This memorandum consists of 18 pages.
**QUESTION 1: MULTIPLE-CHOICE QUESTIONS**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>C ✓</td>
</tr>
<tr>
<td>1.2</td>
<td>B ✓</td>
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<tr>
<td>1.3</td>
<td>D ✓</td>
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<tr>
<td>1.4</td>
<td>D ✓</td>
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<tr>
<td>1.5</td>
<td>A ✓</td>
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<tr>
<td>1.6</td>
<td>C ✓</td>
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<tr>
<td>1.7</td>
<td>D ✓</td>
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<tr>
<td>1.8</td>
<td>D ✓</td>
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<tr>
<td>1.9</td>
<td>B ✓</td>
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<tr>
<td>1.10</td>
<td>D ✓</td>
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<tr>
<td>1.11</td>
<td>D ✓</td>
</tr>
<tr>
<td>1.12</td>
<td>C ✓</td>
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<tr>
<td>1.13</td>
<td>B ✓</td>
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<tr>
<td>1.14</td>
<td>B ✓</td>
</tr>
<tr>
<td>1.15</td>
<td>A ✓</td>
</tr>
<tr>
<td>1.16</td>
<td>C ✓</td>
</tr>
<tr>
<td>1.17</td>
<td>A ✓</td>
</tr>
<tr>
<td>1.18</td>
<td>C ✓</td>
</tr>
<tr>
<td>1.19</td>
<td>D ✓</td>
</tr>
<tr>
<td>1.20</td>
<td>B ✓</td>
</tr>
</tbody>
</table>

[20]
QUESTION 2: SAFETY

2.1 Safety – Centre lathe
- Look out for revolving work pieces ✓
- Do not remove shavings by hand ✓
- Be careful not to run the cutting tool into the chuck ✓
- Do not make any adjustments on the work piece while the machine is running ✓
- Do not leave tools on the machine while in operation ✓

(Any 2 x 1) (2)

2.2 Safety – Tensile Tester
- Use safety goggles ✓
- Do not apply excessive pressure ✓
- Test piece to be well secured for testing ✓
- Check hydraulic fluid level ✓

(Any 2 x 1) (2)

2.3 Safety – Spring Tester
- Spring tester should be in a good condition ✓
- Spring tester must be fitted correctly and firmly ✓
- Ensure that the spring cannot slip out of position before applying the load ✓
- An uniform load must be applied ✓
- Release the load carefully and uniformly ✓

(Any 2 x 1) (2)

2.4 Safety – Cylinder Leakage
- Clean the area around the spark plug, before removing the spark plug ✓
  ➢ To prevent dirt from falling into the cylinder. ✓
- Be careful when removing radiator cap ✓
  ➢ The water may be hot and under pressure. ✓
- Do not exceed the specified pressure to test the cylinder ✓
  ➢ To prevent damage to the seals and tester. ✓
- The tester must fit properly and be well tightened in the spark hole or injector hole ✓
  ➢ To prevent damage to the tester and spark hole or injector hole. ✓

Any 2 x 2 (4)

[10]
QUESTION 3: TOOLS AND EQUIPMENT

3.1 Compression testing

3.1.1
- Wet compression test ✓
- Dry compression test ✓ (2)

3.1.2
- Worn cylinders ✓
- Worn piston rings ✓
- Worn piston ✓
- Leaking inlet valve ✓
- Leaking exhaust valve ✓
- Leaking cylinder head gasket ✓ (Any 2 x 1) (2)

3.2 Oil pump
- Oil pressure meter or oil pressure tester ✓ (1)

3.3 Cooling system test
- Remove the radiator cap and fit the tester ✓
- Pump air at the prescribed pressure into the system ✓
- Note the reading ✓ and if the reading drops, it indicates a leaking system ✓
- To test for a leaking cylinder-head gasket, ✓ the engine is started. ✓
- If the reading increases while the engine idles, it indicates on a leaking cylinder-head gasket ✓ (7) [12]
QUESTION 4: MATERIALS

4.1 Iron-carbon properties

4.1.1 Pearlite:
- Good ductility ✓
- Hard ✓
- Strong and tough ✓
- Resistant to deformation ✓

(Any 2 x 1) (2)

4.1.2 Cementite:
- Intensely hard ✓
- Brittle. ✓

(2)

4.2 Critical points

4.2.1 $AC_1$ – lower critical point
- The lowest temperature to which steel must be heated to be hardened. ✓✓
- The lowest temperature where the structure starts to change. ✓✓

(Any 1 x 2) (2)

4.2.2 $AC_3$ – high critical point
- The highest temperature to which the steel can be heated to obtain maximum hardness. ✓✓
- The temperature where the steel completely loses its magnetic properties. ✓✓
- The temperature where the steel's structure is at its finest. ✓✓

(Any 1 x 2) (2)

4.3 Carbon content determines the hardness of steel. ✓

(1)

4.4 Cementite structure in steel determines the hardness. ✓

(1)

4.5 Ferrite structure in steel determines the ductility. ✓

(1)

4.6 Austenite is a solid solution of iron and carbon also called iron carbide. ✓
- The structure is at its finest. ✓

(2) [13]
QUESTION 5: TERMINOLOGY

5.1 Gear calculation

5.1.1 Circular pitch = \( m \times \pi \)

module = \( \frac{\text{circular pitch}}{\pi} \)

\[ \begin{align*}
\text{module} &= \frac{12.567}{\pi} \\
&= 4 \text{ mm}
\end{align*} \] (3)

5.1.2 Outside diameter = \( \text{PCD} + 2m \)

\[ \begin{align*}
\text{PCD} &= \text{OD} - 2m \\
&= 112 - 2(4) \\
&= 104 \text{ mm}
\end{align*} \] (3)

5.1.3 Cutting Depth = \( 2.157m \) OR \( 2.25m \)

\[ \begin{align*}
\text{Cutting depth} &= 2.157 \times 4 \\
&= 8.628 \text{ mm} \\
\text{Cutting depth} &= 2.25 \times 4 \\
&= 9 \text{ mm}
\end{align*} \] (2)

5.1.4 Addendum = \( m \)

\[ \begin{align*}
\text{Addendum} &= 4 \text{ mm}
\end{align*} \] (1)

5.1.5 Dedendum = \( 1.157m \) OR \( 1.25m \)

\[ \begin{align*}
\text{Dedendum} &= 1.157 \times 4 \\
&= 4.628 \text{ mm} \\
\text{Dedendum} &= 1.25 \times 4 \\
&= 5 \text{ mm}
\end{align*} \] (2)

5.1.6 Clearance = \( 0.157m \) OR \( 0.25m \)

\[ \begin{align*}
\text{Clearance} &= 0.157 \times 4 \\
&= 0.628 \text{ mm} \\
\text{Clearance} &= 0.25 \times 4 \\
&= 1 \text{ mm}
\end{align*} \] (2)

5.1.7 module = \( \frac{\text{PCD}}{\text{Teeth}} \)

\[ \begin{align*}
\text{PCD} &= \frac{104}{4} \\
&= 26 \text{ teeth}
\end{align*} \] (3)
5.2 **Indexing**

Indexing = \( \frac{40}{n} \) \\
\[ = \frac{40}{26} \] \\
\[ = \frac{20}{13} \] \\
\[ = \frac{7}{13} \times \frac{3}{3} \] \\
\[ = \frac{21}{39} \]

Indexing = 1 full turn of the crank and 21 holes on the 39 hole circle

\( \text{(4)} \)

5.3 **Screw thread cutting**

- Set up the work piece in the lathe and turn the part to be threaded to the major diameter of the thread. \( \checkmark \)
- Set the compound slide to the correct angle (30°) to the right and set the tool up accurately in the post. \( \checkmark \)
- Consult the index plate of the quick-change gearbox for 2 mm pitch and move the levers accordingly. \( \checkmark \)
- Start the lathe and set the cutting tool so that it just touches the work piece. Set graduated dials to zero (cross feed and compound slide) \( \checkmark \)
- Move cutting tool a short distance off end of work piece and feed compound slide say 0.06 mm inwards. \( \checkmark \)
- With lathe turning, engage half nuts at the correct line on the chasing dial, putting the first cut in progress. \( \checkmark \)
- Withdraw the cutting tool quickly and disengage the half-nut lever. Return the carriage to the starting point of the thread. \( \checkmark \) OR Stop the machine, leave half nut engaged, back off slide past zero and return carriage to start position in reverse \( \checkmark \)
- Check with thread gauge to see if thread pitch is correct. \( \checkmark \)
- Repeat with successive cuts until thread is complete. (Remember to bring cross-feed collar back to zero for each cut) \( \checkmark \)
- Each successive cut is set by means of the compound slide. Check thread with ring gauge for correct fit. \( \checkmark \)
QUESTION 6: JOINING METHODS

6.1 MIG/MAGS welding equipment

6.1.1 MIG/MAGS welding equipment ✓

6.1.2 Labels
A = Shielding gas cylinder ✓
B = Regulator ✓
C = Gas flow meter ✓
D = Continuous wire reel ✓
E = Welding gun ✓
F = Arc ✓
G = Earth clamp ✓

(7)

6.1.3 Purpose
Prevents oxygen ✓ to come in contact with the molten metal. ✓

(2)

6.2 Weld defects

6.2.1 Defect: Slag inclusion
Causes:
• Included angle is too narrow. ✓
• Rapid chilling. ✓
• Weld temperature is too low. ✓
• High viscosity of molten metal. ✓
• Slag from previous run weld not removed. ✓

(Any 2 x 1)

(2)

6.2.2 Defect: Undercutting
Causes:
• Faulty electrode manipulation. ✓
• Current too high. ✓
• Arc length too long. ✓
• Speed of weld too fast. ✓

(Any 2 x 1)

(2)
6.3  Welding defects

6.3.1  Defect: Lack of fusion
Preventions:
• Adjust the electrode angle and prepare the V groove properly. ✓
• Weave must be sufficient to melt sides of the joint. ✓
• Proper current will allow fusion. ✓
• Adjust welding speed to ensure fusion. ✓

(Any 2 x 1)  (2)

6.3.2  Defect: Weld craters
Preventions:
• Use lower current. ✓
• Use proper welding technique. ✓
• Use correct electrode ✓

(Any 2 x 1)  (2)

6.4  Dye penetration test
• Clean the weld that needs to be tested. ✓
• The dye is sprayed onto the clean surface. ✓
• Allow the dye to penetrate the weld joint. ✓
• Excess dye is cleaned away with a cleaning agent. ✓
• Allow surface to dry thoroughly. ✓
• Spray a developer onto the surface to bring out the dye trapped in the crack. ✓
• The dye will show all the surface defects ✓

(7)  [25]
QUESTION 7: FORCES

7.1 Resultant

\[\sum HC = 4,7 - 3,1\cos 50^\circ - 1,5\cos 40^\circ\]
\[= 4,7 - 1,99 - 1,15\]
\[= 1,56 \text{kN}\]

\[\sum VC = 2,1 + 1,5\sin 40^\circ - 3,1\sin 50^\circ\]
\[= 2,1 + 0,96 - 2,37\]
\[= 0,69 \text{kN}\]

<table>
<thead>
<tr>
<th>7.1.3 Horizontal components</th>
<th>Magnitudes</th>
<th>7.1.4 Vertical components</th>
<th>Magnitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,7 kN</td>
<td>4,7 kN ✓</td>
<td>2,1 kN</td>
<td>2,1 kN ✓</td>
</tr>
<tr>
<td>3,1 kN Cos50°</td>
<td>-1,99 kN ✓</td>
<td>1,5 kN Sin40°</td>
<td>0,96 kN ✓</td>
</tr>
<tr>
<td>1,5 kN Cos40°</td>
<td>-1,15 kN ✓</td>
<td>3,1 kN Sin50°</td>
<td>-2,37 kN ✓</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,56 kN ✓</td>
<td>TOTAL</td>
<td>0,69 kN ✓</td>
</tr>
</tbody>
</table>
\[ E^2 = HC^2 + VC^2 \]
\[ E = \sqrt{1,56^2 + 0,69^2} \]
\[ E = 1,71 \text{kN} \]

\[ \tan \alpha = \frac{VC}{HC} \]
\[ = \frac{0,69}{1,56} \]
\[ \alpha = 23,86^0 \]

\[ E = 1,71 \text{kN at 23,86}^0 \text{north from east} \]

7.2 Stress and Strain

Forces

\[ \text{Force} = \text{load} \times \text{gravity} \]
\[ = 600 \times 10 \]
\[ = 6000 \text{N} \]

\[ \text{Area} = \frac{\pi r^2}{4} \]
\[ = \frac{\pi \times 0,016^2}{4} \]
\[ = 2,011 \times 10^{-4} \text{m}^2 \]

\[ \text{Stress} = \frac{\text{Force}}{\text{Area}} \]
\[ = \frac{6000}{2,011 \times 10^{-4}} \]
\[ = 29841551,83 \text{ Pa} \]
\[ = 29,84 \text{ MPa} \]

7.3 One Pascal (1 Pa) is equal to one Newton force (1 N) acting onto an area of one square metre (1 m²).
7.4  Reactions

Taking moments around A

\[
(B \times 3.5) + (1400 \times 0.7) = (350 \times 6.7)2.65 + (1600 \times 6)
\]

\[
3.5B + 980 = 6214.25 + 9600
\]

\[
3.5B = \frac{6214.25 + 9600 - 980}{3.5}
\]

\[
B = 4238.36 \text{ N}
\]

Taking moments around B

\[
(A \times 3.5) + (1600 \times 2.5) = (350 \times 6.7)0.85 + (1400 \times 4.2)
\]

\[
3.5A + 4000 = 1993.25 + 5880
\]

\[
3.5A = \frac{1993.25 + 5880 - 4000}{3.5}
\]

\[
A = 1106.64 \text{ N}
\]

\[\text{[30]}\]
QUESTION 8: MAINTENANCE

8.1 Routine maintenance.
- Tear on the belt.
- Misalignment of belt drive.
- Overheating of components.
- Belt slip.
- Belt wear.
- Pulley wear.
- Financial loss due to the damage suffered.
- Loss of valuable production time.

(Any 2 x 1) (2)

8.2 Cutting fluid
- To allow it to flow easily
- Dissipate excess heat
- Prevent excessive load on pump

(Any 2 x 1) (2)

8.3 Flash point
Is the lowest temperature at which the oil gives off a vapour which will ignite.

(2)

8.4 'API'
American Petroleum Institute

(2)

8.5 Automatic transmission fluid
- Transmit power in the torque convertor
- Let hydraulic fluid transmit energy in order to move various parts such as the servo unit.
- Acts as heat transfer medium to transfer heat within the transmission to outside and assist in cooling it down.
- Acts as a lubricant for gears and bearings.

(Any 2 x 1) (2)

8.6 Replace belt in a drill press
- Machine should be switched off the locked out.
- Tension on the belt to be released by loosening an adjusting screw or releasing the belt tensioner.
- Remove the belt.
- Replace with new belt of the correct type and size.
- The belt should be re-tensioned and aligned.

(5) [15]
QUESTION 9: SYSTEMS AND CONTROL

9.1 Gear drive

9.1.1 Rotational frequency of the electric motor:

\[
\frac{N_A}{N_D} = \frac{T_B \times T_D}{T_A \times T_C}
\]

\[
N_A = \frac{80 \times 63 \times 2}{30 \times 40}
\]

\[
N_A = \frac{10080}{1200}
\]

\[
N_A = 8.4 \text{ r/s}
\]

\[
(5)
\]

9.1.2 Speed ratio of gear train:

\[
\text{Speed ratio} = \frac{\text{Input}}{\text{Output}} = \frac{8.4}{2} \quad \checkmark \quad \text{OR}
\]

\[
\frac{n_{1}}{n_{2}} = 4.2:1 \quad \checkmark
\]

\[
(2)
\]

9.2 Belt drive

9.2.1 Diameter of the driven pulley

\[
N_1 \times D_1 = N_2 \times D_2
\]

\[
N_1 = \frac{N_2 \times D_2}{D_1}
\]

\[
= \frac{7.2 \times 600}{800}
\]

\[
= 5.4 \text{ r/s}
\]

\[
(3)
\]
9.2.2 Power transmitted:

\[ P = \frac{\left(T_1 - T_2\right) \cdot V}{D_n} \]

\[ P \neq 300 \text{-} 120 \implies 0.6 \times 7.2 \checkmark \]
\[ = 2442.90 \text{ Watt} \checkmark \]
\[ = 2.44 \text{ kW} \]

\[ \frac{T_1}{T_2} = 2.5 \]
\[ T_2 = \frac{300}{2.5} \]
\[ = 120 \text{ N} \]

OR

\[ P = \frac{\left(T_1 - T_2\right) \cdot V}{D_n} \]

\[ P \neq 300 \text{-} 120 \implies 0.8 \times 5.4 \checkmark \]
\[ = 2442.90 \text{ Watt} \checkmark \]
\[ = 2.44 \text{ kW} \]

\[ \frac{T_1}{T_2} = 2.5 \]
\[ T_2 = \frac{300}{2.5} \]
\[ = 120 \text{ N} \]

(3)

9.3 The volume of gas can be changed by the altering of ...
- its pressure \checkmark
- its temperature \checkmark
- both its pressure and temperature \checkmark

(Any 2 x 1) (2)

9.4 Definition of Boyle's law

The volume of a given mass of gas is inversely proportional to the pressure on it, if the temperature remains constant

(3)
9.5 Hydraulics

9.5.1 Fluid pressure

\[ A_A = \frac{D^2}{4} \]
\[ = \frac{0.04^2}{4} \]
\[ = 1.26 \times 10^{-3} \text{ m}^2 \]

\[ P_A = \frac{F}{A_A} \]
\[ = \frac{80}{1.26 \times 10^{-3}} \text{ Pa} \]
\[ = 63661.98 \text{ Pa} \]
\[ = 63.66 \text{ kPa} \]

(3)

9.5.2 Diameter of piston B

\[ P_B = P_A \]
\[ P_B = \frac{F_B}{A_B} \]
\[ A_B = \frac{F_B}{P_B} \]
\[ A_B = \frac{320}{63492.06} \]
\[ A_B = 5.04 \times 10^{-3} \text{ } \checkmark \]
\[ A = \frac{D^2}{4} \]
\[ D_B = \sqrt{\frac{A_B \times 4}{E}} \]
\[ = \sqrt{\frac{5.04 \times 10^{-3} \times 4}{E}} \]
\[ = 0.08 \text{ m} \]
\[ = 80 \text{ mm} \]

(4) [25]
QUESTION 10: TURBINES

10.1 Water turbine blades
To supply water pressure ✓ to the turbine ✓ (2)

10.2 Reverse flow
• Deriaz ✓
• Francis ✓ (2)

10.3 Supercharger
• Roots ✓
• Twin screw ✓
• Centrifugal ✓
• Vane ✓ (Any 2 x 1) (2)

10.4 Turbocharger
• Exhaust gases drive the turbine ✓
• The turbine drives a compressor via a common shaft ✓
• The compressor forces ✓ compressed air above atmospheric pressure into the cylinder ✓
• Exhaust gases leave system through the exhaust pipe ✓ (5)

10.5 Supercharger over turbocharger
• Do not suffer lag ✓
• More efficient at low revolution per minute. ✓
• Does not require extensive exhaust modification. ✓
• No special shutdown procedure is required. ✓ (Any 2 x 1) (2)

10.6 Lag
Lag is the delay ✓ between pressing the accelerator pedal ✓ and feeling the pressure building up. ✓ (3)

10.7 Supercharger drive
• Belt drive ✓
• Gear drive ✓
• Chain drive ✓ (Any 2 x 1) (2)
10.8 **Gas turbine disadvantages**

- Cost is much greater than for a similar-sized reciprocating engine since the materials must be stronger and more heat resistant. ✓
- Manufacturing operations are also more complex. ✓
- Usually less efficient than reciprocating engines, especially at idling speed. ✓
- Delayed response to changes in power settings. ✓

(Any 2 x 1) (2) [20]

**TOTAL:** 200