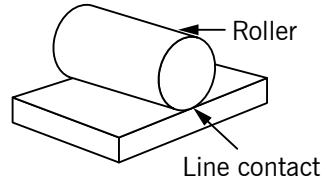
10.
   - Solid bearings
   - Part bearings
   - Split bearing
   - Thrust bearing
   - Guide bearing

   (*Any FOUR*)

11. The friction bearing works/operates on the principle of sliding friction between two surfaces, which will normally be between the shaft and the housing. A film of oil or any other lubricant can be used to separate the two surfaces.

12.





Point contact of a ball rolling element *Line contact of a cylindrical rolling element*

13. **Overheating**
   - Insufficient lubrication due to disruption in lubrication supply
   - Excessive lubrication
   - Poor properties of the lubricant due to the incorrect grade of oil
   - Foaming oil
   - Grease liquification – This means that the grease loses the force that holds the substance together and this will result in the grease starting to flow away from the part it is supposed to keep lubricated.

- Incorrect bearing clearance can cause overheating due to the raceway turn on the shaft or in the housing.
- Corrosive or abrasive dirt in the bearing or foreign material in the bearing
- Inadequate internal clearance of the bearing after its installation which means it will fit too tightly in the housing or on the shaft. Its operating temperatures will therefore be affected.
- Operating speed higher than manufacturer's recommended speed, this generates excessive frictional heat.
- Insufficient cooling conditions
- Bearing fitted incorrectly.

Excessive vibration

- The presence of foreign matter in the bearing and its housing or shaft
- Incorrect bearing clearances between inner raceway and shaft; and outer raceway and housing causing raceways to turn on shaft or in housing.
- Raceways may have indents due to improper handling or assembly.
- The shaft and housing is not round or true.
- Variation in the sizes of the rollers or balls.
- Excessive clearance between the shaft and the bearing or between the housing and the bearing.

Excessive noise

- Incorrect bearing clearances between inner raceway and shaft; and outer raceway and housing causing raceways to turn on shaft or in housing.
- The presence of foreign matter in the bearing and its housing or shaft
- A rolling element may be displaced or flattened by foreign material in the bearing.
- Raceways may have indents due to improper handling or assembly.
- Insufficient lubrication due to disruption in lubrication supply

14. Nominal outside diameter
    Nominal bore diameter

15. The roller element of the roller bearing has a large contact area. This forms the line contact and makes the roller bearing more suitable for heavier loads. The ball bearing has point contact as the contact area is concentrated at the point where the ball touches the surface.

4 *Water pumps, cooling and lubrication*

Learning objectives

On completion of this module you should be able to:

Water Pumps

- Describe the difference between a centrifugal (non positive displacement) water pump and a reciprocating (positive displacement) water pump with regard to the working principles.
- Identify the main parts from a given drawing and explain the functions of the main parts for:
  - Reciprocating water pumps – single and double acting (piston and plunger types)
  - Centrifugal water pumps (single and multi-stage types).
- Explain the following regarding water pumps:
  - Reading basic pump curves
  - Maximum suction head with respect to atmospheric pressure 1–10 m
  - Incapability of pumping hot water.
- Describe the stopping and starting procedures of a centrifugal pump for positive and negative suction.
- Identify from a given drawing basic components in a water pump system.
- Explain the reasons for good, planned maintenance procedures.
- Interpret the functions of maintenance control sheets such as a fluid record, fluid inspection plan, discrepancy report and a data test sheet.

Cooling

- Describe the need for cooling of the following:
  - Internal combustion engines (petrol and diesel)
  - Compressors
  - Electric motors
  - Welding machines (AC 1 DC).
- Discuss and compare the advantages and disadvantages of the following air cooling systems:
  - Direct cooling
  - Indirect cooling.
- Compare the advantages and disadvantages of the following water (coolant) cooling systems:
  - Thermosyphon (siphon) cooling system
  - Impeller assisted cooling systems.

- Describe the principle and function of:
  - Heat exchangers
  - Oil coolers.
- Explain the causes, dangers and prevention of:
  - Overcooling
  - Overheating.

Lubrication

- Describe the need for lubrication of the following:
  - Bearings
  - Gearboxes (including reduction gearboxes)
  - Compressors
  - Internal combustion engines (petrol and diesel engines).
- Discuss the purpose of oil filtering.
- Explain the working concept and application of the following lubrication methods:
  - Lubrication by mixing oil and petrol
  - Splash lubrication
  - Siphon wick lubrication
  - Sight feed lubrication (gravity feed)
  - Force-feed lubrication
  - Dry-sump lubrication
  - Manual feed.

SB page 73

Exercise 4.1

1. Firstly, I would choose a double acting plunger pump because the pumping action is smooth as there is a constant flow of water being delivered by the pump. This ensures that there is no water-hammer in the pipe line. There is, therefore, no noise or destructive vibration of the pipes.

   Secondly, I would choose this pump as the delivery rate is twice that of a single acting pump.

2. At least two. There is one or more inlet valves on either end of the cylinder. There would also be the same number of outlet valves.

3.
   - Slip is when the liquid being pumped slips out of the pump when it should not or from the one chamber to the other due to worn packing, either internal or external. This reduces the efficiency of the system.
   - When less liquid is pumped than calculated due to the foot-valve not being totally submerged allowing air into the system.

- Faulty or loose flange connections.
- Weak or faulty valve springs causing ineffective valve sealing.
- Non return valve not working properly allowing fluid to slip back down the pipe system between strokes, especially in the case op piston pumps.
- Driving belts driving the pump are slipping.

(*Any FIVE*)

4. Centrifugal pumps cannot pump very hot water when the water is below the pump level and must be sucked up to pump level before it can be delivered. Water boils at a lower temperature when the surrounding pressure is lowered, therefore when the pump sucks, the surrounding pressure drops and the water begins to boil, thus turning the water into a (vapour) gas. Centrifugal pumps cannot pump gasses or vapour.

5. We solve this problem by flooding the supply side by having the incoming hot water higher than the pump intake.

6.
- They are more efficient.
- They deliver a constant, uninterrupted stream of liquid.
- They have no valves.
- They have no reciprocating parts. The movement of the components are all rotary.

(*Any THREE*)

7. Firstly, check that the pump is on a securely fixed, solid base.

   Check that all piping and connections are in good order and that there are no leaks. Make sure that the pump is rotating in the correct direction as indicated on the housing. Make sure that the coupling is correctly aligned and rotating freely. Make sure that the pump is primed. Check the foot valve for condition and that it is functioning properly. Check the packing and that its water supply is unbroken. Check that the supply liquid to be pumped is sufficient and that there are no blockages or flow restrictions.

   Close off the delivery tap to build up pressure yet reduce start up load.

   Start the motor. Open the delivery tap gradually. Do not let the pump run dry. Make sure that the delivery tap is fully open.

8.
- Down time is reduced.
- It is more cost effective to maintain a machine than replace it or repair it unexpectedly.
- Bottlenecks are not encountered as machines do not break down unexpectedly.
- Minimal disruption to planned runs of production.

9.
   - A record of parts replaced or repaired.
   - Photographs of damaged or warn parts removed and or replaced.
   - A detailed record must be kept of all the details of what was done during the maintenance procedure. Date done and time taken included.

10. To displace as much liquid as possible in the shortest possible time using the least possible electric energy and in the smoothest unbroken flow possible.

SB page 77

Exercise 4.2

1. This system is the most popular because it is so positive.

   Being pump driven there is no lag as far as propulsion is concerned as in the case of the thermosyphon system where the water has to heat up before it starts to move. Impeller pumps work well as they can have partially open impellers that allow slip should the thermostat be closed and flow is temporally stopped. Impeller pumps have only rotating parts and supply a constant smooth flow of coolant.

2. Electric motors are most commonly air cooled as electricity and water do not go well together. In many cases natural air convection is sufficient but cooling fans are common, especially if the electric motor is placed where it cannot receive natural air flow. In special cases water jackets are used but with care that there is no chance that the water can leak out and get into the electric components.

3. Motor cycle engines, lawn mower engines, weed-eaters, chain saws.

   (*Any TWO*)

4. The water has to get hot before it starts to move and when the engine heats up more quickly than usual the water flow does not react quickly enough, and does not circulate fast enough to prevent overheating and damage, often devastating damage.

5. When over cooling takes place excessive wear takes place, also fuel consumption increases proportionately. Performance drops.

6.
   - Too little coolant in the system.
   - A blockage in the system or a faulty pump prevents sufficient flow rate.
   - The engine is overloaded, over revved or driven in the wrong gear, for example, up a long uphill with the vehicle moving too slowly to allow sufficient air flow over the heat exchanger (radiator) to cool the cooling water.

7.
- Over heating causes the pistons to expand and seize in the cylinders. This causes damage to both the pistons and the cylinders.
- Over heating causes the engine main bearings to melt resulting in damage to the crankshaft mains and journals.
- Overheating causes the piston rings to loose their elasticity after which they no longer seal the cylinders, resulting in low compression.

(*Any TWO*)

8. Oil is the most common coolant used, there are however various new synthetic cooling liquids available today.

9. Air, fan driven.

10. Oil coolers are used on racing and high performance cars, motor cycles, aircraft, boat and ship engines. They are used not only to cool the engine oil but gearbox oil as well, especially automatic gearboxes. Sometimes they are also needed to cool differential oil and turbocharger oil. Oils lose viscosity when the temperature levels climb. The oil loses many of its other properties when too hot which makes it less efficient and leads to other complications, and finally damage. The oil cooler is fitted in front of the main radiator and cool air from the main radiator cools the oil circulating through the small radiator.

SB page 82

Exercise 4.3

1.
- Reduce friction
- Absorb shock
- Reduce noise
- Dissipate heat
- Clean the engine internally and flush away metal shavings to the filter.

(*Any FOUR*)

2.
- High adhesion properties
- High cohesion
- High viscosity
- Resistant to foaming

(*Any TWO*)

3. A two-stroke petrol engine.

4. The reservoir of this type of feeder is transparent so that you can see the oil level without having to open the feeder to see. The top is fitted with a snap lever that can start or stop the process. The reservoir can be filled by screwing off the top and topping it up. The rate of feed can be pre-set by either turning the needle anti-clockwise (moving the needle away from the seat) thus increasing the flow rate or clock-wise, then reducing the flow rate.

5. This system is fed by an oil pump that is driven by a gear, either on the camshaft or crank shaft, inside the engine. The rotation speed of the pump increases as the engine revolutions increase. The oil supply is from the sump, either of the wet or the dry type. The oil is fed at a constant rate and pressure through channels and pipes to all moving parts. The oil pressure keeps the moving parts apart and there is thus no metal to metal contact. The oil pump that supplies the pressure can be delivered by an electric motor outside the engine or machine.

6. On aircraft engines where the engine in sometimes up-side-down which would leave the foot valve high and dry.

   On racing cars where the cars go around the corners very fast causing excessive g-forces that push the oil to one side of the normal wet type sump and again leaving the foot valve pick up without oil.

7.
   - Liquid form, oil
   - Semi-solid, grease
   - Solid form, graphite, soap or white lead

8.
   - Mineral oil from below the earths surface
   - Vegetable oil from plants such as sunflowers
   - Animal oil as from whales
   - Synthetic oil, where man has chemically manipulated the molecules.

9. Oil is filtered to remove the impurities that the oil has picked up during its travels inside the engine. Remember that we mostly use detergent oil in South Africa, with the specific purpose of removing gum and other goo and metal shavings from inside the engine.

10. The oil filter becomes blocked with all the refuse it has removed from the oil and in some cases needs changing more often than the oil or it cannot do its job properly.

5 *Hydraulics and pneumatics*

Learning objectives

On completion of this module you should be able to:

Hydraulics

- Explain the following important factors to consider in a hydraulic system:
  - Pressure
  - Flow rate
  - Area.
- Describe the functions of the following basic components in a hydraulic system:
  - Motor
  - Pump
  - Reservoir
  - Valves
  - Pipes
  - Actuator
  - Fluid (water or oil)
  - Accumulators.
- Identify the following symbols in a basic hydraulic system:
  - Motor (vane, gear, and piston type)
  - Pump
  - Pressure gauge
  - Pressure relief valve (directional control and flow control)
  - 4-port 2-position directional control valve
  - Actuator (cylinder, motor)
  - Reservoir
  - Filters
  - Accumulators.
- Arrange a basic hydraulic circuit by using the components given above.
- State the three characteristics of the fluid in a hydraulic system.
- Calculate the pressure, area, and force in a hydraulic system from given information.

Pneumatics

- Explain the following important factors to consider in a pneumatic system:
  - Pressure

  - Flow rate
  - Area.
- Describe the functions of the following basic components in a pneumatic system:
  - Compressor
  - Air receiver
  - Pressure gauge
  - Relief valve
  - Service unit
  - 4-port 2-directional control valve (DCV)
  - Pipes
  - Actuator (motor, cylinder).
- Identify the following symbols in a basic pneumatic system:
  - Compressor
  - Air receiver
  - Pressure gauge
  - Relief valve
  - Service unit
  - 4-port 2-directional control valve (DCV)
  - Actuator (motor, cylinder).
- State the main difference between a pneumatic and a hydraulic system.
- Arrange a basic pneumatic circuit by using the components given above.

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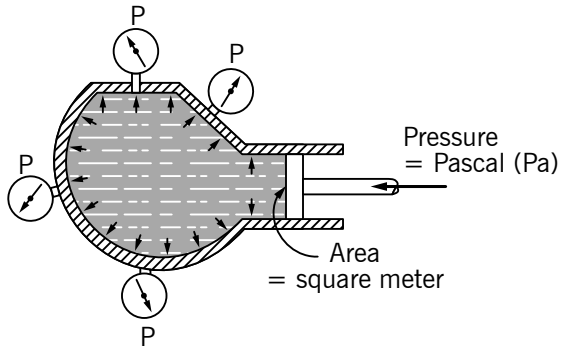
Exercise 5.1

1. Absolute pressure is gauge pressure plus atmospheric pressure.

   Most people do not realise that there is a pressure of approximately one bar present around you, at sea level at all times. When you start pumping a flat tyre, there is already one bar of pressure in the tyre before you start pumping. Once you have pumped the tyre to two bar according to the gauge, there is an absolute pressure of three bar in the tyre.

2. If you apply an external force to an enclosed liquid, the liquid comes under pressure. This pressure does not compress the liquid as liquids are basically incompressible, but the pressure builds up in the form of stored energy that can be applied to do work. In the case of a hydraulic jack. When pressure is applied to the liquid, it will be transferred to the ram that can move, and work is done. The car under which the jack has been placed will start to lift up.

3. The shape and size of the container is not important, as stated in Pascal's Law.



3.1 **Pressure and its SI unit**: Liquid pressure is expressed in Pascals (Pa). This is a force of one Newton applied at right angles to an area of one square meter.

3.2 **Flow rate**: Flow rate is the volume of liquid which passes a given point in the system in a given time.

3.3 **Area**: The area referred to here is measured in square metres, and in the case of a round cylinder would be obtained with the formula:
Area = $\pi \times d^2 \div 4$

4.
- Firstly, to transmit power in the system from the input side to the output side of the system.
- Secondly, the modern hydraulic fluid is oil based and it must lubricate the system internally.
- Thirdly, it must not change its volume when under pressure. It must also adapt to the shape of the container with ease. It must transmit the pressure in all directions equally.
- It must resist corrosion.

(*Any THREE*)

5.
- To store the hydraulic fluid of the hydraulic system, over and above that, it must function as an overflow and refill device. To keep the system full and act as a backup.
- It is a point of reference where the fluid level can be checked, topped up and from where samples can be drawn for inspection and testing. It is also an outlet for air and heat from the system.
- In some systems a glass sight plate is fitted, so as to be able to see the fluid level.
- The reservoir is often also used as a mounting point for various valves and even the motor.

(*Any TWO*)

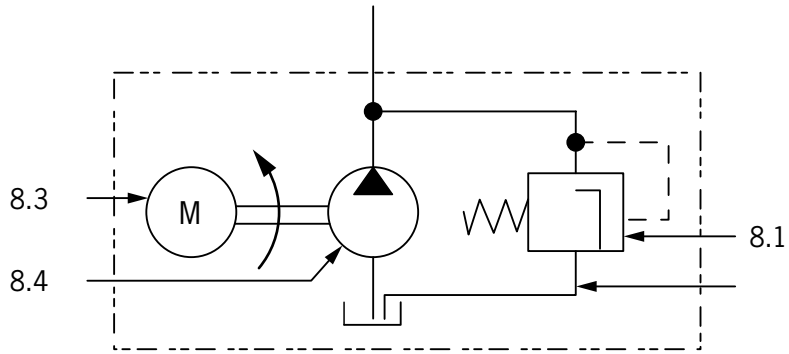
6.
- Hydraulic systems are normally fitted with a pressure relief valve as a safety device.
- High pressure that is released into the atmosphere, at any point, without warning, due to a pipe, receiver , connector or other part bursting could have disastrous consequences and must obviously be avoided at all costs. Thus, with a pressure relief valve (safety valve) in the system such disasters can be avoided.
- Should the pressure rise to beyond the predetermined maximum pressure, the valve will open and allow just enough liquid and accompanied pressure to return to the receiver.
- No loss of liquid, no chance of harm to either the system or persons in the vicinity.

7. With this system it is a case of , what you put in is what you get out minus frictional and other losses. Work is done in applying pressure on the liquid in the accumulator.

The work is stored by either compressing a spring, or a gas or by raising a weight against the force of gravity. The stored work can then be re-used when required.

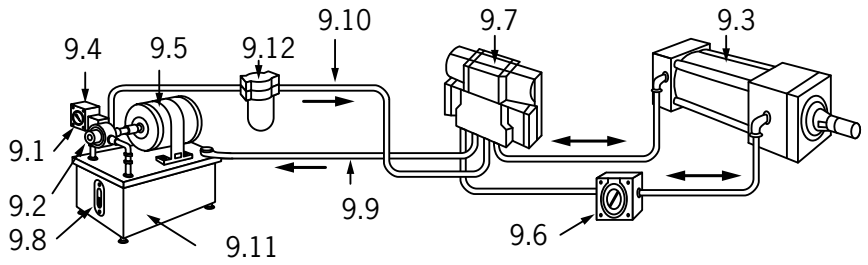
The size of the weight or the physical strength of the spring will determine the force with which the actuator will be able to operate.

8.



8.1 Pressure relief valve
8.2 Overflow to reservoir
8.3 Electric motor
8.4 Pump

9.



9.1 Pressure gauge
9.2 Pressure relief valve
9.3 Hydraulic cylinder
9.4 Pressure gauge housing
9.5 Electric motor
9.6 Flow control valve
9.7 4-way directional control valve
9.8 Oil level gauge (sight glass)
9.9 Hydraulic fluid return tube
9.10 Hydraulic fluid delivery tube
9.11 Hydraulic fluid reservoir
9.12 In line filter (high fluid pressure)

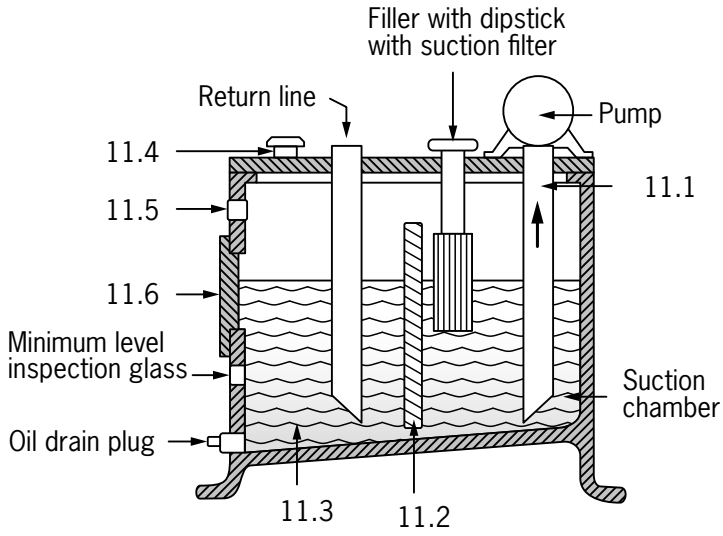
10.
- Firstly, what device is it we want to drive? Is it a hand drill or a steering system?
- Secondly, how much space is there at the point of application and what is the distance from the source.
- Thirdly, how much pressure is required to drive the system?
- A fourth factor to consider is weight, fluid is much heavier than air.

11. 11.1 This is a baffle plate which prevents the liquid from surging or moving around uncontrolled in the reservoir. It also prevents incoming, hot liquid from going directly to the out pickup, ensuring that it cools first.

11.2 The base of the container slopes away from the pickup side and the returning, dirty fluid is deposited on the drain side. The drain plug is usually magnetic which would attract metal particles. There is a filter through which the liquid must pass to get to the delivery side.

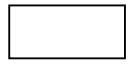
11.3 The electric motor.

11.4



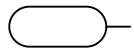
11.1 Pickup or suction tube through which the fluid is sucked up to the pump
11.2 Baffle plate
11.3 The hydraulic fluid
11.4 Air breather and filter
11.5 Upper fluid level (sight glass) to see maximum fluid level
11.6 Removable plate for maintenance purposes

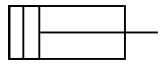
12. 12.1 Non-return valve 

12.2 Closed tank 

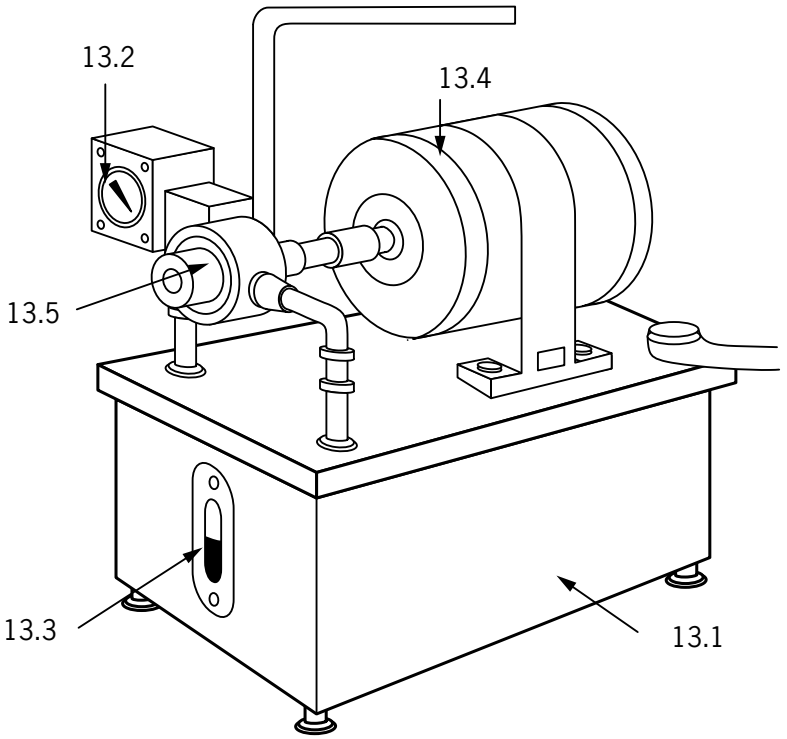
12.3 Electric motor 

12.4 Pump 

12.5 Accumulator 

12.6 Double-acting cylinder 

13.

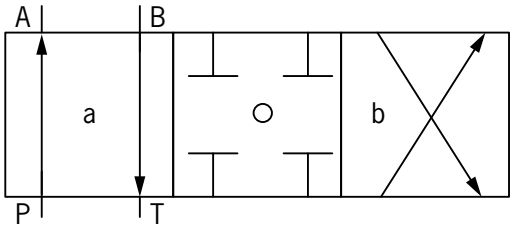


13.1 Reservoir – closed tank
13.2 Pressure gauge
13.3 Fluid level sight glass
13.4 Electric motor
13.5 Hydraulic pump

14.
- To control the rate of flow.
- To control the direction of flow.
- To control the pressure. To act as a safety device.

15. The electric or other motor and the pump.

16.



16.1 Cross over valve four way, three position
16.2 Normally open
16.3 Four.
P = pressure port; T = tank port; A and B are the actuator or cylinder ports.
16.4 Three

17. 17.1 Area of plunger = $[\pi \times d_2^2] \div 4$
$= \pi \times (0{,}045 \times 0{,}045) \div 4$
$= 0{,}001590431$ m

Area of ram = $[\pi \times d_1^2] \div 4$
$= \pi \times (0{,}095 \times 0{,}095) \div 4$
$= 0{,}007088218$ m

Pressure = load ÷ area
= 5 000 N ÷ 0,007088218
= 705395,87 Pa

17.2 **Number of strokes (#) required to raise ram 750 mm**
A2 × # × L2 = A1 × L1
= (A1 × L1) ÷ (A2 × L2)
= (0,007088218 × 750) ÷ (0,001590431 × 75)
= 5,3161638 ÷ 0,119282346
= 44,5679 strokes

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Exercise 5.2

1. Newtons

2. We would see that the pressure gauge will indicate an increase in pressure. The receiver would get warmer as air under pressure is warmer.

3.
- Drain valves
- Direction valves (check valves)
- Pressure reducing valves (safety valves)

4. A double-action cylinder can do work equally well in two directions.

5.
- Cost – is it an economically viable option? Is it not easier to just use electrical tools?
- On a big scale, pneumatic tools are by far longer lasting, easier and cheaper to repair.
- The conditions under which it must work: for example, very dusty, very wet, very hot?
- The noise factor. If you are going to work in a noise sensitive area, a compressor running. Continuously is not your best option.

(*Any TWO*)

6.
- Piston
- Sliding vane
- Screw
- Turbo

7. 7.1 **Filter with a water trap**: Incoming air must be filtered before entering the cylinder where it is going to be compressed as compressors often have to work in dirty and dusty areas. Dust in the incoming air will lead to excessive wear in the cylinder and the oil of the compressor will have to be changed so much more often.

   The water trap is a must, as compressing air leads to condensation, especially in areas where the air has a high humidity to start with. Water in the air delivered to the equipment that it is going to drive can be a big problem and must be eliminated.

   7.2 **Lubricator**: The compressed air is often delivered to equipment that requires lubricating. It is an ideal situation if the air arrives already containing a predetermined amount of the desired lubricant.

   7.3 **Pressure relief valve**: All compressors should be fitted with, a valve that will open on its own should the pressure rise beyond the necessary tolerance to protect the receiver and anybody near it.

8. **Advantages:**
   - Once the system is up and running it is economical to run, easy to maintain with not much training needed (this is the day to day maintenance, not overhauling it).
   - A compressor can run all day, every day for years, requiring no major maintenance.
   - Compressors are available in all shapes and sizes, price ranges and delivery requirements.

   Disadvantages:
   - Work at a lower pressure than hydraulic systems.
   - They do not have an even action.
   - They are more expensive.
   - Pressurised air can be dangerous.
   - Setup costs are high.

9. - A reservoir is usually used on a hydraulic system and has a breathing system.
   - It is usually fitted with a one way valve that is overridden when the pressure is off, allowing the plunger to return to its starting position. No liquid is lost in the working process.
   - A pneumatic system mostly uses a receiver that is an airtight container that is fitted with a drain valve, to be able to drain off any liquid, condensation or muck in the receiver, daily.
   - It is also fitted with a safety valve as well as a minimum pressure sensor that instructs the compressor to start pumping again as the low pressure has been reached and to stop pumping when the maximum pressure is reached.

- The contents of the receiver is continually changing, new air under pressure is entering the receiver as the compressed air and pressure is fed away to do work.

10. An air receiver, receives the clean air, under pressure from the compressor on an ongoing basis. It stores it under this same pressure for as long as is needed. It sees to it that there is always enough air in stock, and at the correct pressure at all times.

11. A strong metal container of roughly spherical shape to store the air under pressure, onto which are fitted:
    - An inlet from the air supply; an outlet to the system to maintain the flow of air.
    - A cover or manhole for inspection and cleaning.
    - A safety valve, to protect the receiver from over pressure.
    - A drain valve to rid the receiver of unwanted moisture and gunge.
    - Various adaptors to connect to various outside pipes etc.
    - One or more pressure gauges to monitor the pressure.

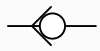
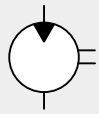
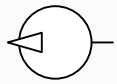
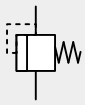
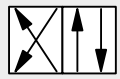
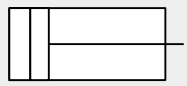
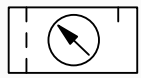
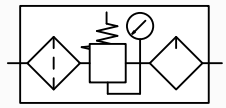
12. - Single acting cylinder
    - A double acting cylinder
    - A pump
    - A motor
    - A calliper
    - A set of jaws
    - Single-acting spring return
    - Double-acting double rod
    - Single or double acting telescope.

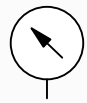
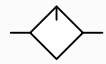
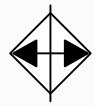
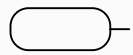
    (*Any FIVE*)

13. - The compressor
    - The air receiver
    - The electric motor (actuator)
    - The safety valve
    - The pressure gauge

14. The drain cock is situated at the lowest point of the receiver, underneath, at an easily reached spot so that it can be opened with ease, daily.
    The purpose of it is to drain off any fluid or muck that has accumulated in the receiver.

15.

Description	Symbol	Use
Directional control valve (non-return valve)		Allows fluid in one direction only, can be used as a by-pass valve or to isolate sections of the system.
Hydraulic motor (fixed capacity one direction of flow)		Motor transforms hydraulic working energy into mechanical energy.
Compressor		Used to pressurise air.
Pressure relief valve		When pressure exceeds pre-set level will allow air to flow. When pressure drops valve closes.
Flow control valve (fixed)		Used to control the rate of flow of the fluid in the line of the system.
Flow control valve (adjustable)		Used to control the rate of flow of the fluid in the line system, but is adjustable to suit needs.
Electric motor		Motor to drive pump.
4-port 2-directional control valve		Controls the fluid flow in certain directions. First number indicates ways or directions; second number refers to the number of positions.
Lubricator		Lubricates air to lubricate the system.
Actuator (linear)		Used to move an object or apply a force in a straight line. Can be single and double acting or spring-loaded.
Service unit (simplified symbol) Service unit	 	Combination of filter, regulator and lubricator.
Pump		Displaces fluid to cause a pressurised flow.

Description	Symbol	Use
Pressure gauge		Measures system pressure.
Actuator (rotary)		Used to move an object in a circular path.
On-off cock (shut off valve) normally open		Indicates a normally open valve with an on-off function.
Water separator (filter with water trap)		Removes water vapour from the air.
Lubricator		Lubricates air to lubricate the system.
Heater		Heats air.
Cooler		Dissipates excess heat.
Filter		Protect hydraulic system from dirt.
Air receiver		Stores compressed air.

6 *Internal combustion engines*

Learning objectives

On completion of this module you should be able to:

- Describe, from given drawings, the basic operation of the four stroke petrol engine and the four stroke diesel engine with respect to:
  - The inlet stroke
  - The compression stroke
  - The power stroke
  - The exhaust stroke.
- Compare the four stroke petrol engine to the four stroke diesel engine with respect to:
  - Method of fuel supply (petrol: carburettor and fuel injection)
  - General maintenance costs.
- Describe, from given drawings, the basic operation of the two stroke petrol engine and two stroke diesel engine.
- Compare the advantages and disadvantages of the two stroke petrol engine and the two stroke diesel engine.
- Make diagrammatical layouts of the fuel system of the four stroke petrol engine (carburettor and fuel injection) and the four stroke diesel engine.
- Compare the application of the petrol and diesel engines as stationary engines for open, confined and hazardous (flammable) areas with respect to:
  - Exhaust fumes
  - Noise
  - General maintenance.

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Exercise 6.1

1.
   - Fuel injection makes the vehicle much lighter (about 10%) on fuel.
   - More power is obtained due to the exactly correct mixture being delivered at all times.
   - Less maintenance is required as there are less moving parts.

2.
   - A lawn mower
   - A weed-eater
   - A chain saw
   - A light motor cycle

   (*Any THREE*)

3. The blower, which is often a roots-type supercharger, is used to supply the engine with intake air under pressure. There are in many cases no inlet valves and no full inlet stroke to suck air in so the air must already be under pressure when it enters the cylinder. This ensures that the cylinder receives a full charge of air each time.

4.
   - Stationary units of large capacity, for example to drive a large electric generator.
   - Where the engine has to turn over for hours on end, for example to drive a water pump.
   - Marine engines on ships.
   - Big heavy trucks and busses.

   (*Any TWO*)

5.
   - Diesel engines are more robust and stronger alloys are used in the manufacture of the pistons, con-rods, cylinder heads and engine blocks, due to the much higher compression ratio.
   - The cooling system of a diesel engine has a larger coolant capacity and radiator per unit size as it has to cope with higher temperatures.

6. The cycle works as follows: The inlet stroke takes place while the piston is going up for the compression stroke. A low pressure zone is created in the crank-case, the area below the piston, by the piston moving up. The air-fuel-oil mixture is sucked in through the now open inlet port. When the piston reaches TDC the power stroke begins with a spark igniting the air-fuel mixture. The oil that was in the air-fuel mixture has been deposited on the various moving parts leaving the air and fuel to be ignited. As the piston moves down on the power stroke it first closes the inlet port then compresses the new air-fuel-oil mixture in the crank-case. Before the piston reaches BDC the transfer port is opened allowing the air-fuel-oil mixture to transfer from below the piston to above it. While this transfer is taking place the piston, that is still moving down, opens the exhaust port.

The new mixture entering the cylinder hits the deflector on the piston top causing it to swirl up and over the piston pushing the old, spent mixture out of the open exhaust port. The piston turns at BDC and starts the cycle again.

7. Petrol, air and oil.

8.
- TDC = top dead centre
- BDC = bottom dead centre
- CI engines = compression ignition engine

9. Plus minus, this varies slightly from case to case.
Petrol engine 10 : 1 and diesel engine 20 : 1

10. Firstly, the temperature of the air in the cylinder at the end of the compression stroke will be much higher, high enough to ignite the fuel once it is introduced into the cylinder. This is why a diesel engine does not require a spark to ignite the mixture.

Secondly, the pressure in the cylinder will be much higher.

Should you raise the compression ratio sufficiently on a petrol engine the fuel will ignite before the spark is released and before the piston has even reached TDC. This will be a major problem. The higher you raise the ratio the sooner the air fuel mixture in the cylinder will ignite. On racing cars they raise the compression ratio as this improves the volumetric efficiency of the engine, but they use fuel with a much higher octane rating which prevents pre-ignition (they use more than 105 rating we use 95 octane rating fuel).

Additional exercise

Some additional questions and points of interest for the lecturer

1. **Modern vehicles are driven by what type of engines?**

Most modern vehicles make use of some type of internal combustion engine. Most of these are four-stroke, reciprocating engines, either petrol or diesel. Gas turbine engines are also internal combustion engines but are not practical for use in the average motor vehicle.

2. **Which is the most popular, petrol or diesel engines, and why?**

More and more engines are diesel turbo charged and intercooled engines. Mainly because the modern diesel engine is so much more fuel efficient than a petrol engine, partly due to the much higher compression ratio. Gas turbine engines have an even higher compression ratio than a diesel engine and are even more efficient than diesel engines.

Modern diesel engines are lighter and faster revving than they were just a few years ago.

Diesel fuel is far more dense (C20H42) and contains more mega joules of energy per kilogram than petrol (C8H18).

Diesel fuel is also an excellent lubricant resulting in much longer engine life.

The last five Dakar-Rallies and LeMans 24-hour endurance races (at least) have been won by diesel engine vehicles, confirming both that they last better, and are more efficient even in races.

3. **Describe the difference between an internal combustion engine and an external combustion engine:**

   The internal combustion engine is one where the combustion of the fuel (chemical energy conversion to mechanical energy) takes place within the engine, usually directly above a piston.

   External combustion engines are engines like steam engines and steam turbines, where the fuel is burned outside the engine, work is done by the burning fuel to convert water to super-heated steam, then piped to the engine or turbine where it is converted to mechanical energy.

4. **Describe the basic operation of the four-stroke petrol engine and the four-stroke diesel engine with respect to the order of strokes.**

   The strokes are the same and in the same order as they both follow the Otto-cycle:
   - The inlet stroke
   - The compression stroke
   - The power stroke
   - The exhaust stroke.

5. **Method of fuel supply:**

   Petrol: carburettor and fuel injection
   Diesel: fuel injection

6. **Describe each of the four strokes in detail.**

   6.1 **Stroke one: The inlet stroke**

   The piston is at the top of the cylinder, TDC (top dead centre) with the exhaust valve closed and the inlet valve open. The piston moves down causing a drop in pressure that sucks a fresh air fuel mixture in at a 14 : 1 air to fuel ratio. The inlet valve will start closing just before the piston reaches the end of its downward journey, BDC (bottom dead centre).

This is the end of the inlet stroke. Most modern engines apply valve overlap which means that the exhaust valve opens before BDC and only closes after TDC. This means that the valve is open for more than 180°. The other valves also open early and close late. This can now change as you drive along as we now have (VVT) variable valve timing.

6.2 **Stroke two: The compression stroke**

Both valves are closed, the piston is moving upwards, compression is taking place. The air fuel mixture is compressed to a ratio of ± 10 : 1. The temperature and pressure of the air-fuel mixture in the cylinder increase proportionately as the volume decreases (Boyle's gas law). When the piston reaches TDC the compression stroke is finished and it will change direction by 180°.

6.3 **Stroke three: The power stroke**

Both valves are closed during this stroke. The air-fuel mixture is ignited by an electric spark in the area above the piston called the combustion chamber. The temperature and pressure rise sharply causing expansion of the air-fuel mixture which forces the piston downwards with great force and acceleration. The power stroke is now taking place. When the piston is about two-thirds of the way down towards (BDC) the exhaust valve will begin to open. This will give the valves a chance to begin opening so that they will be ready to let the burned gasses out the moment that the piston changes direction at BDC and starts moving up for the exhaust stroke.

6.4 **Stroke four: The exhaust stroke**

The piston turns at BDC and starts to move upwards, the exhaust valve will be fully open shortly after the piston has turned, allowing the burned gasses out of the open exhaust valve. Just before the piston reaches TDC the inlet valve will begin to open and the exhaust valve will begin to close. The four-stroke cycle will be repeated.

7. **The two-stroke petrol engine is used where?**

It was found long ago in motor cars like a DKW that was later absorbed into the Audi group. Today it is found in small motor-cycles, chain-saws, weed-eaters, petrol lawn mowers and other light power tools.

8. **Where would you find a two-stroke diesel engine today?**

- On a big ship as the main engine, 50 000 KW and more.
- Marine engine, turbo-charged, 1 500 mm diameter pistons. Six in a line.

9. **Give three advantages of a two-stroke petrol engine over a four-stroke engine.**

    - No valves required
    - No camshaft therefore no drive required from crankshaft
    - Lighter and simpler

10. **Why are four-stroke engines, both petrol and diesel more commonly used in modern motor vehicles than two-stroke engines?**

    They are much more reliable, cause less noxious gasses, are more efficient at low revolutions, have more torque at low revolutions, and more.

11. **What is used to drive a turbo-charger?**

    Exhaust gasses. There is no positive, physical, driving device like gears, a chain or belt connecting the turbo and the engine it is mounted on.

12. **How is a supercharger driven?**

    By a belt, gears or chain. There is a direct physical connection between the supercharger and the engine it feeds. There is a drive ratio; the supercharger turns 1,5 times faster than the engine at all revs.

13. **Why do drag racing cars use superchargers in preference to turbo chargers?**

    Superchargers have no lag, they boost power immediately to the max. even at low revolutions, they are ideal for improved pull away. Superchargers do not increase boost when revolutions increase so some performance vehicles have both. They use the supercharger to get away quickly and then the turbo comes in at high revolutions when large amounts of exhaust gasses are being released. The supercharger has a maximum on revolutions, namely one and a half times the engine revs. The turbo charger however runs at about 10 000 RPM to 20 000 RPM when the engine is not accelerating but during acceleration it keeps increasing to over 100 000 RPM and more if you keep accelerating. The boost keeps rising to a pre-set pressure maximum when a safety valve opens and allows the excess boost to escape, this is to prevent damage to the engine. This safety valve is often referred to as a dump valve. On standard production vehicles the excess boost is prevented by the excess exhaust gasses being re-routed, bypassing the turbocharger. A noise is heard when the waste gate is used on performance vehicles where the exhaust gasses are not re-routed.

    Make use of pictures of the engine that are cut away as in the textbook, but without the labels then let the pupils fill in the missing names as they have done in old examination papers.

7 *Cranes and lifting machines*

Learning objectives

On completion of this module you should be able to:

- Explain the purpose of a crane in respect to mechanical advantage (load/effort).
- Distinguish, from given drawings, between the following types of cranes:
  - Overhead travelling
  - Tower (fixed and climbing)
  - Wharf
  - Mobile (jib and telescopic).
- State the general purpose, advantages and disadvantages of the cranes mentioned above.
- Explain what is meant by the 'drop' in a rope and list the advantages when increasing the number of drops.
- List the advantages of the infrared signal remote control when comparing it to the drivers' cabin on the overhead travelling crane.
- Explain the basic purpose of the load limiter on cranes.
- State the advantages and disadvantages of the following ways in which tower cranes can be mounted:
  - Static on a concrete base
  - On a bogie on a rail
  - The climbing tower crane.
- State the general safety precautions while in operation for the cranes mentioned above.
- List important factors in choosing a steel rope with special reference to the relevant codes.
- Explain slinging requirements.
- Explain the factors to bear in mind when inspecting steel ropes and the upkeep of a log book.
- Identify and name hand signals from given drawings.

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Exercise 7.1

1.
- The size of the load to be lifted
- The length of each drop
- The number of drops
- Groove size on the drum or pulley
- The velocity at which the rope will move

(*Any THREE*)

2.
- It uses minimum space, but has maximum coverage.
- It is mounted on a mobile chassis, which moves under its own power.
- The crane can move itself into the best possible position to execute a specific job.
- The crane has no height limitations.
- Compared to the static or climbing tower crane, it can cover a larger area due to its mobility.
- The initial set-up, tear-down and rental costs can be offset by the high production rates achieved by tower cranes.

(*Any FOUR*)

3. A crane is a machine that is capable of raising and lowering heavy objects and moving them horizontally. It is mainly used for lifting heavy objects and transporting them to other places.

4.
- It supports the strands and keeps them from jamming against each other under normal loads.
- It lubricates the inside of the cable and so prevents wear as the wires rub against each other.
- The lubrication also helps to prevent corrosion on the inside of the cable.
- It provides a cushion effect to absorb shock.

5.
- It has a dense, smooth outside surface.
- Wear take place more evenly.
- A 'Langs lay' has a better resistance to fatigue.
- It is more flexible.

6.
- A remote-control operation improves safety, because there is no need for an individual to be physically near the crane and its operation and risk being struck by either the crane or its load.
- The use of a remote or infrared control will realise greater efficiencies, as one of the individuals who would otherwise be involved in the crane operation – either the cab operator or the outside 'spotter' – can be assigned to perform other work.

- Remote-control units allow cranes to operate more quickly, meaning that more work can be done in less time than when units are operated by cab operators. The handling of the load is faster, because operators are no longer 'tied' to the crane. They are closer to the load to be shifted and can clearly see what they have to do.

7.
- Electrical hazards
- Overloading
- Material falling

8.
- It is very versatile type of crane. It can move a load in any direction up or down, across or along a workshop.
- Overhead travelling cranes can be used to assist in the assembling process of a job.
- It can be designed to carry extra heavy loads.
- If we change the number of drops, we can obtain different speed ratios and mechanical advantages.
- Because of the height of the driver's cabin, the driver has a clear view most of the time.
- This type of crane can be equipped with a remote control in order to promote safety and productivity.

(*Any TWO*)

9. On construction sites where loads must be lifted onto high buildings.

10. This type of crane must not be used on high levels when strong cross winds are blowing. Where possible no workers must be present in the area under the raised, slung load. The area under which the load will be moved must be cordoned off if possible.

11. Wharf cranes are usually employed in dock areas and are usually more mobile than tower cranes. They are able to work in bad, windy weather conditions. They can straddle trains and trucks (the train or truck can travel between its legs).

12.
- To move loads over distance greater than other cranes as the whole crane can move while carrying a load.
- The crane can easily be relocated as it is on wheels and is self-propelled.
- To move such a crane from one construction site to another is simple compared to other cranes as it is a self-contained unit.

13.
- The mass that has to be handled.
- The number of drops the steel rope makes.
- The maximum length per drop.
- The size of the grooves on the hoisting drum and pulley.
- The velocity at which the rope will move.

(*Any THREE*)

14.
- The number of drops regulate or control the speed ratio at which the load is lifted or lowered.
- Also allow heavier loads to be lifted without using a more powerful motor to drive the crane.

15. It is recommended a sheave diameter be at least 20 times that of the rope. The groove should be 5% to 7% bigger than the rope.

16. 6 strands

17. The core is in the centre of most steel ropes. The functions of the core are:
- It support the strands and keeps them from jamming against each other under normal loads.
- It lubricates the inside of the cable and so prevents wear as the wires rub against each other.
- The lubrication also helps to prevent corrosion on the inside of the cable.
- It provide a cushion effect to absorb shock.

18. A maximum of 120 degrees is allowed for special applications. However it is safer to limit the angle to a maximum of 90 degrees.

19. 90 degrees

20. 100%, e.g. 120° can lift 5,0 tons at 30° a sling can lift 10,0 tons.

21.
- Make use of "Ferrules".
- U-bolt clamps with lock-nuts work well.

22.
- A metal mesh tray on which the objects can be placed and secured in safety.
- Adjustable length span arms that prevent the cable from squeezing the object.
- Sling nets into which you place the object to be lifted, The crane hook is connected to the edges of the net. The net closes like a bag around the object, the cable is above the load and cannot damage the objects being lifted.

23.
- Plastic flow and wear at the crossing sections of the rope
- Plastic flow over the length of the rope
- Many broken wires in one place
- Damage to the core of the rope
- Corrosion
- Kinks in the rope
- Weakening of material
- Drying out of lubrication of the rope
- Overload
- Overwinding due to cross-winding
- Mechanical damage

(*Any FIVE*)

24.
- Plastic flow and wear at the crossing sections of the rope
  - Plastic flow can be prevented by never lifting loads too heavy for the particular rope.
  - Never making the rope bend too sharply.
- Plastic flow over the length of the rope
  - Plastic flow can be prevented by never lifting loads too heavy for the particular rope.
  - Never making the rope bend too sharply.
- Many broken wires in one place
  - Broken wire ends can be prevented by not using "eyes" that are too small for the rope diameter.
  - The rope is being made to pass over a too small diameter pulley when under load. or being subjected to shocks in one particular place continuously.
- Damage to the core of the rope
  - The rope, when loaded is being accelerated away too fast.
  - The load is too great, thus, squeezing the core beyond its elastic limit.
- Corrosion
  - The steel rope being exposed to moisture, heat and acid rain.
  - Corrosion is also caused by neglect to lubricate the steel rope.
- Kinks in the rope
  - Kinks are caused by stopping too suddenly.
  - Or letting the rope get tangled and then loading it without first removing the tangles.
- Weakening of material
  - Weakening of the material can be caused by rust or other chemical attacks.
  - Extreme changes in temperature can cause the metal to become brittle, in the case off a drop in temperature.
- Drying out of lubrication of the rope
  - Drying out of the lubricant can be due to lack of maintenance.
  - The rope being exposed to extreme weather an abnormal temperatures.
- Overload
  - (1) Overloading can be avoided by using devices such as "load limiters".
  - (2) Proper supervision and a few calculations can prevent this.
- Overwinding due to cross-winding
  - Overwinding is usually caused by excessive cross-winding which is usually the operators fault. Give the necessary guidance to the operator.
  - Overwinding can also be caused by poor operating, mind not on the job.

- Mechanical damage
  - Mechanical damage is most often caused by ignorance, incorrect use of equipment.
  - Another cause is using the equipment for the wrong purpose.

25. The fibre core

26.
- Grab hook with cradle eye
- Grab Hook with cradle clevis
- Foundry hook
- Sling hook
- Self-locking hook

27. An appointed competent person should be responsible and the following information should be recorded in the logbook:
- Date of fitting
- The measured diameter of the steel rope
- The construction of the steel rope
- Any defects found during inspection
- The duration of service

28. Signalman and the crane operator

29. High-visibility gloves, usually bright yellow

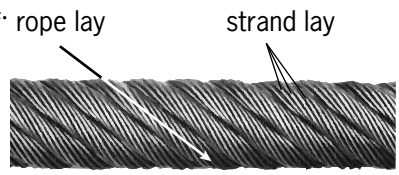
30. The crane operator and the person on the workshop floor, called the signalman or slinger.

31.
- Because of the distance between the crane operator and the signalman
- Obstruction between the two
- The noise level on site

32.
- Use hand signals which are clearly visible to the operator.
- Be responsible for keeping the public and all unauthorised personnel outside the crane's operating radius.
- Direct the load so that it never passes over any person.

33. 33.1 **Langs lay**:
The strands in the ropes are laid in the same direction.
33.2 **Ordinary lay**:
Also called cross-lay, in which the wires in the strands lie in one direction while the strands lie in the opposite direction.

34.



Lang lay

Ordinary lay

35. **6 × 37 (9/9/1), fibre core, langs lay**

- The number 6 indicates the number of strands that make up the steel rope.
- The number 37 indicates the number of wires each strand contains.
- The set of numerals in brackets (9/9/1) shows the pattern of the wires in the strands. The pattern can be round, flattened, concentric or triangular. Almost all lifting tackle ropes are round pattern classification.

8 *Material and material processes*

Learning objectives

On completion of this module you should be able to:

- State the purpose of colour coding and identify metals such as low- and high-carbon steels according to the colour coding system.
- Explain the differences between the following:
  - Iron and an alloy
  - Ferrous and non-ferrous metals.
- Briefly describe the following properties of metals:
  - Toughness
  - Tensile strength
  - Malleability
  - Ductility
  - Elasticity
  - Hardness
  - Plasticity.
- Briefly describe the purpose of the following heat-treatment processes:
  - Case hardening
  - Hardening
  - Tempering
  - Annealing
  - Normalising.
- Briefly compare the general behaviour of metals when:
  - Forming using a hammer
  - Cutting by means of a hacksaw
  - Arc welding and gas (oxy-acetylene) welding of the following metals:
    - Low carbon steel
    - Aluminium
    - Copper
    - Grey cast iron
    - Austenitic stainless steel.
- Differentiate between the following main groups of polymers:
  - Thermoplastics
  - Thermosets.

- Identify and differentiate between the basic characteristics of the following polymers, based on non-laboratory tests (touch, sound, surface hardness, flame and odour):
  - Polyethylene (PE)
  - Polypropylene (PP)
  - Polyvinylchloride (PVC)
  - Polystyrene (PS)
  - Acrylonitrite Butadiene Styrene (ABS)
  - Polymethylmethacrylate (PMMA) (Perspex)
  - Polyamide (PA)
  - Phenol Formaldehyde (PF)
  - Unsaturated Polyesters (UP)
  - Natural Rubber (NR)
  - Styrene Butadiene Rubber (SBR).

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Exercise 8.1

1.
- Bearing
- Rope
- Sliding plates
- Bolts and nuts
- Gears
- Trolley wheels
- Fan blades

(*Any TWO*)

2.
- **Thermoplastics**: this plastic softens when heated and can be recycled.
- **Thermosetting plastic**: Once these plastic solidify after the moulding process they can never be softened by reheating therefore cannot be recycled.

3.
- **Thermoplastics**: this plastic softens when heated and can be recycled.
- **Thermosetting plastic**: Once these plastic solidify after the moulding process they can never be softened by reheating therefore cannot be recycled.

4.
- Polyethylene
- Poly propylene
- Polyvinyl-chloride (PVC)
- Polystyrene

5.
- Polyester
- Epoxy
- Phenolic
- Vinyl ester
- Polyurethane
- Silicone
- Polyamide and polyamide-imide

6. Nylon is a good insulator, making it a poor conductor.

7.
- Gears
- Bushes
- Spacers
- Coupling Discs
- Gauge cases
- Vice jaws

(*Any ONE*)

8. Steel is an alloy of iron and iron carbide with a small amount of other elements in controlled quantities.

   Steel is produced from iron ore and scrap metals, and is called an alloy of iron, with controlled carbon. Whereas, around 4% of carbon in iron makes it cast iron, and less than 2% of carbon makes it steel.

9. The difference between low carbon steel and high carbon steel, as the name implies, stems from the amount of Carbon in the steel. The difference in characteristics is low carbon steel is worked when hot but does not machine easily whereas high carbon steel has greater strength after heat treatment. However, as a result of adding more carbon, the steel also tends to become brittle and less ductile.

10. Metals that contain iron as a basic material are called ferrous metals and those metals without iron as a basic material are called non-ferrous metals.

11.

	Material	Touch	Sound	Surface hardness	Ignites	Flame type	Odour when burned
11.1	**Polyethylene (PE)**	Waxy	Dull when dropped	PE-LD: Fairly soft and flexible PE-HD: Hard and stiff	Yes, easily	Blue with yellow tip Transparent when drips as it burns	Candle wax
11.2	**Polypropylene (PP)**	Waxy	Dull when dropped	Hard and stiff, but softens at higher temperature than polythene	Yes, easily	Yellow, with blue base	Hot oil Paraffin and candle wax
11.3	**Polyvinylchloride (PVC)**	PVC-P: Soft and rubbery PVC-U: Smooth	Dull when dropped	PVC-P: Soft and flexible PVC-U: Hard and stiff	Yes, but with difficulty	Yellow, with green base	Acrid, chlorine
11.4	**Polystyrene (PS)**	Smooth	Metallic	Rigid	Yes, easily	Orange	Sweet, smoke carries 'smut'
11.5	**Polyamide (PA)**	Waxy	Dull	Stiff	Difficult	Blue with yellow tip, but no continuous flame	Phenol, woody
11.6	**Phenol formaldehyde (PF)**	Cold	Metallic	Rigid	Yes, with difficulty	No continuous flame; does not burn, only chars	Phenol, spitty flame; burning smell with a little smoke

12. 12.1 **Toughness**: A measure of the ability of a metal to withstand impact or a hammering load.
    12.2 **Tensile strength**: A measure of the ability of a metal to resist forces acting to pull it apart and to withstand a stretching load without breaking.
    12.3 **Malleability**: Metal having the property of being permanently extended in all directions by hammering, bending, twisting or rolling without cracking or breaking.
    12.4 **Ductility**: The property of ductility of a metal allows the metal to be drawn out in strands of a considerable length without breaking.
    12.5 **Elasticity**: It is the ability of a metal to return to its original shape after a load has been removed from it.
    12.6 **Hardness**: The ability of a metal to resist surface wear, such as scratching and denting.
    12.7 **Plasticity**: Metals have the property of plasticity when a load placed on a piece of metal causes deformation and the metal retains that deformation permanently when the load is removed.

13. Heat treatment is a process of controlled heating and cooling which changes the physical properties of a metal without changing their shape. In this way, special properties, such as hardness, strength, toughness and elasticity of unalloyed and alloy steels can be changed.

14. 14.1 **Hardening**: This is a process of heating up the material to increase wear resistance and strength of the components.
    14.2 **Tempering**: Tempering gives hardened steel increased ductility with only a slight loss of strength. This process removes stresses and strains induced by hardening, reduces brittleness and increases toughness.
    14.3 **Annealing**: Annealing is the process of heating steel to a particular temperature and then cooling it down very slowly. Annealing brings back the steel's softness and ductility after it has been work-hardened. This process releases internal stresses, refines the grain structure and reduces brittleness.
    14.4 **Normalising**: The steel is heated slowly to a normalising temperature and then allowed to cool in air. This process refines the structure to obtain a uniform structure in the steel and give the steel back its softness and ductility.
    14.5 **Case hardening**: The purpose of case hardening is to present a good wearing surface and the inner soft core can resist the shock loads.

15. To avoid confusion in trying to identify different types of metals from one another if there were no method or means to identify them.
    15.1 **Low-carbon steel**: Orange
    15.2 **High-carbon steel**: Brown
    15.3 **Case-hardened steel**: Orange
    15.4 **Low-alloy steel**: Light purple
    15.5 **Structural steel**: Red
    15.6 **Stainless steel**: Black
    15.7 **Cast steel**: Blue

9 *Industrial organisation and planning*

Learning objectives

On completion of this module you should be able to:

- Describe briefly effective communication skills in a multi cultural environment with regard to:
  - Writing and compiling reports and memorandums
  - Verbal and non verbal skills
  - Application of listening skills.
- Discuss organisational communication with respect to the following communication channels (routes):
  - Vertical line
  - Horizontal line
  - Diagonal line.
- Describe briefly the basic outlines of the following acts:
  - Labour Relations Act with respect to:
    - Grievance procedures
    - Disciplinary handling procedures
    - Code of conduct
    - Conditions of employment
    - Rights and duties.
  - Occupational Health and Safety Act with respect to:
    - Reports and incidents
    - General duties of employer and employees
    - First aid
    - Records and registers.
- Describe the purpose of an administration system.
- Describe briefly the purpose of each of the following documents:
  - Clock cards
  - Job cards
  - Requisition cards
  - Production flow charts
  - Maintenance schedules.
- Describe the purpose of budgeting and control of expenses.
- Describe labour efficiency to improve and increase productivity.

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Exercise 9.1

1.
- Clock cards
- Job cards
- Requisition cards
- Production flow charts
- Maintenance cards

2.
- It takes much longer to produce
- There is no automatic feedback
- There is no guarantee that the written communication will be read

3.
- Contain costs
- Increase productivity
- Give moral support
- Overcome obstacles

4. To maintain or preserve and to remove employees' grievance and consequently maintain, preserve, restore and promote good labour relations.

5.
- Face the speaker and maintain eye contact.
- Be attentive, but relaxed.
- Keep an open mind.
- Listen to the words and try to picture what the speaker is saying.
- Don't interrupt and don't impose your "solutions."
- Pay attention to what isn't said – to non-verbal cues.

(*Any FOUR*)

6.
- Brief
- Open-minded and insightful
- Objective
- Accurate
- Clear

7.
- To determine the personnel's attitude.
- To determine the feelings of the subordinates.
- To know what is going on in the business on ground level.
- This information helps management to coordinate business activities.
- To receive feedback on personnel's attitudes, motivation and perceptions.

8.
- Plan the business's operations.
- Show if the business's financial goals are being met.
- Help to transform goals into reality.
- Serve as a control mechanism when it comes to cutting down expenses.

9.
- Quantity of the item needed
- When the items are needed
- Where the items are needed
- By whom the request is made

10. It is the plan for investment in property, equipment and other physical facilities in order to maintain or expand existing production capacity.

11.
- Coordination between departments
- Review activities assigned to subordinates
- Stimulate quantity and applicability of decisions

12.
- Clock cards
- Job cards
- Requisition cards
- Production flow cards
- Maintenance schedules

13.
- Workers can bring their grievances to the notice of management.
- Management is prepared to listen to workers grievance.
- All workers can approached management with their grievances, without fear of intimidation, discrimination or harm.
- Workers grievances will receive attention at management level.

14.
- Informal talks
- Planned appointments
- Telephone calls

15.
- Inform
- Remind
- Persuade
- Understand
- Educate
- Stimulate action
- Socialise
- Entertain
- Command
- Bring about a certain action

16. To maintain control over a firm's cash requirements, e.g. stock and debtors.

17.
- To enable a firm to take precautionary measures and arrange in advance for investment and loan facilities whenever cash surpluses or deficits arise.
- To show the feasibility of management's plans in cash terms.
- To illustrate the financial impact of changes in management policy, e.g. change of credit terms offered to customers.
- It provides a sound basis for obtaining credit.

18.
- Bring to the employee's attention ongoing deficiencies in his/her conduct and/or performance.
- Support and help the workers become better employees by indicating to them what the correct, expected or acceptable behaviour should be.
- It also supports the employer in any future legal action including discrimination or unlawful termination.

19.
- Energy
- Transport and industrial machinery
- Communication
- Logistics

20.
- Contain costs
- Increased productivity
- Give moral support
- Overcome obstacles to communication

(*Any THREE*)

21.
- Information passed downward is not always relevant and sometimes gets lost between management and sub-ordinates.
- Organisations have problems with the functional literacy (a person's ability to read and prepare the messages necessary for a specific job) of their staff and that can result in sub-ordinates not always being sure whether information is simply a notification or not. They do not know whether information is intended only for them or whether they must pass it on.
- Too much information is sent downwards and the order in which the information is sent could have limitations. People remember a later message more easily than an earlier message. It could be that the message that was received earlier had more value than the more recent message.
- Managers are not sure what types of messages to pass downwards. If the receivers perceive the source of the message to be unreliable, the message will lose its value.

22. Discipline can be defined as an action, on the part of the authority in control of a social system, which is aimed at stopping the trespasser's behaviour because it threatens to disrupt the functioning of the system.

23.
- Regulation of working time – The maximum number of ordinary hours per week an employee may work is 45 hours and gradually be reduced to 40-hour working week.
- Leave – Employees are entitled to 21 consecutive days' annual leave.
- Particulars of employment and remuneration – An employer must supply an employee with written particulars of employment when the employee starts employment.

(d) Termination of employment – Minimum notice periods for terminating employment by employers or employees ranges from one week's notice during the first four weeks of employment to one month for employees with more than one year service.

(e) Prohibition against employment of children and forced labour – It is an offence to employ a child under 15 years of age or who is under the minimum school leaving age in terms of the law, if this is 15 or older.

24.
- The right to freedom of association
- The right to strike
- The right not to be unfairly dismissed
- The right to work
- The right to bargain collectively
- The right to protection
- The right to develop

25.
- To provide regular services in order to keep the machines in good running condition.
- To avoid or minimise breakdown and time-loss periods that lead to a loss of production.
- To keep a record of the type or nature of maintenance that has been done in order to establish the running cost of a machine.
- To prevent a machine or a piece of equipment from causing an unsafe condition.

10 *Entrepreneurship*

Learning objectives

On completion of this module you should be able to:

- Explain in basic terms the concepts:
  - Entrepreneurship
  - Small business enterprise.
- Name and briefly describe FIVE characteristics of an entrepreneur and complete a self-analysis.
- Name and explain the process of generating ideas for establishing a small business.
- Describe the general resources necessary for the small business entrepreneur.
- Name and briefly describe the factors that will influence the location of a small business enterprise.

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Exercise 10.1

1. Entrepreneurs start new businesses, employ people and generate revenue, they should have the ability to mobilise and co-ordinate resources, capital and labour in such a way as to generate a profit.

2.
   - Knowledge and skills
   - Contacts and friends
   - Finance

3. Service businesses do not require special premises or offices, because the entrepreneur visits the premises of the customer when he/she does business with that client. Therefore the business can operate from a site where rental is relatively cheap or owners can even use their own living premises.

4. Let cost price be X and Selling price SP
SP = X + markup + 15% VAT
SP = X + (0,35 × X) + 0,15 [X + (0,35 × X)]

$$R146,21 = X + 0,35X + 0,15 (X + 0,35X)$$
$$= 1,35X + (0,15 \times 1,35X)$$
$$= 1,35X + 0,203X$$
$$= X(1,35 + 0,203)$$
$$= 1,553X$$
$$X = \frac{R146,21}{1,553}$$

Cost price = R94,15

5.
- Physiological needs
- Security needs
- Social needs
- Status and respect needs
- Personal growth and development needs

(*Any FOUR*)

6.
- Be your own boss
- See the direct results of your labour
- Interest and enjoyment
- Efficiency
- To make money
- Innovative and creative

(*Any FIVE*)

7. SWOT, which stands for strengths, weakness, opportunities and threats, is an analytical framework that can help your business face its greatest challenges and find its most promising new markets. In a business context, the SWOT analysis enables businesses to develop a full awareness of all the factors involved in a decision.

8.

Company:	**Outstanding debt:**
Company A	R4 500,00
Company B	R2 500,00
Company C	R6 000,00

R4 500,00 + R2 500,00 + R6 000,00 = R13 000,00

$\frac{4\,500}{13\,000} \times$ R5 200,00 = R1 800,00

$\frac{2\,500}{13\,000}$ = R1 000,00

$\frac{6\,000}{13\,000}$ = R2 400,00

9.
- Knowledge and skills
- Contacts and friends
- Finance

10.
- Is it located near a busy road?
- Will the business or your advertising board be visible from the road?
- Where and how far away is your opposition or competition?
- Are there businesses around that draw similar customers?
- Is there something for customers to do while they are waiting?
- Is there enough parking space?
- Can your business be reached by public transport?
- Are the buildings in a relatively good condition?
- Are the premises close to your target market?
- Is traffic from other areas also passing your business?
- What is the crime situation in the area during trading hours and after hours?

(*Any FIVE*)

11. 40% = R7 561,20 $\quad 1 + 2 + 3 = 6$

$\frac{1}{6}$ = R1 260,20

$\frac{2}{6}$ = R2 520,40

$\frac{3}{6}$ = R3 780,60

12.
- Be action orientated – have a desire to produce results immediately.
- Have a high degree of drive and energy – because of long hours, you need lots of energy.
- Have a high level of self-confidence and persistence – confidence in yourself and being optimistic and positive.
- Have a high level of determination and need to achieve and to solve problems.
- Be ready and keen to take moderate, challenging risks.
- Set goals consistent with interests, values and talents.

13.
- Nature of product
- Competition
- Convenience and accessibility
- Symbiosis
- Expansion potential
- Service businesses
- Manufacturing concerns

(*Any SIX*)

14.
- Is it located near a busy road?
- Will the business or your advertising board be visible from the road?
- Where and how far away is your opposition or competition?
- Are there businesses around that draw similar customers?
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