



basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

**NATIONAL
SENIOR CERTIFICATE**

GRADE 12

MECHANICAL TECHNOLOGY

NOVEMBER 2012

MARKS: 200

TIME: 3 hours

This question paper consists of 17 pages and a 5-page formula sheet.

INSTRUCTIONS AND INFORMATION

1. Write your centre number and examination number in the spaces provided on the ANSWER BOOK.
2. Read ALL the questions carefully.
3. Answer ALL the questions.
4. Answer QUESTION 1 on the inside of the front cover page of the ANSWER BOOK. Choose an answer and make a cross (X) in the block (A–D) next to the question number (1.1–1.20) in the ANSWER BOOK.
5. Number the answers correctly according to the numbering system used in this question paper.
6. Start EACH question on a NEW page.
7. Show ALL calculations and units. Round off final answers to TWO decimal places.
8. Candidates may use non-programmable scientific calculators and drawing instruments.
9. The value of gravitational force should be taken as 10 m/s^2 .
10. All dimensions are in millimetres, unless stated otherwise in the question.
11. Write neatly and legibly.
12. Use the criteria below to assist you in managing your time.

QUESTION	CONTENT COVERED	MARKS	TIME
1	Multiple-choice questions	20	18 minutes
2	Tools and Equipment	20	18 minutes
3	Materials	20	18 minutes
4	Safety, Terminology and Joining Methods	50	45 minutes
5	Maintenance and Turbines	40	36 minutes
6	Forces, Systems and Control	50	45 minutes
TOTAL		200	180 minutes

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Various options are provided as possible answers to the following questions. Choose the answer and make a cross (X) in the block (A–D) next to the question number (1.1–1.20) on the inside of the front cover page of the ANSWER BOOK.

Example:

QUESTION	OPTIONS			
1.21	A	B	C	<input checked="" type="checkbox"/> D

- 1.1 What is the advantage of down-cut milling?
- A The strain on the arbor and cutter is less.
 B Finish obtained is finer.
 C More vibration is experienced.
 D Built-up pressure is developed. (1)
- 1.2 Which ONE of the following safety procedures does NOT relate to the cylinder leakage tester?
- A Use water to remove dust around the spark-plug area.
 B Clean and remove the oil filler cap.
 C Do not exceed the prescribed pressure in the test cylinder.
 D The tester must fit properly and be well tightened in the spark-plug hole or injector hole. (1)
- 1.3 What is the function of a gas analyser?
- A Analyse inlet gases
 B Analyse oil gases
 C Analyse fuel gases
 D Analyse exhaust gases (1)
- 1.4 The main reason for using a torsion tester is to measure the ability of metal to ... without breaking.
- A bend
 B twist
 C elongate
 D shorten (1)
- 1.5 Alloys can ...
- A reduce electrical conductivity.
 B increase resistance to corrosion.
 C reduce strength and hardness.
 D alter insulation properties. (1)

1.6 Thermosetting plastic materials are materials that ...

- A can be stretched and return rapidly to their original shape.
- B cannot be softened and reshaped by reheating.
- C soften under heat and become hard when cooled.
- D stay soft after reheating.

(1)

1.7 Identify the type of milling cutter shown in FIGURE 1.1 below.

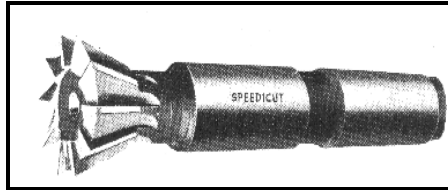


FIGURE 1.1

- A Dovetail slot cutter
- B Convex cutter
- C Cylindrical/Helical cutter
- D Single corner rounding cutter

(1)

1.8 Which lathe operation is shown in FIGURE 1.2 below?

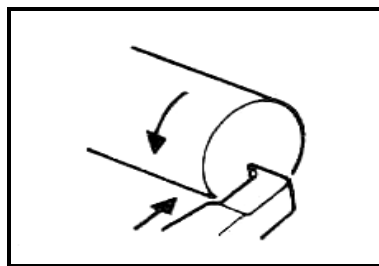


FIGURE 1.2

- A Diameter turning
- B Thread cutting
- C Facing off
- D Boring

(1)

1.9 Upcut milling is also known as ...

- A gang milling.
- B slot milling.
- C climb milling.
- D conventional milling.

(1)

1.10 What is the reason for using a free-bend test?

- A To measure the ductility of the weld metal
- B To test the skill of the welder
- C To train welders
- D To approve welds according to certain standards

(1)

- 1.11 What is the advantage of a helical cutter?
- A Vibration experienced by the machine is more.
 B Narrow cuts may be made.
 C No side thrusts due to sliding action of the cutter.
 D Wider cutters may be used. (1)
- 1.12 Tensile stress can be defined or described as an internal force in a material resisting ...
- A a shearing load.
 B a pulling load.
 C a pushing load.
 D any load. (1)
- 1.13 What is understood by the term *Young's modulus*?
- A The force value required to produce a unit area in a tensile test specimen
 B The ratio between stress and strain in a metal, provided that the limit of elasticity is not exceeded
 C A measurement of the extension or contraction of material due to the load experienced
 D A ratio of the deformation by application of an external force (1)
- 1.14 Which step in adjusting the tension in the chain of a chain drive does FIGURE 1.3 below show?

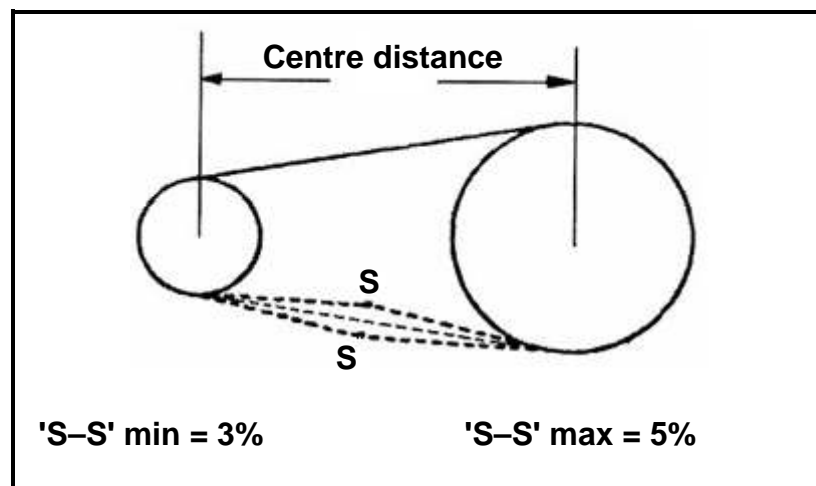


FIGURE 1.3

- A Check the distance between the centres.
 B Slacken the clamp bolts and screw the adjusting bolts in or out.
 C Check the amount of slack in the chain. If it is between 3% and 5% it is acceptable.
 D Tighten the clamping bolts. (1)

1.15 Which procedure for removing a bearing is shown in FIGURE 1.4 below?

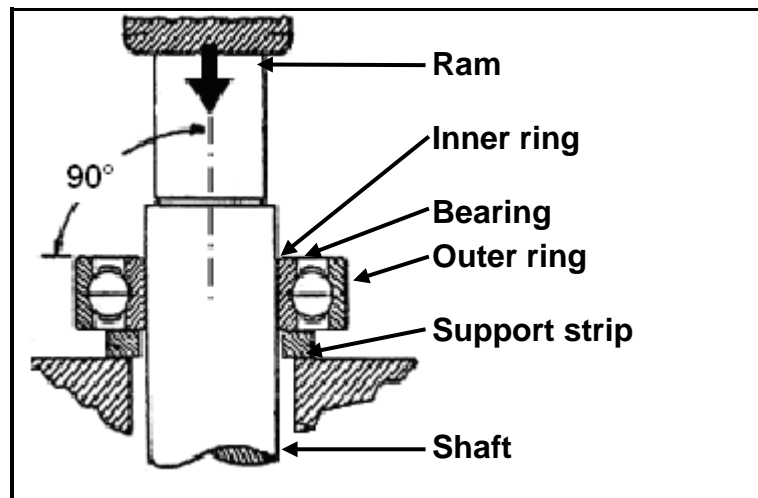


FIGURE 1.4

- A Applying force to remove the shaft
 - B Applying force to the bearing
 - C Removing any rust from the shaft with emery paper
 - D Measuring the position of the bearing
- (1)

1.16 Which ONE of the following is an advantage of V-belts?

- A Can be used on loose pulleys
 - B May be used over long distances
 - C Able to absorb shock loads
 - D Operate at a high bearing pressure
- (1)

1.17 What is the purpose of the linkage shown in FIGURE 1.5 below?

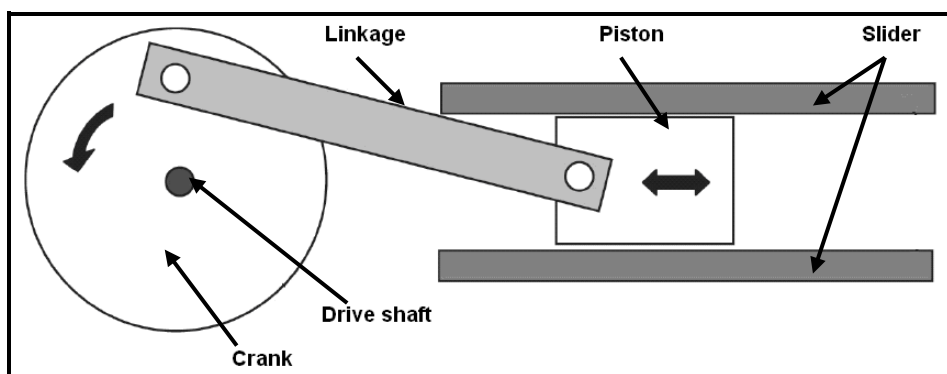


FIGURE 1.5

- A Converts rotary motion into oscillating motion
 - B Converts oscillating motion into rotary motion
 - C Converts reciprocating motion into rotary motion
 - D Converts rotary motion into reciprocating motion
- (1)

- 1.18 Determine the distance 'D' moved by the follower for one full revolution of the pear-shaped cam shown in FIGURE 1.6 below, given that $d_1 = 5$ mm and $d_2 = 12$ mm.

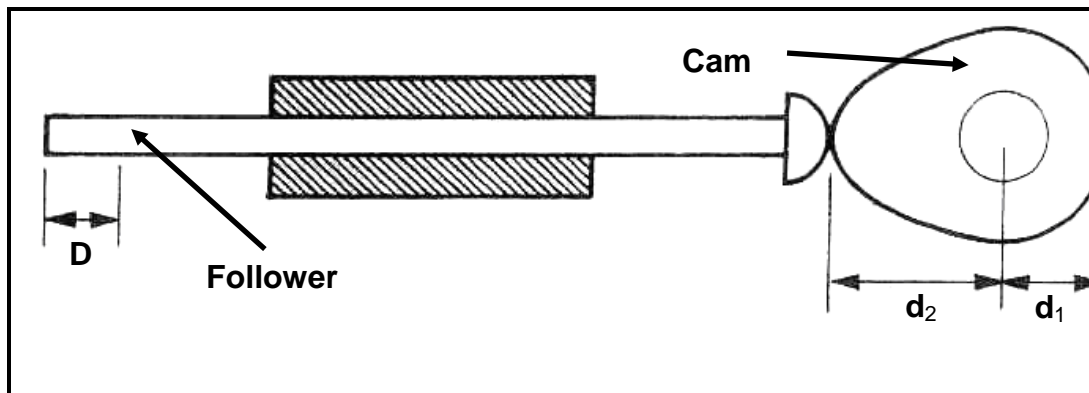


FIGURE 1.6

- A 7 mm
 B 17 mm
 C 5 mm
 D 12 mm (1)
- 1.19 What is understood by the term *pressure ratio* in turbochargers?
 A The pressure that the turbocharger generates in the intake manifold
 B The pressure that the turbocharger generates in the exhaust manifold
 C The inlet pressure compared to the outlet pressure
 D Decreased pressure in the exhaust manifold (1)
- 1.20 The volumetric efficiency of a blower is the ...
 A ability to heat intake air.
 B ability to cool exhaust air.
 C ability to drive the blower.
 D ability to fill the cylinder with air above atmospheric pressure. (1)

[20]

QUESTION 2: TOOLS AND EQUIPMENT

- 2.1 When a dry compression test was conducted on cylinder number one of a four-stroke, four-cylinder, spark-ignition engine the result was very low compared to the engine specifications. State THREE possible causes of the low compression in cylinder number one. (3)
- 2.2 Define *torsion*. (2)
- 2.3 FIGURE 2.1 below indicates a multimeter that is used to test different electrical components and circuits. Label parts A–E on the multimeter. (5)

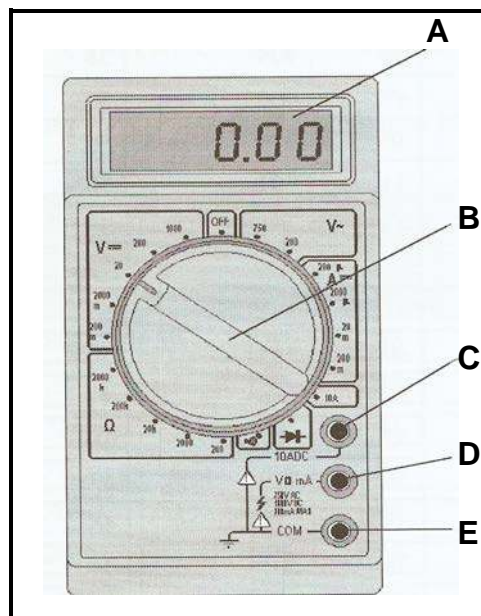


FIGURE 2.1

- 2.4 The function of the cylinder leakage tester is to check whether the engine leaks gases from the cylinder during compression strokes. State THREE possible leakages during the cylinder leakage test and state the cause of each. (6)
 - 2.5 What does the abbreviation *MAGS/MIGS* stand for in welding equipment? (2)
 - 2.6 Name TWO gases that can be used in *MAGS/MIGS* welding. (2)
- [20]**

QUESTION 3: MATERIALS

3.1 Name ONE difference between non-ferrous metals and composites. (2)

3.2 FIGURE 3.1 below shows the results of a compressive strength test on two materials, A and B.

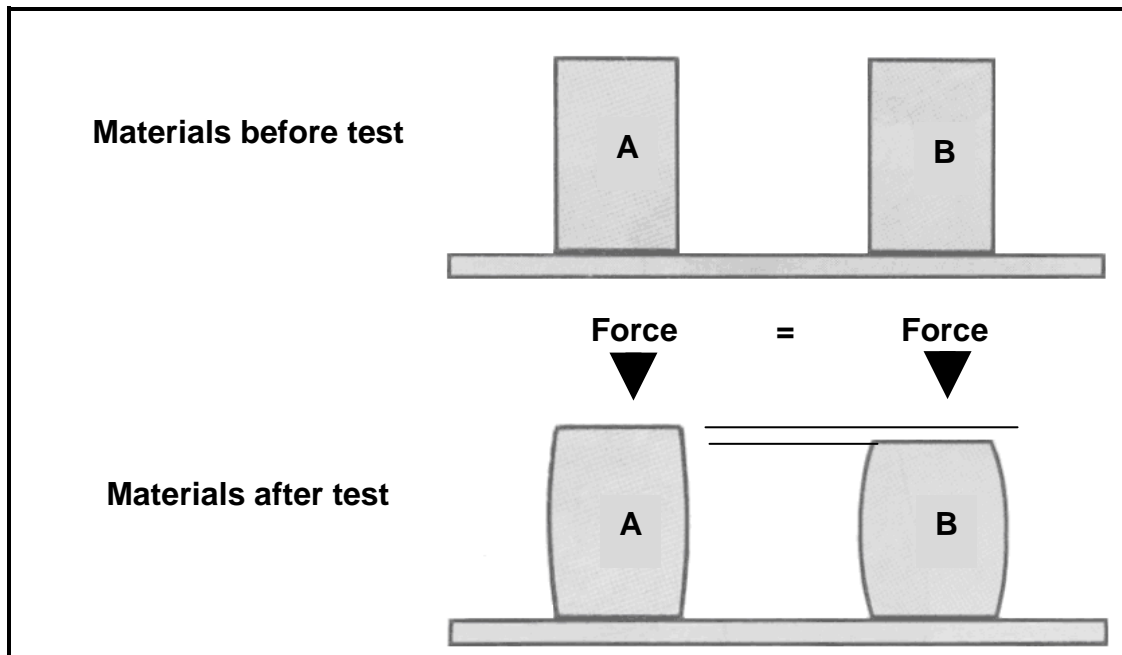


FIGURE 3.1

3.2.1 Which of the materials, **A** or **B**, has the highest compressive strength? (1)

3.2.2 Give a reason for the answer to QUESTION 3.2.1. (2)

3.3 Name THREE main classes/groups of carbon steel. (3)

3.4 Name FOUR properties of carbon steel that will change when the carbon content is increased. (4)

3.5 Choosing the most suitable material for a particular product requires you to have good knowledge of materials. State TWO uses and TWO properties of the following engineering materials:

3.5.1 Duralumin (2 + 2) (4)

3.5.2 Polyvinyl chloride (PVC) (2 + 2) (4)

[20]

QUESTION 4: SAFETY, TERMINOLOGY AND JOINING METHODS

- 4.1 State THREE safety precautions to be observed when operating a beam bending tester. (3)
- 4.2 State THREE safety precautions to be observed when storing gas cylinders. (3)
- 4.3 Give TWO advantages of each of the following milling operations:
- 4.3.1 Upcut milling (2)
- 4.3.2 Down-cut milling (2)
- 4.4 A gear with 63 teeth has to be machined on a milling machine. Use $A = 60$ or $N = 60$.
- 4.4.1 Calculate the indexing required. (4)
- 4.4.2 Calculate the change gears required. (5)
- 4.5 Calculate the feed in millimetres per minute of an 80 mm diameter cutter with 14 teeth, operating at a cutter speed of 20 metres per minute and a feed of 0,08 mm per tooth. (7)
- 4.6 Mary is a quality controller who inspects welded joints on workpieces. She uses an ultrasonic test to determine whether the welds have any welding defects. Explain the principle of operation of the ultrasonic test on welded joints. (5)
- 4.7 State TWO possible causes and ONE preventive action for each of the following weld defects:
- 4.7.1 Slag inclusion (2 + 1) (3)
- 4.7.2 Undercutting (2 + 1) (3)
- 4.8 Which milling cutter can be used to cut the following profiles?
- 4.8.1 Spur gear (1)
- 4.8.2 Groove (1)
- 4.8.3 Rack (1)
- 4.8.4 Blind hole (1)

QUESTION 5: MAINTENANCE AND TURBINES

5.1 FIGURE 5.1 below shows a clutch and pressure-plate assembly.

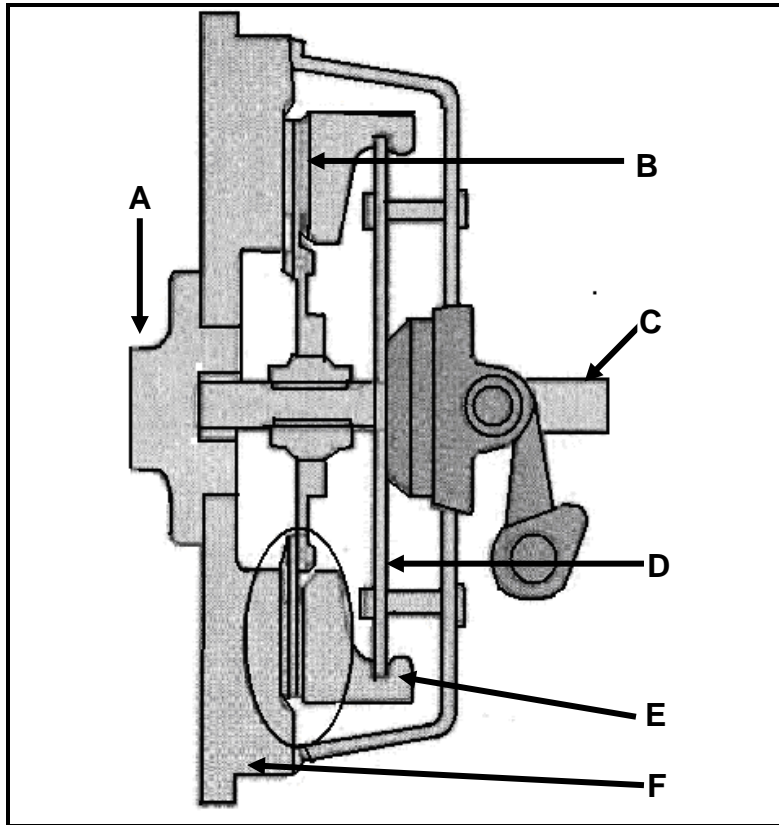


FIGURE 5.1

- 5.1.1 Label parts A–F in the clutch and pressure-plate assembly. (6)
- 5.1.2 State TWO functions of the clutch plate in this clutch and pressure-plate assembly. (4)
- 5.1.3 Name THREE causes of slip in this clutch and pressure-plate assembly. (3)
- 5.1.4 Name TWO types of clutches used in the engineering environment. (2)
- 5.2 State THREE functions of lubricating oil. (3)
- 5.3 State THREE guidelines for the maintenance of cutting fluid used in a lathe. (3)

5.4 The performance of smaller engines can be improved by using superchargers (FIGURE 5.2).

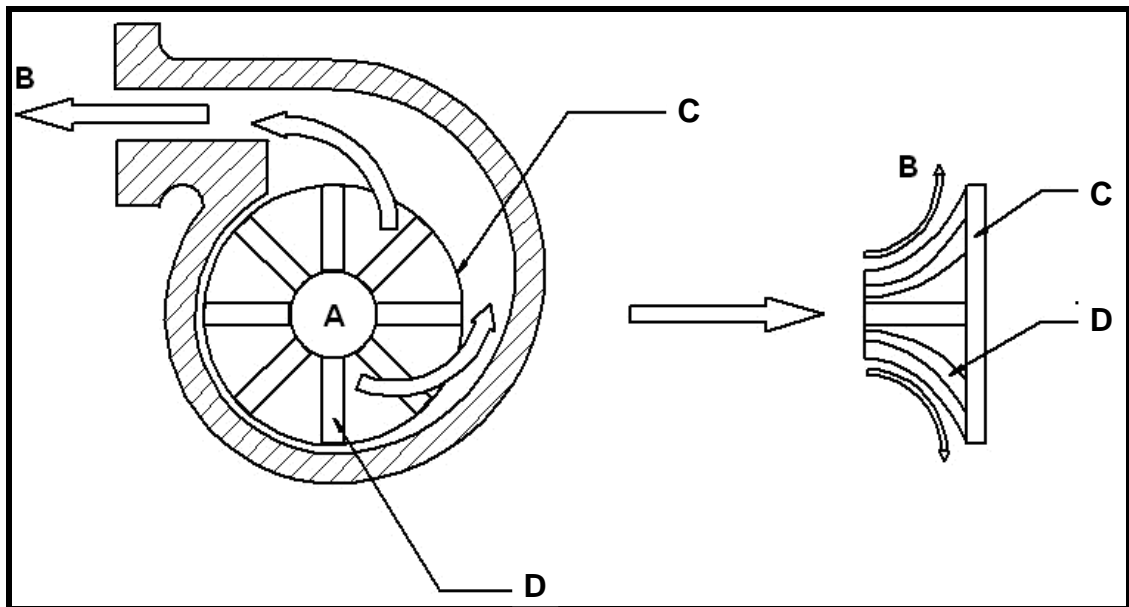
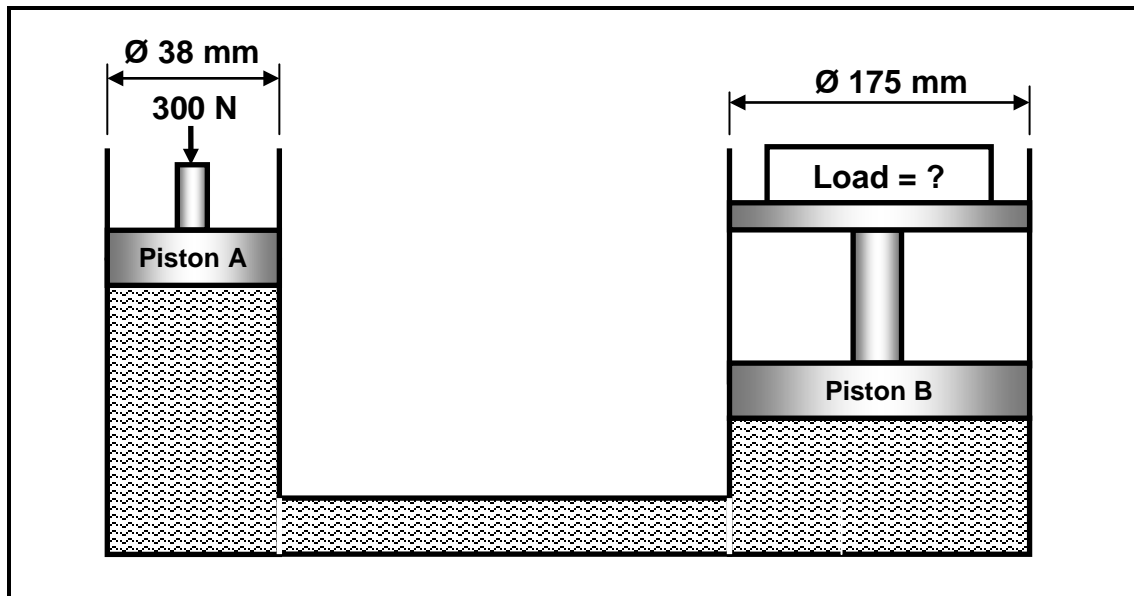


FIGURE 5.2

- 5.4.1 Identify the type of supercharger shown in FIGURE 5.2. (1)
 - 5.4.2 Label parts A–D. (4)
 - 5.4.3 Explain the operation of the supercharger shown in FIGURE 5.2. (5)
 - 5.4.4 Name THREE advantages of superchargers. (3)
 - 5.5 Name THREE classifications of steam turbines. (3)
 - 5.6 State THREE advantages of gas turbines. (3)
- [40]**

QUESTION 6: FORCES, SYSTEMS AND CONTROL

- 6.1 A hydraulic system is being used to lift a machine part into position. The specifications of the system are diagrammatically presented in FIGURE 6.1 below.

**FIGURE 6.1**

Determine the following by means of calculations:

- 6.1.1 The fluid pressure in the hydraulic system when in equilibrium (5)
- 6.1.2 The load that can be lifted by piston B when a force of 300 N is applied to piston A (6)
- 6.2 A steel spoke of a bicycle wheel has a cross-sectional area of $2,2 \text{ mm}^2$ and a length of 300 mm . The nut of the spoke is tightened until the length increases by $0,2 \text{ mm}$. Determine, by means of calculations, the tensile force in the spoke material. Take Young's elasticity modulus for the spoke material as 245 GPa . (9)

- 6.3 FIGURE 6.2 shows a belt-drive system. A pulley with a diameter of 0,25 m drives a driven pulley with a diameter of 0,35 m. The driver pulley rotates at 1 000 r/min. $T_1 = 200$ N and $T_2 = 90$ N.

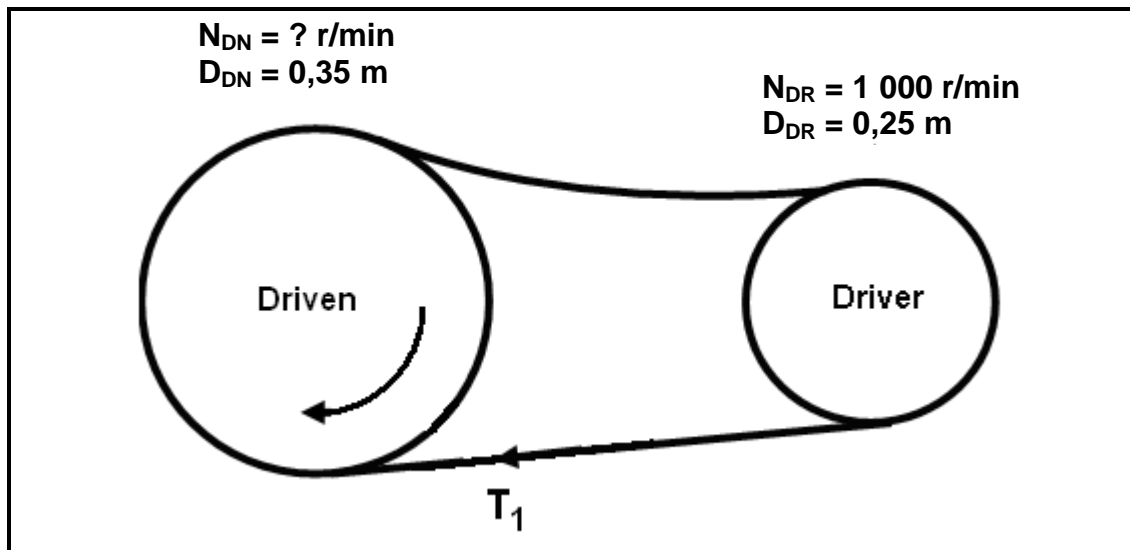


FIGURE 6.2

Determine by means of calculations:

- 6.3.1 The rotation frequency of the driven pulley in r/min (revolutions per minute) (3)
- 6.3.2 The power transmitted (3)
- 6.3.3 The belt speed of the system in metres per second (3)

- 6.4 FIGURE 6.3 shows a gear drive system. A driver gear on the shaft of an electric motor has 24 teeth and meshes with a gear on a counter shaft with 40 teeth. On this counter shaft is another driver gear with 20 teeth that meshes with a gear with 48 teeth on a second counter shaft. The second counter shaft has a driver gear with 42 teeth which drives a gear with 90 teeth on the output shaft.

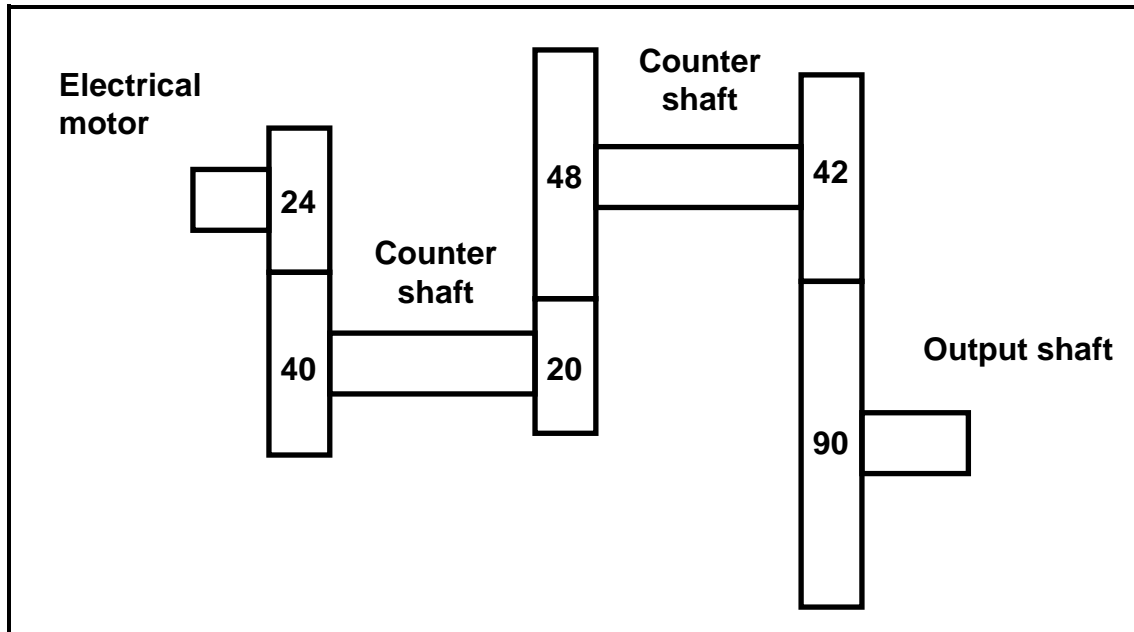


FIGURE 6.3

Calculate:

- 6.4.1 The rotation frequency of the output shaft if the electric motor rotates at 1 440 r/min (4)
- 6.4.2 The velocity ratio between the input and output shaft (2)

6.5 A differential wheel-and-axle lifting machine is shown in FIGURE 6.4 below. A load of 2,4 kN is lifted when an effort of 400 N is applied. The diameters of the pulleys are 210 mm, 160 mm and 140 mm respectively.

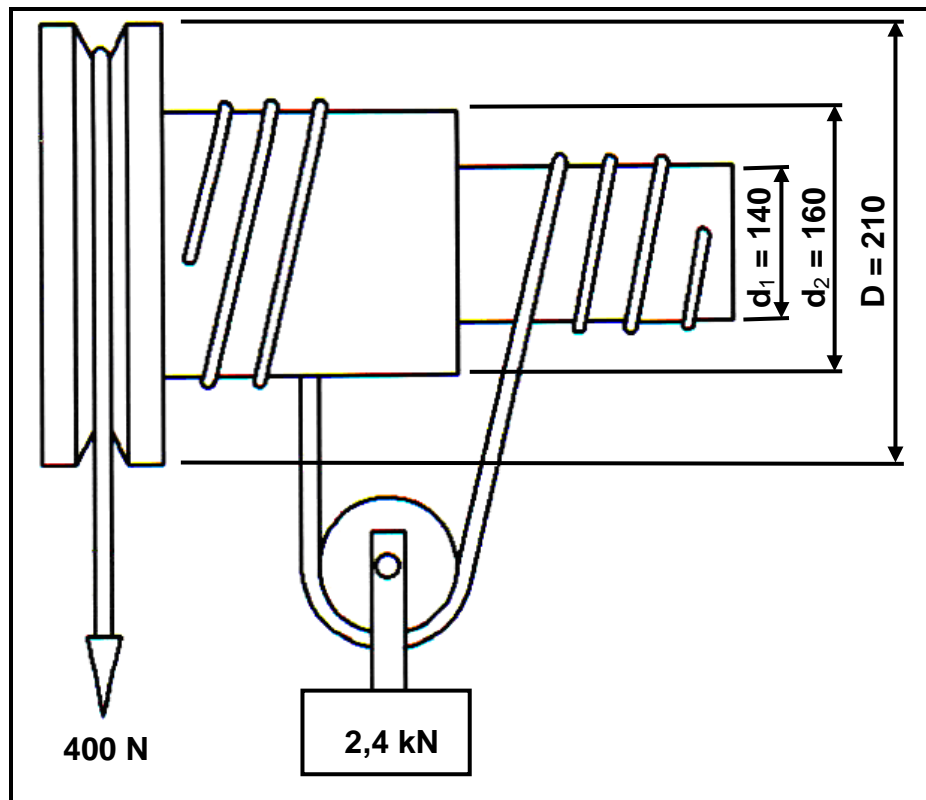


FIGURE 6.4

Determine by means of calculations:

6.5.1 The mechanical advantage (2)

6.5.2 The velocity ratio (3)

6.5.3 The mechanical efficiency of the machine (2)

6.6 A single-plate friction clutch transmits a maximum torque of 336 Nm. The clutch plate has friction material on both sides with a friction co-efficient of 0,4. The total applied force on the friction surfaces is 3,5 kN.

Determine by means of calculations:

6.6.1 The effective diameter of the clutch plate in millimetres (5)

6.6.2 The power transmitted at 3 200 r/min (3)

[50]

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY – GRADE 12**1. BELT DRIVES**

$$1.1 \quad \text{Belt speed} = \frac{\pi DN}{60}$$

$$1.2 \quad \text{Belt speed} = \frac{\pi (D+t) \times N}{60} \quad (t = \text{belt thickness})$$

$$1.3 \quad \text{Belt mass} = \text{Area} \times \text{length} \times \text{density} \quad (A = \text{thickness} \times \text{width})$$

$$1.4 \quad \text{Speed ratio} = \frac{\text{Diameter of driven pulley}}{\text{Diameter of driver pulley}}$$

$$1.5 \quad N_1 D_1 = N_2 D_2$$

$$1.6 \quad \text{Open-belt length} = \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4c} + 2c$$

$$1.7 \quad \text{Crossed-belt length} = \frac{\pi(D+d)}{2} + \frac{(D+d)^2}{4c} + 2c$$

$$1.8 \quad \text{Power} (P) = \frac{2\pi NT}{60}$$

$$1.9 \quad \text{Ratio of tight side to slack side} = \frac{T_1}{T_2}$$

$$1.10 \quad \text{Power} (P) = \frac{(T_1 - T_2) \pi D N}{60} \quad \text{where } T_1 = \text{force in the tight side}$$

$$1.11 \quad \text{Width} = \frac{T_1}{\text{permissible tensile force}}$$

2. FRICTION CLUTCHES

$$2.1 \quad \text{Torque (} T \text{)} = \mu W n R$$

$\mu = \text{coefficient of friction}$
 $W = \text{total force}$
 $n = \text{number of friction surfaces}$
 $R = \text{effective radius}$

$$2.2 \quad \text{Power (} P \text{)} = \frac{2 \pi N T}{60}$$

3. STRESS AND STRAIN

$$3.1 \quad \text{Stress} = \frac{\text{Force}}{\text{Area}} \quad \text{or} \quad \left(\sigma = \frac{F}{A} \right)$$

$$3.2 \quad \text{Strain (} \varepsilon \text{)} = \frac{\text{change in length (} \Delta L \text{)}}{\text{original length (} L \text{)}}$$

$$3.3 \quad \text{Young's modulus (} E \text{)} = \frac{\text{stress}}{\text{strain}} \quad \text{or} \quad \left(\frac{\sigma}{\varepsilon} \right)$$

$$3.4 \quad A_{\text{shaft}} = \frac{\pi d^2}{4}$$

$$3.5 \quad A_{\text{pipe}} = \frac{\pi(D^2 - d^2)}{4}$$

4. HYDRAULICS

$$4.1 \quad \text{Pressure (} P \text{)} = \frac{\text{Force (} F \text{)}}{\text{Area (} A \text{)}}$$

$$4.2 \quad \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$4.3 \quad \text{Work done} = \text{force} \times \text{distance}$$

$$4.4 \quad \text{Volume} = \text{Cross-sectional area} \times \text{stroke length (} l \text{ or } s \text{)}$$

5. WHEEL AND AXLE

$$5.1 \quad \text{Velocity ratio (VR)} = \frac{\text{effort distance}}{\text{load distance}} = \frac{2D}{d_2 - d_1}$$

$$5.2 \quad \text{Mechanical advantage (MA)} = \frac{\text{Load (W)}}{\text{Effort (F)}}$$

$$5.3 \quad \text{Mechanical efficiency (} \eta_{\text{mech}} \text{)} = \frac{\text{MA}}{\text{VR}} \times 100\%$$

6. LEVERS

$$6.1 \quad \text{Mechanical advantage (MA)} = \frac{\text{Load (W)}}{\text{Effort (F)}}$$

$$6.2 \quad \text{Input movement (IM)} = \text{Effort} \times \text{distance moved by effort}$$

$$6.3 \quad \text{Output movement (OM)} = \text{Load} \times \text{distance moved by load}$$

$$6.4 \quad \text{Velocity ratio (VR)} = \frac{\text{Input movement}}{\text{Output movement}}$$

7. SCREW THREADS

$$7.1 \quad \text{Pitch diameter} = \text{Outside diameter} - \frac{1}{2} \text{ pitch}$$

$$7.2 \quad \text{Pitch circumference} = \pi \times \text{pitch diameter}$$

$$7.3 \quad \text{Lead} = \text{pitch} \times \text{number of starts}$$

$$7.4 \quad \text{Helix angle: } \tan \theta = \frac{\text{Lead}}{\text{Pitch circumference}}$$

$$7.5 \quad \text{Leading tool angle} = 90^\circ - (\text{helix angle} + \text{clearance angle})$$

$$7.6 \quad \text{Following/Trailing angle} = 90^\circ + (\text{helix angle} - \text{clearance angle})$$

$$7.7 \quad \text{Number of turns} = \frac{\text{height}}{\text{lead}}$$

8. GEAR DRIVES

$$8.1 \quad \text{Power (} P \text{)} = \frac{2 \pi NT}{60}$$

$$8.2 \quad \text{Gear ratio} = \frac{\text{Product of the number of teeth on driven gear}}{\text{Product of the number of teeth on driver gear}}$$

$$8.3 \quad \frac{N_{\text{input}}}{N_{\text{output}}} = \frac{\text{Product of the number of teeth on driven gear}}{\text{Product of the number of teeth on driver gear}}$$

$$8.4 \quad \text{Torque} = \text{force} \times \text{radius}$$

$$8.5 \quad \text{Torque transmitted} = \text{gear ratio} \times \text{input torque}$$

$$8.6 \quad \text{Module (} m \text{)} = \frac{\text{Pitch-circle diameter (PCD)}}{\text{Number of teeth (} T \text{)}}$$

$$8.7 \quad N_1 T_1 = N_2 T_2 \quad \text{and} \quad N_1 D_1 = N_2 D_2$$

$$8.8 \quad \text{Pitch-circle diameter (PCD)} = \frac{\text{circular pitch (CP)} \times \text{number of teeth (} T \text{)}}{\pi}$$

$$8.9 \quad \text{Outside diameter (OD)} = \text{PCD} + 2 \text{ module}$$

$$8.10 \quad \text{Addendum (} a \text{)} = \text{module (} m \text{)}$$

$$8.11 \quad \text{Dedendum (} b \text{)} = 1,157 m \quad \text{or} \quad \text{Dedendum (} b \text{)} = 1,25 m$$

$$8.12 \quad \text{Cutting depth (} h \text{)} = 2,157 m \quad \text{or} \quad \text{Cutting depth (} h \text{)} = 2,25 m$$

$$8.13 \quad \text{Clearance (} c \text{)} = 0,157 m \quad \text{or} \quad \text{Clearance (} c \text{)} = 0,25$$

$$8.14 \quad \text{Circular pitch (CP)} = m \times \pi$$

$$8.15 \quad \text{VR (Velocity ratio)} = \frac{N_{\text{input}}}{N_{\text{output}}}$$

9. CINCINNATI DIVIDING HEAD TABLE FOR THE MILLING MACHINE

<i>Hole circles</i>											
<i>Side 1</i>	24	25	28	30	34	37	38	39	41	42	43
<i>Side 2</i>	46	47	49	51	53	54	57	58	59	62	66

<i>Standard change gears</i>										
24 x 2	28	32	40	44	48	56	64	72	86	100

9.1 Simple indexing = $\frac{40}{n}$ (where n = number of divisions)

9.2 Change gears:

$$\frac{Dr}{Dv} = (A - n) \times \frac{40}{A} \quad \text{or} \quad \frac{Dr}{Dv} = \frac{(A - n)}{A} \times \frac{40}{1} \quad \text{or} \quad \frac{Dr}{Dv} = (N - n) \times \frac{40}{N}$$

10. CALCULATIONS OF FEED

10.1 Feed (f) = $f_1 \times T \times N$

Where: f = feed in millimetres per minute

f_1 = feed per tooth in millimetres

T = number of teeth on cutter

N = number of revolutions of cutter per minute

10.2 Cutting speed (V) = $\pi \times D \times N$

Where: D = diameter of the cutter in metres



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**NATIONAL
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GRADE 12

MECHANICAL TECHNOLOGY

NOVEMBER 2012

MEMORANDUM

MARKS: 200

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) |
| | | [20] |

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 Indexing $= \frac{40}{A}$ ✓
 $= \frac{40}{60}$ ✓
 $= \frac{4 \times 4}{6 \times 4}$ ✓
 $= \frac{16}{24}$ or $\frac{20}{30}$ or $\frac{26}{39}$ or $\frac{28}{42}$ or $\frac{34}{51}$ or $\frac{36}{54}$ or $\frac{44}{66}$ ✓

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 $\frac{D_r}{D_v} = (A-n) \times \frac{40}{A}$ OR $\frac{D_r}{D_v} = (N-n) \times \frac{40}{N}$ ✓
 $\frac{D_r}{D_v} = (60-63) \times \frac{40}{60}$ $\frac{D_r}{D_v} = (60-63) \times \frac{40}{60}$ ✓
 $\frac{D_r}{D_v} = \frac{-120}{60}$ $\frac{D_r}{D_v} = \frac{-120}{60}$ ✓
 $\frac{D_r}{D_v} = \frac{-12 \times 4}{6 \times 4}$ $\frac{D_r}{D_v} = \frac{-12 \times 4}{6 \times 4}$ ✓
 $\frac{D_r}{D_v} = \frac{-48}{24}$ or $\frac{56}{28}$ or $\frac{64}{32}$ $\frac{D_r}{D_v} = \frac{-48}{24}$ or $\frac{56}{28}$ or $\frac{64}{32}$ ✓ (5)

4.5 **Cutting feed:**

$V = \pi DN$	✓	
$N = \frac{V}{\pi D}$	✓	
$N = \frac{20}{\pi \times 0,08}$	✓	
$N = 79,577 \text{ r/min}$	✓	
$f = f_1 \times T \times N$	✓	
$f = 0,08 \times 14 \times 79,577$	✓	
$f = 89,13 \text{ mm/min}$	✓	(7)

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. ✓
- (5)

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) (2)

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) (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 ✓ (1)

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 ✓ (1)

Examples: End mill; shell end mill; T-slot cutter and Woodruff keyseat cutter
(Any 1 x 1) (1)

[50]

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**

$$A_A = \frac{\pi D^2}{4} \quad \checkmark$$

$$= \frac{\pi \times (0,038)^2}{4} \quad \checkmark$$

$$= 1,13 \times 10^{-3} \text{ m}^2 \quad \checkmark$$

$$P = \frac{F_A}{A_A} \quad \checkmark$$

$$P = \frac{300}{1,13 \times 10^{-3}} \quad \checkmark$$

$$= 0,27 \text{ MPa} \quad \checkmark$$

Fully extended

$$A_A = \frac{\pi D^2}{4} \quad \checkmark$$

$$= \frac{\pi \times (0,038)^2}{4} \quad \checkmark$$

$$= 0,001134114 \text{ m}^2 \quad \checkmark$$

$$P = \frac{F_A}{A_A} \quad \checkmark$$

$$P = \frac{300}{0,001134114} \quad \checkmark$$

$$= 264523,45 \text{ Pa} \quad \checkmark$$

(5)

6.1.2 Load lifted by piston B:**Rounded off**

$$A_B = \frac{\pi D^2}{4} \quad \checkmark$$

$$= \frac{\pi \times (0,175)^2}{4} \quad \checkmark$$

$$= 24,05 \times 10^{-3} \text{ m}^2 \quad \checkmark$$

$$P = \frac{F_B}{A_B} \quad \checkmark$$

$$F_B = A_B \times P \quad \checkmark$$

$$= (24,05 \times 10^{-3}) \times 0,27 \times 10^6 \quad \checkmark$$

$$= 6,49 \text{ kN} \quad \checkmark$$

Fully extended

$$A_B = \frac{\pi D^2}{4} \quad \checkmark$$

$$= \frac{\pi \times (0,175)^2}{4} \quad \checkmark$$

$$= 0,024052818 \text{ m}^2 \quad \checkmark$$

$$P = \frac{F_B}{A_B} \quad \checkmark$$

$$F_B = A_B \times P \quad \checkmark$$

$$= (0,024052818 \times 264523,45) \quad \checkmark$$

$$= 6362,54 \text{ N} \quad \checkmark$$

(6)

6.2 Stress and Strain:

Tensile force:

Rounded off

$$\begin{aligned}\varepsilon &= \frac{\Delta L}{OL} \\ &= \frac{0,2}{300} \\ &= 0,66 \times 10^{-3}\end{aligned}$$

$$\begin{aligned}E &= \frac{\sigma}{\varepsilon} \\ \sigma &= E \times \varepsilon \\ &= 245 \times 10^9 \times 0,66 \times 10^{-3} \\ &= 161,7 \times 10^6 \text{ Pa}\end{aligned}$$

$$\begin{aligned}\sigma &= \frac{F}{A} \\ F &= \sigma \times A \\ &= 161,7 \times 10^6 \times 2,2 \times 10^{-6} \\ &= 355,74 \text{ N}\end{aligned}$$

Fully extended

$$\begin{aligned}\varepsilon &= \frac{\Delta L}{OL} \\ &= \frac{0,2}{300} \\ &= 0,0006666\end{aligned}$$

$$\begin{aligned}E &= \frac{\sigma}{\varepsilon} \\ \sigma &= E \times \varepsilon \\ &= 245 \times 10^9 \times 0,000666666 \\ &= 163333333,3 \text{ Pa}\end{aligned}$$

$$\begin{aligned}\sigma &= \frac{F}{A} \\ F &= \sigma \times A \\ &= 163333333,3 \times 2,2 \times 10^{-6} \\ &= 359,33 \text{ N}\end{aligned}$$

(9)

6.3 Belt drives:

6.3.1 Rotation frequency of the driven pulley:

$$\begin{aligned}N_A \times D_A &= N_B \times D_B \\ N_B &= \frac{N_A \times D_A}{D_B} \\ &= \frac{1000 \times 0,25}{0,35} \\ &= 714,29 \text{ r/min}\end{aligned}$$

(3)

6.3.2 Power transmitted:

$$P = \frac{(T_1 - T_2)\pi DN}{60} \quad \checkmark$$

$$P = \frac{(200 - 90) \times \pi \times 0,25 \times 1000}{60} \quad \checkmark$$

$$P = 1439,90 \text{ Watts}$$

$$P = 1,44 \text{ kW} \quad \checkmark$$

(3)

6.3.3 Belt speed:

$$v = \frac{\pi DN}{60} \quad \checkmark$$

$$= \frac{\pi \times 0,25 \times 1000}{60} \quad \checkmark$$

$$v = 13,09 \text{ m.s}^{-1} \quad \checkmark$$

(3)

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

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

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

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

$$= 168 \text{ r/min} \quad \checkmark \quad (4)$$

6.4.2 Velocity ratio:

$$VR = \frac{N_A}{N_F} \quad \checkmark$$

$$VR = \frac{1440}{168}$$

$$VR = 8.57 : 1 \quad \checkmark$$

(2)

6.5 Differential wheel and axle:**6.5.1 Mechanical advantage:**

$$MA = \frac{W}{F} \quad \checkmark$$

$$MA = \frac{2400}{400}$$

$$MA = 6 \quad \checkmark \quad (2)$$

6.5.2 Velocity ratio:

$$VR = \frac{2D}{d_1 - d_2} \quad \checkmark$$

$$VR = \frac{2(210)}{160 - 140} \quad \checkmark$$

$$VR = \frac{420}{20}$$

$$VR = 21 : 1 \quad \checkmark \quad (3)$$

6.5.3 Mechanical efficiency:

$$\eta_{mech} = \frac{MA}{VR} \times 100\% \quad \checkmark$$

$$= \frac{6}{21} \times 100\%$$

$$= 28.57\% \quad \checkmark \quad (2)$$

6.6 Clutches:**6.6.1 Diameter of clutch plate:**

$$T = \mu W n R \quad \checkmark$$

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

$$R = \frac{336}{0,4 \times 3500 \times 2} \quad \checkmark$$

$$R = 0,12 \text{ m}$$

$$D = 2 \times 0,12 \quad \checkmark$$

$$D = 0,24 \text{ m} \quad \checkmark$$

$$= 240 \text{ mm} \quad \checkmark$$

(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)

[50]**TOTAL: 200**