This memorandum consists of 17 pages.
QUESTION 1: MULTIPLE-CHOICE QUESTIONS

1.1  B ✓ (1)
1.2  A ✓ (1)
1.3  D ✓ (1)
1.4  B ✓ (1)
1.5  A or B ✓ (1)
1.6  B ✓ (1)
1.7  A ✓ (1)
1.8  C ✓ (1)
1.9  D ✓ (1)
1.10 A ✓ (1)
1.11 D ✓ (1)
1.12 B ✓ (1)
1.13 B ✓ (1)
1.14 C ✓ (1)
1.15 A ✓ (1)
1.16 C ✓ (1)
1.17 D ✓ (1)
1.18 A ✓ (1)
1.19 C ✓ (1)
1.20 D ✓ (1)
QUESTION 2: TOOLS AND EQUIPMENT

2.1 Causes of low compression:
- Worn cylinders ✓
- Worn compression rings ✓
- Worn piston ✓
- Worn valves ✓
- Worn head gasket ✓

(Any 3 x 1) (3)

2.2 Torsion:
Torsion is the twisting action in a member caused by two opposing moments along the longitudinal axis. ✓ (2)

2.3 Multimeter:
A – LCD display screen ✓
B – Range selector switch ✓
C – 10 A DC terminal socket (Input terminal) ✓
D – VΩmA terminal socket (Input Terminal) ✓
E – Common terminal socket ✓ (5)

2.4 Cylinder leakage tester:
- Listen at the carburettor and/or inlet manifold for hissing noise. ✓
  (inlet valve is leaking) ✓
- Listen to the exhaust pipe or exhaust manifold for a hissing noise. ✓
  (exhaust pipe is leaking) ✓
- Listen for hissing noise in the dipstick hole. ✓
  (piston rings worn) ✓
- Remove the filler cap on the tappet cover and listen for hissing noise. ✓
  (rings are worn) ✓
- If you see bubbles in the radiator water, ✓
  (the cylinder head gasket is blown or the cylinder block is cracked) ✓

(Any 3 x 2) (6)

2.5 MAGS/MIGS – meaning
- MAGS: Metal Arc Gas Shielded ✓
- MIGS: Metal Inert Gas Shielded ✓ (2)

2.6 MAGS/MIGS gases
- Argon ✓
- CO₂ ✓
- Helium ✓

(Any 2 x 1) (2)

[20]
QUESTION 3: MATERIALS

3.1 Non-ferrous materials and composites:
- Non-ferrous Metals are metallic and composites are non-metallic. ✓✓
- Non-ferrous metals are original substances and composites are combinations of two or more materials. ✓✓
  (Any 1 x 2) (2)

3.2 Compressive strength test:
3.2.1 Material A has the highest compressive strength. ✓ (1)
3.2.2 The material that can resist a large compression force will have little deformation or compression, and has a higher compressive strength. ✓✓ (2)

3.3 Carbon steel:
- Low-carbon steel ✓
- Medium-carbon steel ✓
- High-carbon steel ✓ (3)

3.4 Carbon steel – properties:
- Greater hardness is obtained ✓
- Tensile strength is increased ✓
- Ductility is decreased ✓
- Welding ability is decreased ✓ (4)

3.5 Uses and properties of engineering materials:
3.5.1 Uses of Duralumin:
It is used to make the following:
- Bars ✓
- Sheets ✓
- Piston rods ✓
- Tubes ✓
- Rivets ✓
- Motorcar and aircraft parts ✓
  (Any 2 x 1) (2)

Properties of Duralumin:
- Lightweight ✓
- High tensile strength ✓
- Good resistance to corrosion ✓
- Hardens with age ✓
  (Any 2 x 1) (2)
3.5.2 **Uses of PVC:**

It is used to make:
- Pipes and fittings ✓
- Cable and services ducting ✓
- Roofing and ceiling systems and membranes ✓
- Healthcare materials ✓
- Automotive industry materials ✓

(Any 2 x 1) (2)

**Properties of PVC:**
- Lightweight ✓
- Weather resistant ✓
- Rigid or flexible ✓
- Clear or coloured ✓
- Good electrical insulator ✓
- Good resistance to corrosion ✓

(Any 2 x 1) (2) [20]
QUESTION 4: SAFETY, TERMINOLOGY AND JOINING METHODS

4.1 Beam bending tester:
- Make sure that the object to be tested is firmly secured. ✓
- Make sure that all the holding devices are properly fitted. ✓
- Check components of tester for wear. ✓
- Check for leaks at the hydraulic pump ram and hose. ✓
- Make sure that the tester is clean and free from oil and grease. ✓

(Any 3 x 1) (3)

4.2 Gas cylinders:
- Store full cylinders apart from empty cylinders. ✓
- Keep in cool, dry place away from sunlight. ✓
- Acetylene cylinders should be stored in an upright position. ✓
- Oxygen cylinders should be stored away from acetylene cylinders. ✓
- Do not allow cylinders to fall. ✓
- No oil and grease should come into contact with oxygen cylinders and fittings. ✓

(Any 3 x 1) (3)

4.3 Milling operations:

4.3.1 Upcut milling:
- Less vibration occurs. ✓
- Less strain on the cutter and arbor. ✓
- There is positive pressure on the feed screw spindle and its nuts because of the direction of the cutter. ✓
- A coarser feed may be used. ✓

(Any 2 x 1) (2)

4.3.2 Down-cut milling:
- Deeper cuts can be made because the force of the cutter is downwards. ✓
- A finer finish is obtained. ✓

(2)
4.4 **Indexing:**

4.4.1

\[
\text{Indexing} \quad = \frac{40}{A} \quad \checkmark
\]

\[
= \frac{40}{60} \quad \checkmark
\]

\[
= \frac{4 \times 4}{6 \times 4} \quad \checkmark
\]

\[
= \frac{16}{24} \quad \text{or} \quad \frac{20}{30} \quad \text{or} \quad \frac{26}{39} \quad \text{or} \quad \frac{28}{42} \quad \text{or} \quad \frac{34}{51} \quad \text{or} \quad \frac{36}{54} \quad \text{or} \quad \frac{44}{66} \quad \checkmark
\]

16 holes on the 24-hole circle or
20 holes on the 30-hole circle or
26 holes on the 39-hole circle or
28 holes on the 42-hole circle or
34 holes on the 51-hole circle or
36 holes on the 51-hole circle or
44 holes on the 44-hole circle

(4)

4.4.2

\[
\frac{D_r}{D_v} = \left( A - n \right) \times \frac{40}{A} \quad \text{OR} \quad \frac{D_r}{D_v} = \left( N - n \right) \times \frac{40}{N} \quad \checkmark
\]

\[
\frac{D_r}{D_v} = \frac{(60 - 63) \times 40}{60} \quad \frac{D_r}{D_v} = \frac{(60 - 63) \times 40}{60} \quad \checkmark
\]

\[
\frac{D_r}{D_v} = \frac{-120}{60} \quad \frac{D_r}{D_v} = \frac{-120}{60} \quad \checkmark
\]

\[
\frac{D_r}{D_v} = \frac{-12 \times 4}{6 \times 4} \quad \frac{D_r}{D_v} = \frac{-12 \times 4}{6 \times 4} \quad \checkmark
\]

\[
\frac{D_r}{D_v} = \frac{-48}{24} \quad \text{or} \quad \frac{56}{28} \quad \text{or} \quad \frac{64}{32} \quad \frac{D_r}{D_v} = \frac{-48}{24} \quad \text{or} \quad \frac{56}{28} \quad \text{or} \quad \frac{64}{32} \quad \checkmark
\]

(5)
4.5  **Cutting feed:**

\[ V = \pi DN \]

\[ N = \frac{V}{\pi D} \]

\[ N = \frac{20}{\pi \times 0.08} \]

\[ N = 79,577 \text{ r/min} \]

\[ f = f_1 \times T \times N \]

\[ f = 0.08 \times 14 \times 79,577 \]

\[ f = 89,13 \text{ mm/min} \]

4.6  **Ultrasonic test:**

- A high frequency sound wave is send into the metal for a very short period of 1 to 3 microseconds.
- The same unit which was used to send the sound wave then acts as a receiver to listen to the ultrasonic waves it reflected through the metal.
- This cycle is repeated from one to five million times per second.
- The oscilloscope is calibrated only to pick up defects of a size that would be considered harmful.
- The oscilloscope wave pattern is also calibrated to show the distance between the searching unit and any defects found.

4.7  **Weld defects:**

4.7.1  **Slag inclusion:**

**Causes:**
- Included angle too narrow  
- Rapid cooling  
- Welding temperature too low  
- High viscosity of molten metal.  
- Welding second run without removing slag  

(Any 2 x 1)  

**Prevention:**
- Increase the included angle.  
- Let the welded metal cool slowly  
- Pre-heat the metal  
- Remove slag before welding a second run  

(Any 1 x 1)
4.7.2 Undercutting:

Causes:
- Faulty electrode manipulation
- Arc length too long
- Current too high
- Welding speed too fast

(Any 2 x 1) (2)

Prevention:
- Use a uniform weaving movement in butt joint
- Use the correct electrode
- Use the correct current
- Weld slowly

(Any 1 x 1) (1)

4.8 Milling Cutters:

4.8.1 Spur gear – Involute cutter
4.8.2 Groove – Side-and-face cutter or end mill or slot drill
4.8.3 Rack – Involute cutter/Fly cutter
4.8.4 Blind hole – Flute-end mill

(4)

4.9 Dividing head of a milling machine:

A = Index plate
B = Index crank
C = Sector arms
D = Single-start worm
E = Wormwheel/gear

(5)

4.10 Classification of milling cutters:

Arbor cutters

Examples: Plain cutter, side cutter, staggered-tooth cutter, slitting-saw cutter, angular cutter, profile/form cutters, side-and-face cutter, helical cutter

(Any 1 x 1) (1)

Shank cutters

Examples: End mill; shell end mill; T-slot cutter and Woodruff keyseat cutter

(Any 1 x 1) (1)
QUESTION 5: MAINTENANCE AND TURBINES

5.1 Clutch

5.1.1 Parts:
A. Crankshaft ✓
B. Clutch plate ✓
C. Gearbox shaft ✓
D. Diaphragm spring ✓
E. Pressure plate ✓
F. Flywheel ✓ (6)

5.1.2 Functions:
• To provide friction between the clutch and pressure plate ✓ ✓
• To connect the flywheel to the gearbox shaft ✓ ✓ (4)

5.1.3 Causes of slip:
• Oil on the friction surfaces ✓
• Worn friction surfaces ✓
• Lack of compressive force on the friction surfaces caused by weak springs ✓
• Lack of compressive force on the friction surfaces caused by incorrect clutch settings ✓
• Uneven friction surfaces ✓
• Overheating ✓
(Any 3 x 1) (3)

5.1.4 Clutch types:
• Single-disc clutch ✓
• Multi-disc clutch ✓
• Centrifugal clutch ✓
(Any 2 x 1) (2)

5.2 Functions of lubricating oil:
• Provides lubrication between contact surfaces ✓
• Resists oxidation ✓
• Prevents rust ✓
• Avoids foaming ✓
• Resists carbon forming ✓
• Prevents corrosion ✓
• Resists extreme pressure ✓
(Any 3 x 1) (3)
5.3 Cutting fluid:
- Avoid contamination of the cutting fluid by draining and regularly replacing it. ✓
- Always clean metal cuttings from the machine’s splash tray after use. ✓
- Regularly wipe cutting fluid splashes off machine parts when machine is stationary. ✓
- Ensure that the sump is topped up from time to time, and check that there is sufficient flow of cutting fluid to the cutting tool. ✓
- Check for correct ratio of cutting fluid to water. ✓

(Any 3 x 1) (3)

5.4 Supercharger

5.4.1 Centrifugal type ✓ (1)

5.4.2 Parts:
A. Inlet port ✓
B. Outlet port ✓
C. Rotor ✓
D. Vane ✓ (4)

5.4.3 Operation:
- The engine drives the rotor ✓
- Air is drawn in behind the rotor ✓
- The air is forced around into a decreasing volume ✓
- This raises the pressure of the air ✓
- The air is forced into the inlet manifold and into the cylinders ✓

(5)

5.4.4 Advantages of a supercharger:
- More power is developed compared to a similar vehicle without a supercharger ✓
- Supercharged engines are more economical per given kilowatt output ✓
- Less fuel is used compared to engine mass ✓
- Power loss above sea level is eliminated ✓

(Any 3 x 1) (3)
5.5 **Steam turbines:**
- Condensing turbines ✓
- Non-condensing turbines ✓
- Reheat turbines ✓
- Extracting turbines ✓
- Induction turbines ✓

(Any 3 x 1) (3)

5.6 **Advantages of gas turbine:**
- High power output from a given weight of engine. ✓
- The torque output permits a notable simplification of the transmission system. ✓
- Smooth vibrationless running due to absence of reciprocating parts. ✓
- No rubbing parts such as piston so that internal friction and wear are almost eliminated. ✓
- Easy starting. ✓
- Can use a wide range of fuels without expensive anti-knock additives. ✓
- Low lubricating oil consumption. ✓
- No water cooling system needed. ✓
- Non-poisonous exhaust gases gives very little trouble with pollution. ✓
- Requires little routine maintenance. ✓

(Any 3 x 1) (3) [40]
QUESTION 6: FORCES, SYSTEMS AND CONTROL

6.1 Hydraulics:

6.1.1 Fluid pressure:

Rounded off
\[ A_a = \frac{\pi D^2}{4} \]
\[ = \frac{\pi \times (0.038)^2}{4} \]
\[ = 1.13 \times 10^{-3} \text{ m}^2 \]
\[ P = \frac{F_a}{A_a} \]
\[ P = \frac{300}{1.13 \times 10^{-3}} \]
\[ = 0.27 \text{ MPa} \]

Fully extended
\[ A_a = \frac{\pi D^2}{4} \]
\[ = \frac{\pi \times (0.038)^2}{4} \]
\[ = 0.001134114 \text{ m}^2 \]
\[ P = \frac{F_a}{A_a} \]
\[ P = \frac{300}{0.001134114} \]
\[ = 264523.45 \text{ Pa} \]  (5)

6.1.2 Load lifted by piston B:

Rounded off
\[ A_b = \frac{\pi D^2}{4} \]
\[ = \frac{\pi \times (0.175)^2}{4} \]
\[ = 24.05 \times 10^{-3} \text{ m}^2 \]
\[ P = \frac{F_b}{A_b} \]
\[ F_b = A_b \times P \]
\[ = (24.05 \times 10^{-3}) \times 0.27 \times 10^6 \]
\[ = 6.49 \text{ kN} \]

Fully extended
\[ A_b = \frac{\pi D^2}{4} \]
\[ = \frac{\pi \times (0.175)^2}{4} \]
\[ = 0.024052818 \text{ m}^2 \]
\[ P = \frac{F_b}{A_b} \]
\[ F_b = A_b \times P \]
\[ = (0.024052818 \times 264523.45 \]
\[ = 6362.54 \text{ N} \]  (6)
6.2 Stress and Strain:

**Tensile force:**

<table>
<thead>
<tr>
<th>Rounded off</th>
<th>Fully extended</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \varepsilon = \frac{\Delta L}{OL} )</td>
<td>( \varepsilon = \frac{\Delta L}{OL} )</td>
</tr>
<tr>
<td>= 0,2 ( \frac{300}{300} )</td>
<td>= 0,2 ( \frac{300}{300} )</td>
</tr>
<tr>
<td>= 0,66 ( \times 10^{-3} )</td>
<td>( = 0,0006666 )</td>
</tr>
</tbody>
</table>

\( E = \frac{\sigma}{\varepsilon} \)  
\( \sigma = E \times \varepsilon \)
\( = 245 \times 10^6 \times 0,66 \times 10^{-3} \)  
\( = 161,7 \times 10^6 \text{ Pa} \)  
\( = 245 \times 10^6 \times 0,0006666 \)  
\( = 1633333333,3 \text{ Pa} \)  

\( \sigma = \frac{F}{A} \)  
\( F = \sigma \times A \)
\( = 161,7 \times 10^6 \times 2,2 \times 10^{-6} \)  
\( = 355,74 N \)  
\( = 1633333333,3 \times 2,2 \times 10^{-6} \)  
\( = 359,33 N \)

(9)

6.3 Belt drives:

6.3.1 Rotation frequency of the driven pulley:

\[ N_A \times D_A = N_B \times D_B \]
\[ N_B = \frac{N_A \times D_A}{D_B} \]
\[ = \frac{1000 \times 0,25}{0,35} \]
\[ = 714,29 \text{ r/min} \]

(3)
6.3.2 **Power transmitted:**

\[
P = \frac{(T_1 - T_2) \pi DN}{60} \checkmark
\]

\[
P = \frac{(200 - 90) \times \pi \times 0.25 \times 1000}{60} \checkmark
\]

\[
P = 1439,90 \text{ Watts} \checkmark
\]

\[
P = 1.44 \text{ kW} \checkmark
\]

(3)

6.3.3 **Belt speed:**

\[
v = \frac{\pi DN}{60} \checkmark
\]

\[
v = \frac{\pi \times 0.25 \times 1000}{60} \checkmark
\]

\[
v = 13.09 \text{ m.s}^{-1} \checkmark
\]

(3)

6.4 **Gears:**

6.4.1 **Rotation frequency of the output shaft:**

\[
N_F = \frac{T_A \times T_C \times T_E}{N_D \times T_B \times T_D \times T_F} \quad \text{or} \quad N_F = \frac{\text{Product of driven gears}}{\text{Product of driver gears}} \checkmark
\]

\[
N_F = \frac{T_A \times T_C \times T_E \times N_A}{T_B \times T_D \times T_F} = \frac{24 \times 20 \times 42 \times 1440}{40 \times 48 \times 90} \checkmark
\]

\[
N_F = \frac{24 \times 20 \times 42 \times 1440}{40 \times 48 \times 90} = 168 \text{ r/min} \checkmark
\]

(4)

6.4.2 **Velocity ratio:**

\[
VR = \frac{N_A}{N_F} \checkmark
\]

\[
VR = \frac{1440}{168} \checkmark
\]

\[
VR = 8.57 : 1 \checkmark
\]

(2)
6.5  **Differential wheel and axle:**

6.5.1  **Mechanical advantage:**

\[ MA = \frac{W}{F} \]

\[ MA = \frac{2400}{400} \]

\[ MA = 6 \]

(2)

6.5.2  **Velocity ratio:**

\[ VR = \frac{2D}{d_1 - d_2} \]

\[ VR = \frac{2(210)}{160 - 140} \]

\[ VR = \frac{420}{20} \]

\[ VR = 21 : 1 \]

(3)

6.5.3  **Mechanical efficiency:**

\[ \eta_{\text{mech}} = \frac{MA}{VR} \times 100\% \]

\[ = \frac{6}{21} \times 100\% \]

\[ = 28.57\% \]

(2)
6.6 **Clutches:**

6.6.1 **Diameter of clutch plate:**

\[ T = \mu W n R \quad \checkmark \]

\[ R = \frac{T}{\mu W n} \quad \checkmark \]

\[ R = \frac{336}{0.4 \times 3500 \times 2} \quad \checkmark \]

\[ R = 0.12 \text{ m} \]

\[ D = 2 \times 0.12 \quad \checkmark \]

\[ D = 0.24 \text{ m} \]

\[ = 240 \text{ mm} \quad \checkmark \]

(5)

6.6.2 **Power transmitted at 3500 rpm in kW:**

\[ P = \frac{2 \pi N T}{60} \quad \checkmark \]

\[ P = \frac{2 \times \pi \times 3200 \times 336}{60} \quad \checkmark \]

\[ P = 112.59 \text{kW} \quad \checkmark \]

(3)

\[ \text{TOTAL: 200} \]