Province of the
EASTERN CAPE
EDUCATION

NATIONAL SENIOR CERTIFICATE

GRADE 12

SEPTEMBER 2023

MECHANICAL TECHNOLOGY: FITTING AND MACHINING

MARKS: **200**

TIME: **3 hours**

This question paper consists of pages 23, including a 4-page formula sheet.

INSTRUCTIONS AND INFORMATION

1. Write your NAME on the ANSWER BOOK.
2. Read ALL the questions carefully.
3. Answer ALL the questions.
4. Number the answers correctly according to the numbering system used in this question paper.
5. Start EACH question on a NEW page.
6. Show ALL calculations and units. Round off final answers to TWO decimal places.
7. You may use a non-programmable scientific calculator and drawing instruments.
8. The value of gravitational force should be taken as 10 m/s^{-2}.
9. All dimensions are in millimeters, unless stated otherwise in the question.
10. A formula sheet is attached to the question paper.
11. Write neatly and legibly.
12. Use the criteria below to assist you in managing your time management.

QUESTION	CONTENT	MARKS	TIME in minutes
GENERIC			
1	Multiple-choice questions	6	6
2	Safety	10	10
3	Materials	14	14
SPECIFIC			
4	Multiple-choice questions	14	10
5	Terminology (Lathe and Milling)	18	20
6	Terminology (Indexing)	28	25
7	Tools and Equipment	13	10
8	Forces	33	33
9	Maintenance	18	12
10	Joining Methods	18	12
11	Systems and Control (Drive systems)	28	28
	TOTAL	**200**	**180**

QUESTION 1: MULTIPLE-CHOICE QUESTIONS (GENERIC) (COMPULSORY)

Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A–D) next to the question numbers (1.1 to 1.6) in the ANSWER BOOK, for example 1.7 A.

1.1 Which of the following options below describes the Labour Relation Act (LRA No. 66 of 1995) in South Africa that protect the people living with HIV/Aids?

A All employers must ensure that the workplace is safe, and that employees are not at risk of becoming infected with HIV at work.
B Elaborates how everybody has the right to fair labour practice.
C Employer cannot simply dismiss an employee who is infected with HIV.
D Promotes non-discrimination in the workplace. (1)

1.2 Examination procedure is one of the processes undertaken to determine the type of first aid measures to be administered to an employee who is involved in an accident in a workplace.
Identify the option below that best describe this process.

A Environmental observation
B Visible signs and symptoms
C Indicators to diagnosis
D All of the above (1)

1.3 The following safety precautions must be followed when handling gas bottles:

A All cylinders must be kept in horizontal position
B Use completely insulated electrode holders
C Never stack cylinders on top of each another
D The colour code of an oxygen cylinder is green (1)

1.4 Which ONE of the heat treatment process is used to remove internal strain and brittleness caused by hardening?

A Annealing
B Case-hardening
C Tempering
D Normalising (1)

1.5 Which of the following test is used to determine the carbon content of steel?

A Sound test
B Bend test
C Filing test
D All of the above (1)

1.6 Why is it important to clamp a small workpiece securely before drilling operation can be carried out?

A To reduce friction
B To prevent the drill bit from breaking as well as preventing accident
C To keep the cutting tool and workpiece cool
D All of the above (1)

[6]

QUESTION 2: SAFETY (GENERIC)

2.1 Give THREE safety precautions you must take into consideration before arc welding operation can commence. (3)

2.2 State TWO safety precautions that you must adhere to when you are operating a pedestal drilling machine to drill a hole on a solid square bar. (2)

2.3 What is the maximum thickness of a steel plate that a manual guillotine can accommodate if cutting with it? (1)

2.4 Give TWO advantages of each of the following workshop layouts:

2.4.1 Product layout of machines (2)

2.4.2 Process layout of machines (2)

[10]

QUESTION 3: MATERIALS (GENERIC)

3.1 State the TWO main purpose of case hardening mild steel. (2)

3.2 Why can high carbon steel not be used for case hardening? (1)

3.3 State THREE factors that determine the hardness of steel during heat treatments of metal. (3)

3.4 List THREE types of quenching mediums. (3)

3.5 What is the purpose of the colour coding marked on engineering materials? (1)

3.6 State the type of test that can be used to obtain the following properties of metals:

3.6.1 Hardness (1)

3.6.2 Carbon content (1)

3.6.3 Ductility (1)

3.7 List the machine that is used for a spark test. (1)

[14]

QUESTION 4: MULTIPLE-CHOICE QUESTIONS (SPECIFIC)

Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A–D) next to the question numbers (4.1 to 4.14) in the ANSWER BOOK, for example 4.15 A.

4.1 FIGURE 4.1 below shows a Brinell hardness tester to determine the hardness of a test piece.

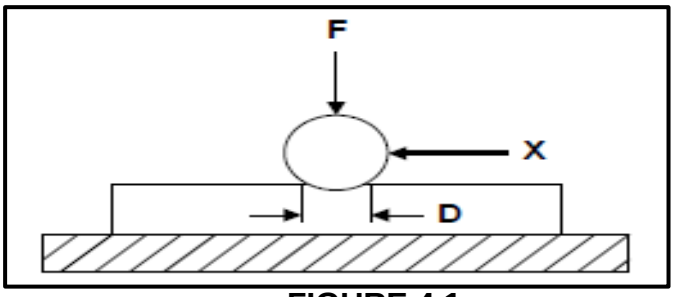

FIGURE 4.1

Identify part **X**.

A Bearing
B Diameter of indentation
C Motion
D Brinell Ball (1)

4.2 Identify the type of milling operation shown in FIGURE 4.2.

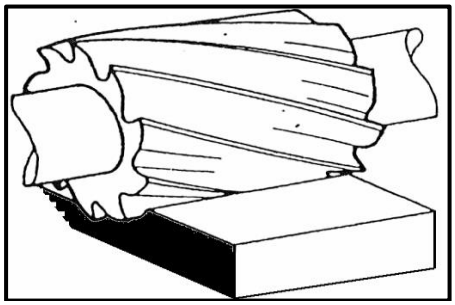

FIGURE 4.2

A Plain straight-tooth cutter
B Straight-tooth side-milling cutter
C Down-cutting
D Slab Cutting (1)

4.3 Which ONE of the following is a lathe component?

A Grinding wheel
B Feed shaft
C Pressure gauge
D Feed lever (1)

4.4 What does the abbreviation CNC stands for?

A Computer Numerical Control
B New Control Coding
C Company Numbers Control
D None of the above (1)

4.5 In a tensile test …

A a test piece is loaded to destruction.
B beams are used to determine the structure of a weld.
C a hammer is used to break the test material.
D liquid dye is used to detect weld flaws. (1)

4.6 The main reason for performing a hardness test on engineering materials is to determine the …

A elasticity of the material.
B resistance of the material against denting
C corrosion of the material.
D fluidity of the metal (1)

4.7 What does the point **E** denote in the stress/strain diagram in FIGURE 4.7?

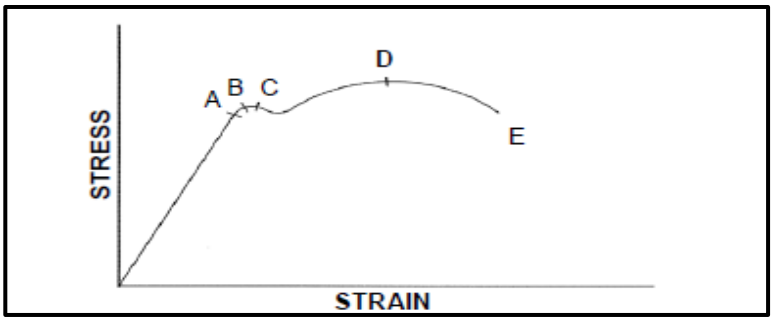

FIGURE 4.7

A Limit of proportionality
B Elasticity limit
C Maximum stress
D Break stress (1)

4.8 Unless stated otherwise, what clearance angle is normally used to calculate the leading and following tool angles of a square thread cutting tool?

A 90°
B 3°
C 60°
D 45° (1)

4.9 What will be the drill size for a M12 x 1,5 screw thread?

A 13,5 mm
B 1,5 mm
C 12 mm
D 10,5 mm (1)

4.10 A work piece must have 13 gear teeth machined on its circumference. What type of indexing would be performed on this gear-blank?

A Angular indexing
B Simple indexing
C Rapid indexing
D New indexing (1)

4.11 If the module of a spur gear is 2,5. What will the addendum be?

A 6 mm
B 3 mm
C 2,5 mm
D 9 mm (1)

4.12 Identify the drilling operation in FIGURE 4.12.

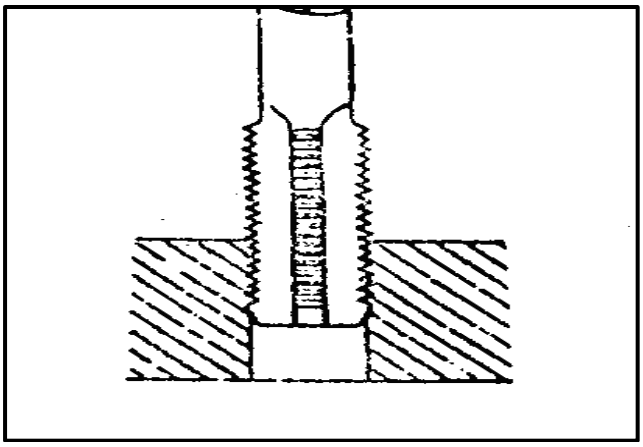

FIGURE 4.12

A Counter-sinking
B Tapping
C Turning
D Milling (1)

4.13 There are different types of machine processes in manufacturing. Which process would be used to enlarge holes to exact tolerances?

A Tapping
B Boring
C Slotting
D Reaming (1)

4.14 Identify the symbol, shown in FIGURE 4.14 below, which relates to a pneumatic system.

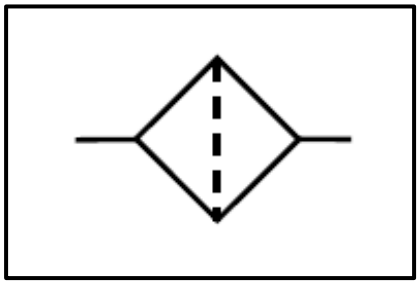

FIGURE 4.14

A Valve
B Filter
C Compressor
D Motor (1)

[14]

QUESTION 5: TERMINOLOGY (LATHE AND MILLING MACHICE) (SPECIFIC)

5.1 Calculate the cutting depth of a metric V-screw thread with a pitch of 2,5 mm using the compound slide method. (3)

5.2 Name TWO methods used to cut screw threads using a centre lathe. (2)

5.3 A circular shaft with an outside diameter of 100 mm must be machined with a two-start square thread of 12 mm pitch.

Calculate the following:

5.3.1 The lead of the thread (2)

5.3.2 The mean diameter of the thread (2)

5.3.3 The helix angle of the thread (2)

5.4 FIGURE 5.4 below shows the components around the cutting area of a milling machine. Answer the questions that follow.

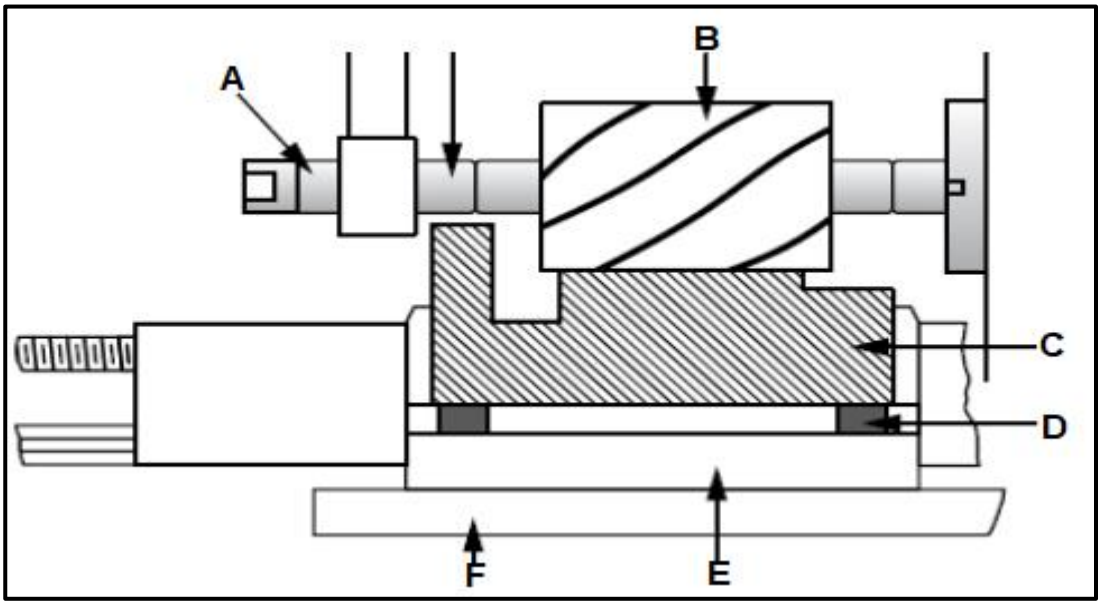

FIGURE 5.4

5.4.1 Identify the type of milling in FIGURE 5.4. (1)

5.4.2 Label parts **A**–**F**. (6)

[18]

QUESTION 6: TERMINOLOGY (INDEXING) (SPECIFIC)

6.1 State TWO advantages of gang milling. (2)

6.2 State ONE use of the following milling cutters.

6.2.1 T-slot milling cutter (1)

6.2.2 End mill cutter (1)

6.2.3 Slitting saw (1)

6.3 Define the term *module* as applied to gears. (1)

6.4 Explain, by using a neat labelled sketch, how up-cut milling must be done. (2)

6.5 Sizwe is a machinist and he is required to mill 163 teeth on a spur gear. The dividing head ratio is 40 : 1. (**HINT** : Use N = 160 divisions for the simple indexing.)

6.5.1 Calculate the indexing required. (3)

6.5.2 Calculate the change gears required for the dividing head. (4)

6.5.3 What is the meaning of the positive (+) sign and the negative (-) sign for the change of gears? (2)

6.6 FIGURE 6.6 show two precision rollers placed in an external dovetail. Use the given information to answer the question the follow.

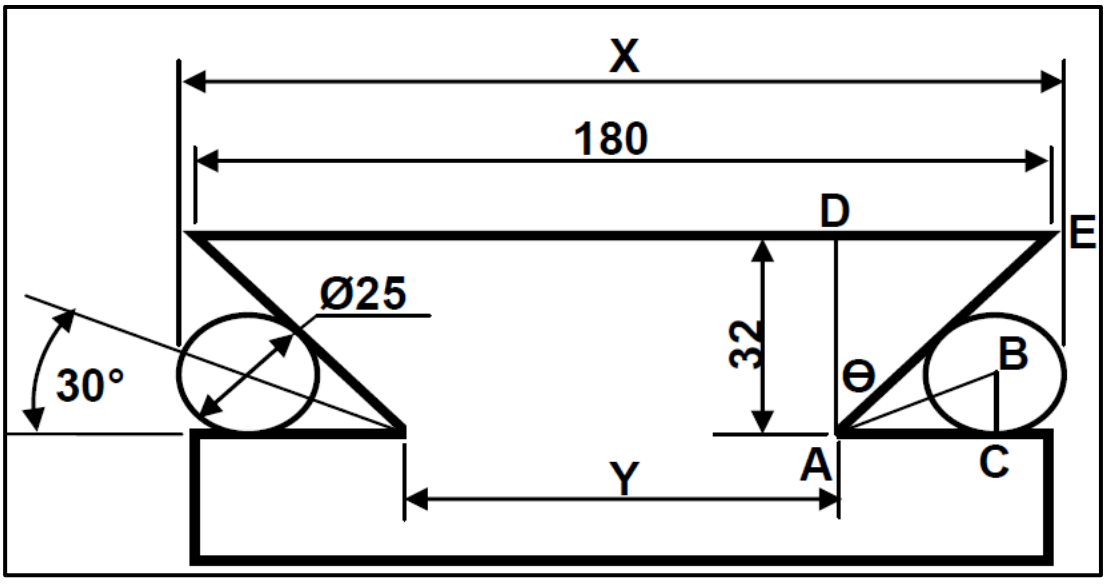

FIGURE 6.6

6.6.1 Calculate distance **Y** and **X**. (11)

[28]

QUESTION 7: TOOLS AND EQUIPMENT (SPECIFIC)

7.1 Explain the procedure/steps of setting up the Brinell hardness tester and performing the test. (5)

7.2 Name the THREE ways that hardness is measured. (3)

7.3 Study the diagram shown in FIGURE 7.3 below and answer the questions that follows.

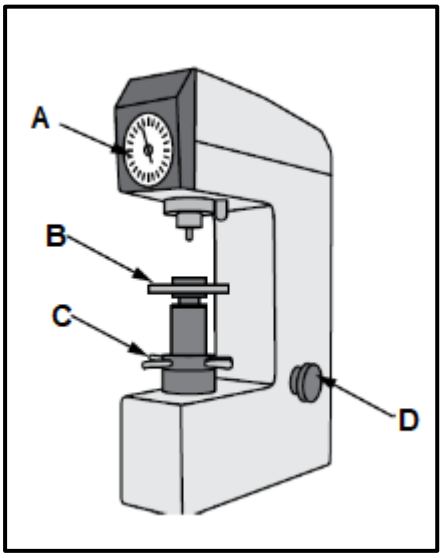

FIGURE 7.3

7.3.1 What is the name of the engineering apparatus in FIGURE 7.3? (1)

7.3.2 Label parts **A**–**D**. (4)

[13]

QUESTION 8: FORCES (SPECIFIC)

8.1 FIGURE 8.1 below shows a system of forces with four concurrent applied forces.

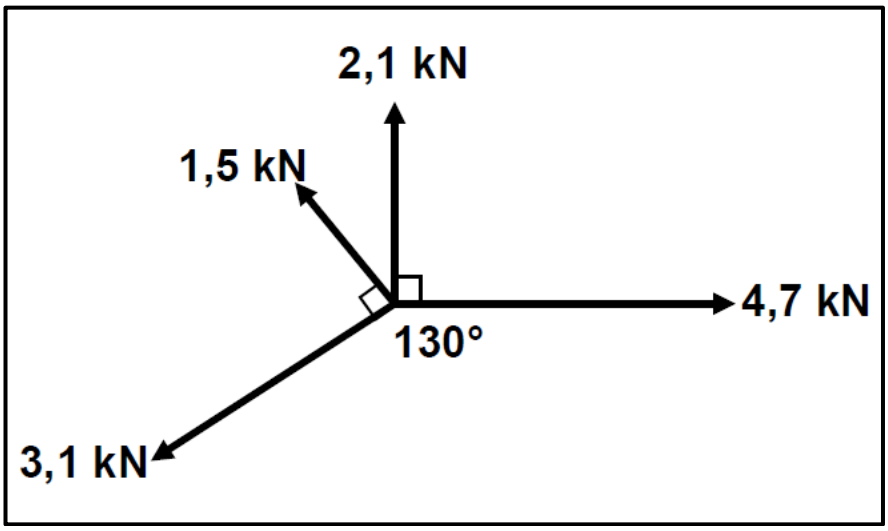

FIGURE 8.1

Calculate the:

8.1.1 Sum of the horizontal components in magnitude and direction (3)

8.1.2 Sum of the vertical components in magnitude and direction (3)

8.1.3 Magnitude and direction of the resultant force and its equilibrant (4)

8.2 FIGURE 8.2 below shows a beam with two vertical applied point loads of 1 400 N and another 1 600 N and also a 350 N/m uniformly distributed load for a total span of 6,7 m.

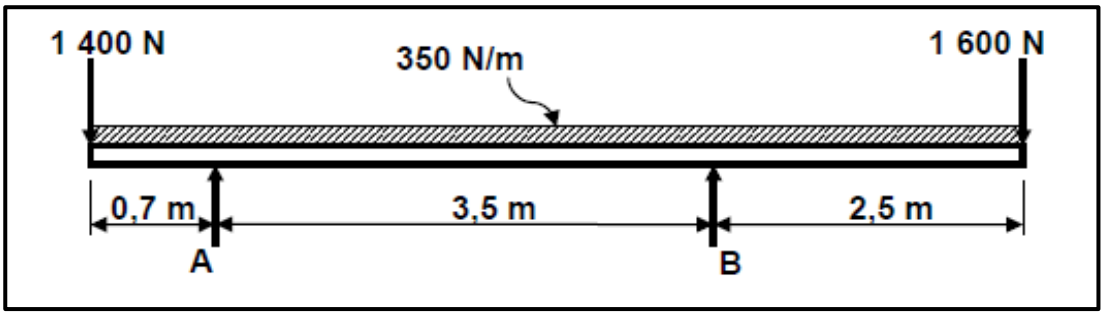

FIGURE 8.2

Calculate the magnitude of reactions R_A and R_B. (7)

8.3 Sakhi was instructed to use a mild steel pin to remove a bush from the yoke using a hydraulic press. The drawing of the pin, shown in FIGURE 8.3, indicates a load of 100 kN that causes a stress of 204 MPa.

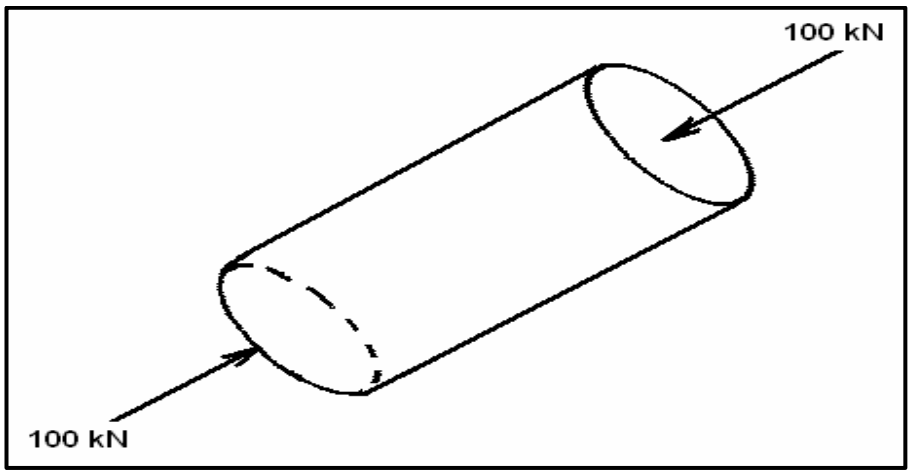

FIGURE 8.3

8.3.1 Calculate the diameter of the pin in millimetres. (6)

8.3.2 Calculate the strain induced in the pin if Young's modulus of elasticity is 210 GPa. (3)

8.3.3 Calculate the change in the length of the pin if the original length is 110 mm. (3)

8.3.4 What type of stress is induced in the pin? (1)

8.4 FIGURE 8.4 shows a stress-strain diagram.

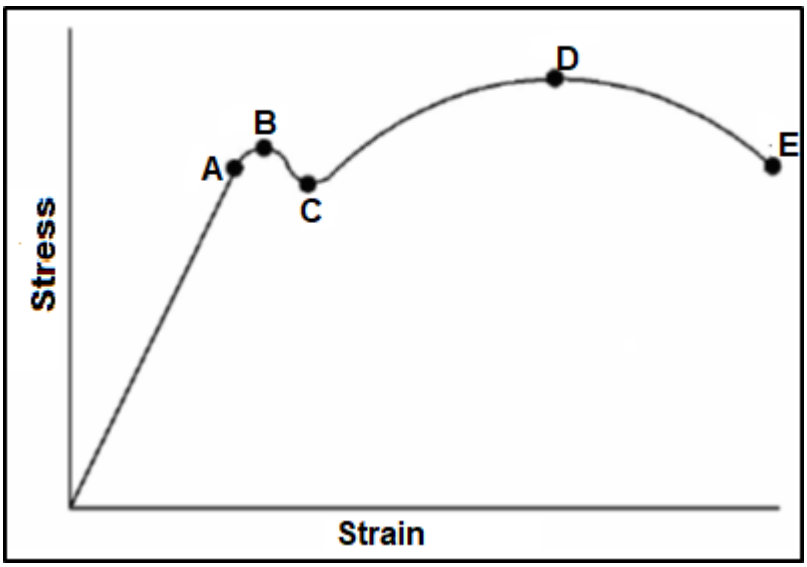

FIGURE 8.4

Label parts **A**, **B** and **C**. (3)

[33]

QUESTION 9: MAINTENANCE (SPECIFIC)

Solid nylon is widely used for engineering purposes. FIGURE 9.1 shows gear wheels made from solid nylon:

Nylon gear wheels

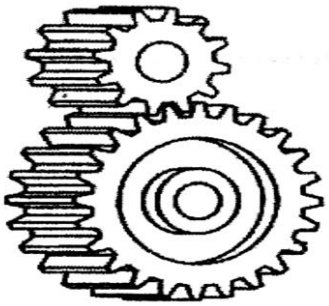

FIGURE 9.1

9.1 Name THREE properties which make nylon particularly suitable for the manufacturing of gears. (3)

9.2 Why is it essential to use a cutting fluid on a milling machine or centre lathe. State TWO reasons. (2)

9.3 What are the possible consequences for failure to do maintenance? (2)

9.4 Give TWO reasons for using carbon fibre in the manufacture of bicycle frames. (4)

9.5 In tabulated form compare TWO characteristics and TWO uses of PVC. (4)

9.6 Name THREE routine aspects when preventative maintenance is conducted. (3)

[18]

QUESTION 10: JOINING METHODS (SPECIFIC)

10.1 A spur gear has 48 teeth and a module of 3.
Determine, by means of calculations, the following:

10.1.1 The pitch-circle diameter (2)

10.1.2 The addendum (1)

10.1.3 The clearance (2)

10.1.4 The dedendum (2)

10.1.5 The outside diameter of the gear (2)

10.1.6 Circular pitch (1)

Study FIGURE 10.2 below and answer the questions that follow.

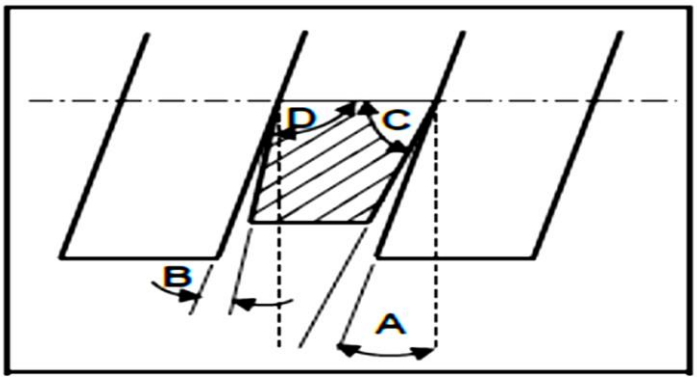

FIGURE10.2

10.2 Label parts **A**–**D**. (4)

10.3 Why would a multi-start thread be preferred mostly to a single start thread? (2)

10.4 What does the abbreviation ISO stands for? (2)

[18]

QUESTION 11: SYSTEMS AND CONTROL (SPECIFIC)

11.1 Define the term *pressure*. (1)

11.2 A hydraulic system is used to lift a lathe. The specifications of the system are presented diagrammatically in FIGURE 11.2.

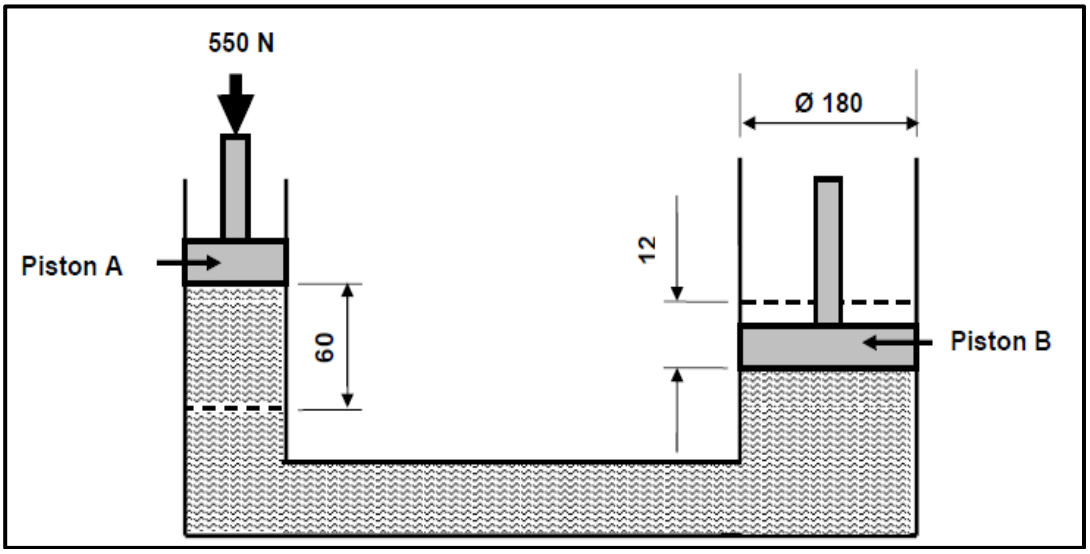

FIGURE 11.2

Calculate the following:

11.2.1 The diameter of piston **A** (**HINT**: VA = VB) (9)

11.2.2 The pressure exerted on piston **A** (2)

11.2.3 The force exerted on piston **B** (4)

11.3 Define what is meant by *hydraulics*. (1)

11.4 A power saw's motor has a pulley, 130 mm in diameter, that turns at 1 205 rpm. The speed at which the driven pulley drives the saw blades is 385 rpm.

Calculate the diameter of the driven pulley. (2)

11.5 Make neat, freehand sketches of the ISO symbols representing the following pneumatic components:

11.5.1 Cylinder (1)

11.5.2 Accumulator (1)

11.5.3 Electric motor (1)

11.6 FIGURE 11.6 below shows a gear-drive system. A driver gear on the shaft of an electric motor has 20 teeth and meshes with a gear on a counter shaft with 36 teeth. On this counter shaft is another driver gear with 18 teeth that meshes with a gear with 46 teeth on a second counter shaft. The second counter shaft has a driver gear with 42 teeth which drives a gear with 80 teeth on the output shaft.

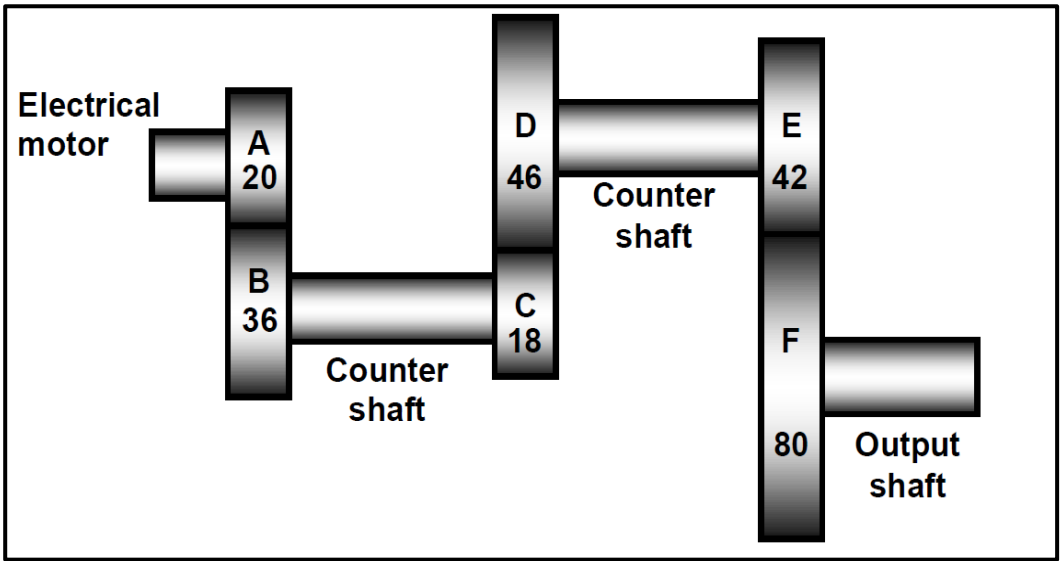

FIGURE 11.6

Calculate the:

11.6.1 Rotation frequency of the output shaft on the electric motor if the electric motor shaft rotates at 160 r/min (3)

11.6.2 Velocity ratio between the input and output shaft (2)

11.6.3 Direction in which the driven shaft will rotate if the driver gear rotates anti-clockwise (1)
[28]

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY (FITTING AND MACHINING)

1. BELT DRIVES

$$\text{Belt speed} = \frac{\pi D N}{60} \qquad \text{or} \qquad v = \frac{\pi D N}{60}$$

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

$$N_1 D_1 = N_2 D_2$$

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

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

$$\text{Power} = \frac{(T_1 - T_2)\pi D N}{60}$$

where T_1 = force in the tight side

T_2 = force in slack side

$T_1 - T_2$ = effective force (T_e)

2. STRESS AND STRAIN

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

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

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

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

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

$$\text{Safety factor} = \frac{\text{Break stress}}{\text{Safe working stress}}$$

3. HYDRAULICS

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

$$\text{Volume} = \text{Cross-sectional area} \times \text{stroke length}$$

4. KEYS AND KEYWAYS

$$\text{Width of key} = \frac{\text{Diameter of shaft}}{4}$$

$$\text{Thickness of key} = \frac{\text{Diameter of shaft}}{6}$$

$$\text{Length of key} = 1{,}5 \times \text{Diameter of shaft}$$

$$\text{Standard taper for taper key} : 1 \text{ in } 100 \text{ or } 1:100$$

5. GEAR DRIVES

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

$$N_1T_1 = N_2T_2$$

$$\text{Gear ratio} = \frac{\text{Product of the number of teeth on driven gears}}{\text{Product of the number of teeth on driving gears}}$$

$$\frac{N_{input}}{N_{output}} = \frac{\text{Product of the number of teeth on driven gears}}{\text{Product of the number of teeth on driving gears}}$$

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

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

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

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

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

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

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

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

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

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

$$\text{Add}_c = \text{m} + \frac{\text{Tm}}{2}\left(1 - \cos\frac{90°}{\text{T}}\right)$$

$$t_c = \text{Tm}\sin\frac{90°}{\text{T}} \quad \text{or} \quad t_c = \text{PCD}\sin\frac{90°}{\text{T}}$$

6. SCREW THREADS

Pitch diameter = Outside diameter – ½pitch

Pitch circumference = $\pi \times$ pitch diameter

Lead = pitch $\times$ number of starts

Height of screw thread = 0,866 $\times$ p where p = pitch of the screw thread

Depth of screw thread = 0,613 $\times$ p where p = pitch of the screw thread

$$\text{Number of turns} = \frac{\text{length}}{\text{lead}}$$

$$\text{Helix angle : } \tan\theta = \frac{\text{lead}}{\text{pitch diameter}}$$

$$\text{Leading tool angle} = 90° - (\text{helix} + \text{clearance angle})$$

$$\text{Following tool angle} = 90° + (\text{helix} - \text{clearance angle})$$

7. CINCINNATI DIVIDING HEAD TABLE FOR THE MILLING MACHINE

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

Change Gears										
24 x 2	28	32	40	44	48	56	64	72	86	100

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

$$\text{Angular Indexing} = \frac{n}{9°}$$

$$\text{Change gears: } \frac{Dr}{Dn} = (A - n) \times \frac{40}{A} \quad \text{or} \quad \frac{Dr}{Dn} = \frac{(A - n)}{A} \times \frac{40}{1}$$

(where A = chosen divisions) (where n = given divisions)