basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

MECHANICAL TECHNOLOGY: FITTING AND MACHINING

2023

MARKS: 200

TIME: 3 hours

This question paper consists of 19 pages and a 6-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. 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. Candidates may use non-programmable scientific calculators and drawing instruments.
8. The value of gravitational acceleration should be taken as 10 m/s^2.
9. All dimensions are in millimetres, unless stated otherwise in the question.
10. Write neatly and legibly.
11. A formula sheet is attached at the end of the question paper.
12. Use the criteria below to assist you in managing your time.

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 Machine)	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)

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

1.1 Which ONE of the following safety precautions is applicable to the bench grinder?

A Oil the surface of the machine.
B Remove all guards when grinding.
C Wear safety goggles when grinding.
D Ensure that the machine is on. (1)

1.2 What does the Occupational Health and Safety Act state regarding HIV/Aids awareness?

A All employers must make sure that the workplace is safe, and that employees are not at risk of contracting HIV.
B It does not contain common guidelines on how employers, employees and trade unions should respond to persons with HIV in the workplace.
C Employers may demote or promote an employee based on his/her HIV status.
D Employers can simply dismiss a person who has HIV. (1)

1.3 Which ONE of the following procedures is applicable when applying basic medical treatment?

A Examine the injured person.
B Remove the object from the wound.
C Use an oily substance or lotion on a burn.
D Phone the insurance company. (1)

1.4 Why is steel heated slowly to a certain temperature during heat treatments? To ensure that …

A high heat is obtained.
B the room temperature is correct.
C a uniform temperature is obtained.
D the safety process is correct. (1)

1.5 Which ONE of the following is an example of case-hardening?

A Frying pans
B Gears
C Wheel rims
D Chisels (1)

1.6 What does the term *quenching rate* during heat treatment mean?

A Cooling rate
B Heating rate
C Tempering rate
D Hardening rate (1)

[6]

QUESTION 2: SAFETY (GENERIC)

2.1 Which safety precaution must be adhered to after the work on any machine is completed? (1)

2.2 Give TWO reasons why the space between the tool rest and the grinding wheel on a bench grinder must not exceed 3 mm. (2)

2.3 Identify the workshop layouts shown in FIGURES 2.3.1 and 2.3.2 below.

2.3.1

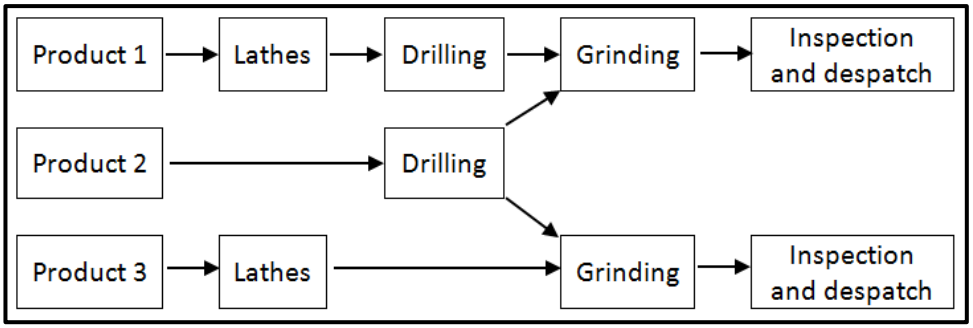


FIGURE 2.3.1 (1)

2.3.2

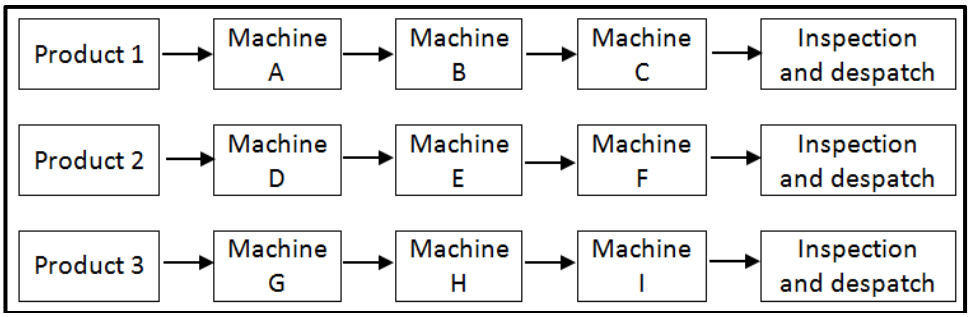


FIGURE 2.3.2 (1)

2.4 State ONE type of personal protective equipment that must be worn when working on a hydraulic press machine. (1)

2.5 State ONE function of the safety guard on a portable angle grinder. (1)

2.6 State ONE safety precaution, other than environmental safety, that must be observed when using a shearing machine/guillotine. (1)

2.7 State TWO safety precautions that must be adhered to when storing gas cylinders. (2)
[10]

QUESTION 3: MATERIALS (GENERIC)

3.1 Why is tempering of steel done after hardening? (2)

3.2 Give ONE reason for EACH of the following heat-treatment processes on steel:

3.2.1 Case hardening (2)

3.2.2 Annealing (2)

3.3 Explain how to conduct a spark test to identify the type of steel. (2)

3.4 Explain how you will conduct the following tests:

3.4.1 Filing test (2)

3.4.2 Bend test (2)

3.5 What sound do the following materials make when performing a sound test?

3.5.1 Low-carbon steel (1)

3.5.2 High-carbon steel (1)
[14]

QUESTION 4: MULTIPLE-CHOICE QUESTIONS (SPECIFIC)

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

4.1 What is the use of the centre lathe machine component in FIGURE 4.1 below? It supports …

FIGURE 4.1

A centre drilling.
B the work piece on the lathe.
C setting up a centre gauge.
D the dead centre. (1)

4.2 Which ONE of the following milling cutters can be used to cut a keyway a certain distance from the shaft end?

A Helical cutter
B Flute mill
C Shell mill
D Rotation mill (1)

4.3 The size of the centrifugal force depends on the ...

A mass of the rotating element.
B extent to which the mass is on centre.
C amount of braking power applied to the work piece.
D specific machine that is used. (1)

4.4 What does the abbreviation *CNC* stand for?

A Computer naming control
B Computer negative control
C Computer neutral control
D Computer numerical control (1)

4.5 Identify the precision tool that is used to measure the length of a cylinder:

A Outside micrometer
B Inside micrometer
C Depth micrometer
D Screw-thread micrometer (1)

4.6 Identify the type of hardness tester in FIGURE 4.6 below.

FIGURE 4.6

A Pascal hardness tester
B Tensile hardness tester
C Brinell hardness tester
D Moment hardness tester (1)

4.7 What is the definition of *equilibrant?*

A An equilibrant has the same magnitude as a resultant and acts in the same line of action, but in the opposite direction.
B An equilibrant has a different magnitude than a resultant and acts in a different line of action, but in the opposite direction.
C An equilibrant has the same magnitude as a resultant and acts in a different line of action, but in the same direction.
D An equilibrant has a different magnitude than a resultant and acts in the same line of action, but in the opposite direction. (1)

4.8 How is Young's modulus defined?

A It is the ratio between the hardness and strain on the surface of a metal, providing that the limit of elasticity is not exceeded.
B It is the ratio between the stress and strain in a metal, providing that the limit of elasticity is not exceeded.
C It is the ratio between the stress and load on a metal, providing that the limit of elasticity is exceeded.
D It is the ratio between the force and strain outside a metal, providing that the limit of elasticity is not exceeded. (1)

4.9 Which ONE of the following is an application of Vesconite?

A Artificial leather
B Bearings and bushes
C Window panels
D Roof panels (1)

4.10 How is polyvinyl chloride (PVC) joined?

A Arc welding
B Air blower
C Brazing
D Adhesive

4.11 Why are the crest and the root of metric V-screw threads rounded?

A For safety reasons
B To strengthen the screw thread
C Allow for smoother movement
D Prevent screw thread from stripping (1)

4.12 What is the included angle of a metric V-screw thread?

A 60°
B 30°
C 55°
D 29° (1)

4.13 How can *torque* be described? It is the ... effect of a force.

A turning
B compressive
C tensile
D pressing (1)

4.14 Identify the hydraulic symbol in FIGURE 4.14 below.

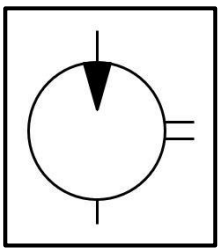


FIGURE 4.14

A Hydraulic pump
B Hydraulic filter
C Hydraulic motor
D Hydraulic reservoir (1)
[14]

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

5.1 FIGURE 5.1 below shows a screw-cutting dial found on a lathe machine. Label parts **A**–**C**.

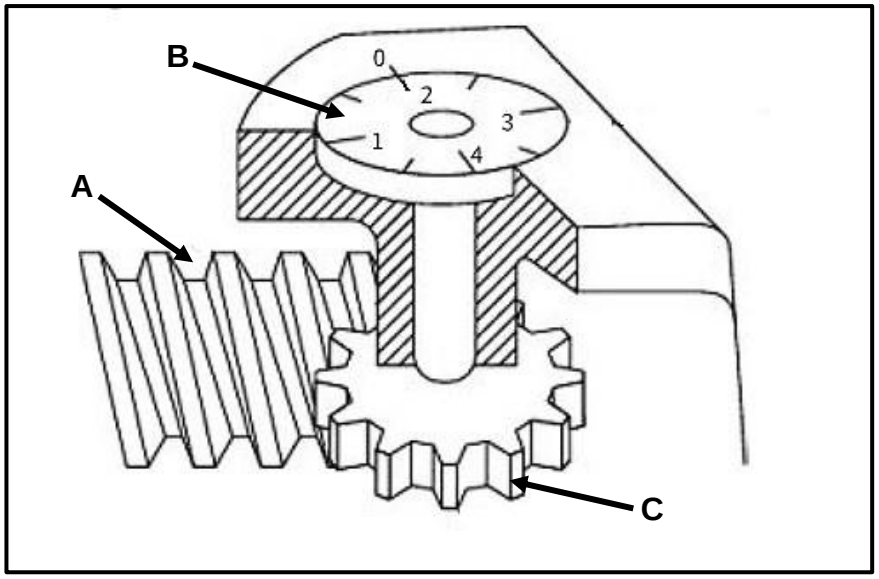


FIGURE 5.1 (3)

5.2 FIGURE 5.2 below shows a diagram of a taper with an included angle of 11°, which should be machined between two centres.

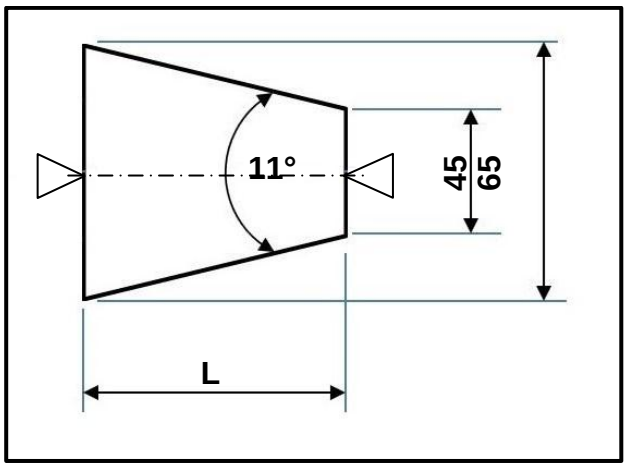


FIGURE 5.2

Calculate the following:

5.2.1 The length of the taper (4)

5.2.2 The set-over of the tailstock required to cut the taper (3)

5.3 A parallel key suitable for a 70 mm diameter shaft is needed in a forklift gearbox.

Calculate the following key dimensions:

5.3.1 Width (2)

5.3.2 Thickness (2)

5.3.3 Length (2)

5.4 Calculate the mean diameter for a two-start square thread that has an outside diameter of 38 mm and a pitch of 4 mm. (2)
[18]

QUESTION 6: TERMINOLOGY (INDEXING) (SPECIFIC)

6.1 Willy is a machinist and is tasked to cut a spur gear with a pitch-circle diameter of 120 mm and a module of 3.

Calculate the following:

6.1.1 Number of teeth (3)

6.1.2 Dedendum (2)

6.1.3 Outside diameter (2)

6.1.4 Circular pitch (2)

6.2 FIGURE 6.2 below shows an external dovetail that must be manufactured for a compound slide on a lathe machine.

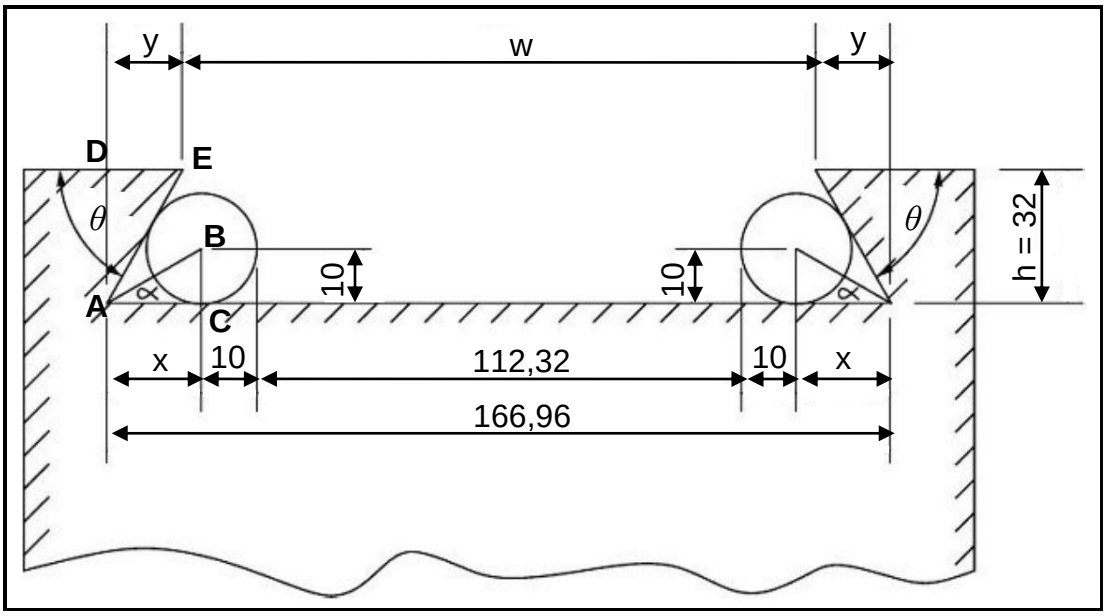


FIGURE 6.2

Calculate the following:

6.2.1 The angle θ (6)

6.2.2 Minimum width (w) distance of the dovetail (6)

6.3 Dinnesh is required to mill a spur gear with 137 teeth for an engineering client. The dividing head he is using has a ratio of 40 **:** 1.

HINT: Use A = 140 divisions for the simple indexing.

Calculate the following:

6.3.1 The indexing that is needed (3)

6.3.2 The change gears that are required (4)

[28]

QUESTION 7: TOOLS AND EQUIPMENT (SPECIFIC)

7.1 Name the different types of indenters used in the following hardness testers:

7.1.1 Rockwell hardness tester (1)

7.1.2 Brinell hardness tester (1)

7.2 FIGURE 7.2 below shows a Rockwell hardness tester. Label **A**–**D**.

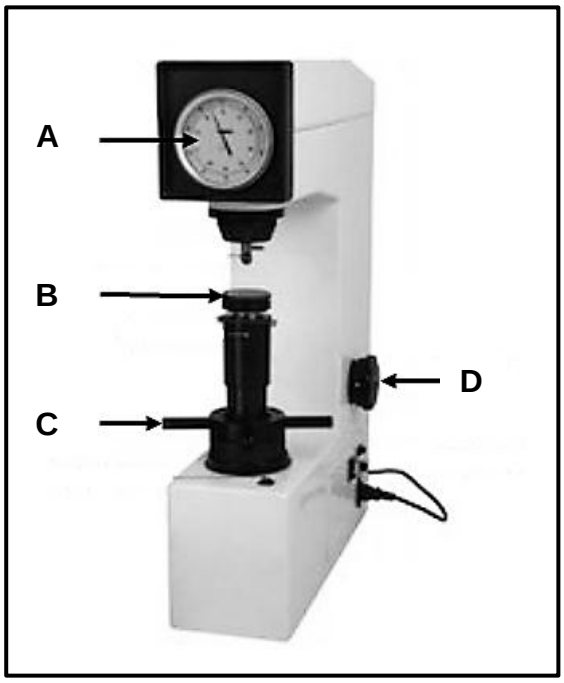


FIGURE 7.2 (4)

7.3 What is represented by the following in an M10 x 1,25 screw thread?

7.3.1 M (1)

7.3.2 10 (1)

7.3.3 1,25 (1)

7.4 FIGURE 7.4 below shows a screw thread micrometer. Label **A**–**D**.

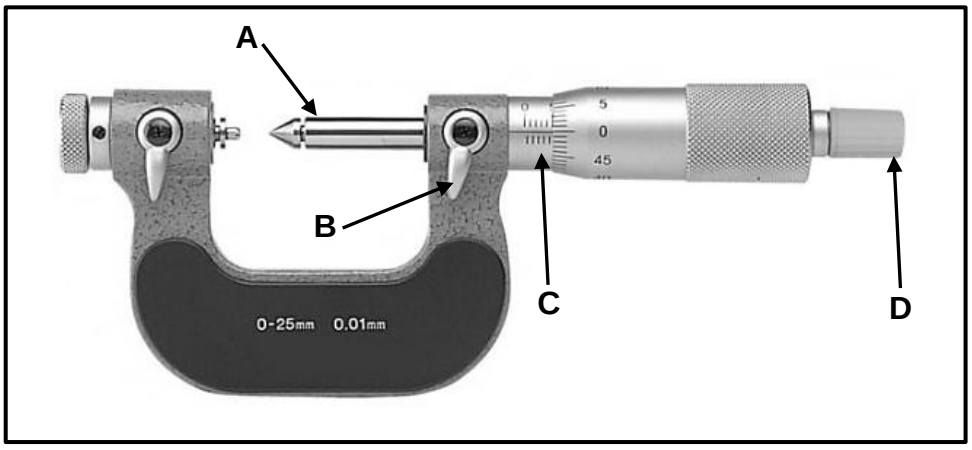


FIGURE 7.4 (4)

[13]

QUESTION 8: FORCES (SPECIFIC)

8.1 FIGURE 8.1 below shows a system of forces with three tensile forces and one compressive force acting onto the same point.

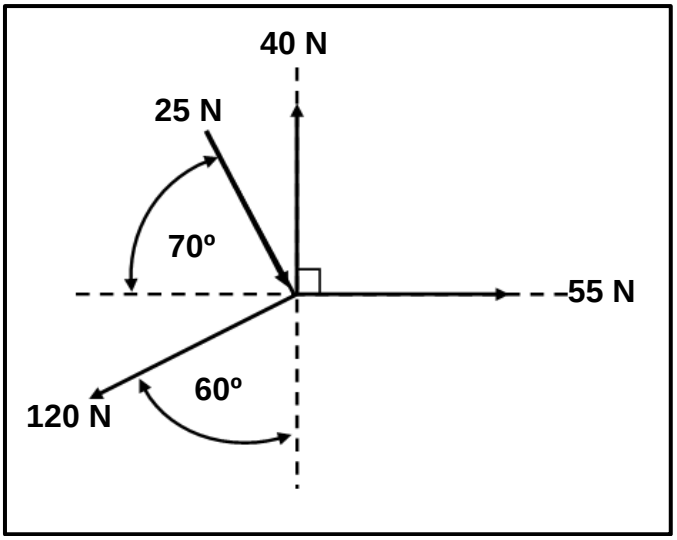


FIGURE 8.1

HINT: To assist you, draw and complete the force diagram shown in FIGURE 8.1. Show ALL the horizontal (HC) and vertical components (VC) before you do the calculations.

Calculate the following:

8.1.1 The sum of the horizontal components (4)

8.1.2 The sum of the vertical components (4)

8.1.3 The magnitude of the resultant (2)

8.1.4 The angle of the resultant (2)

8.1.5 The direction of the resultant (1)

8.2 FIGURE 8.2 below shows a uniform beam that is supported by two vertical supports, **A** and **B**. Two vertical point loads and one uniformly distributed load (**UDL**) are exerted onto the beam.

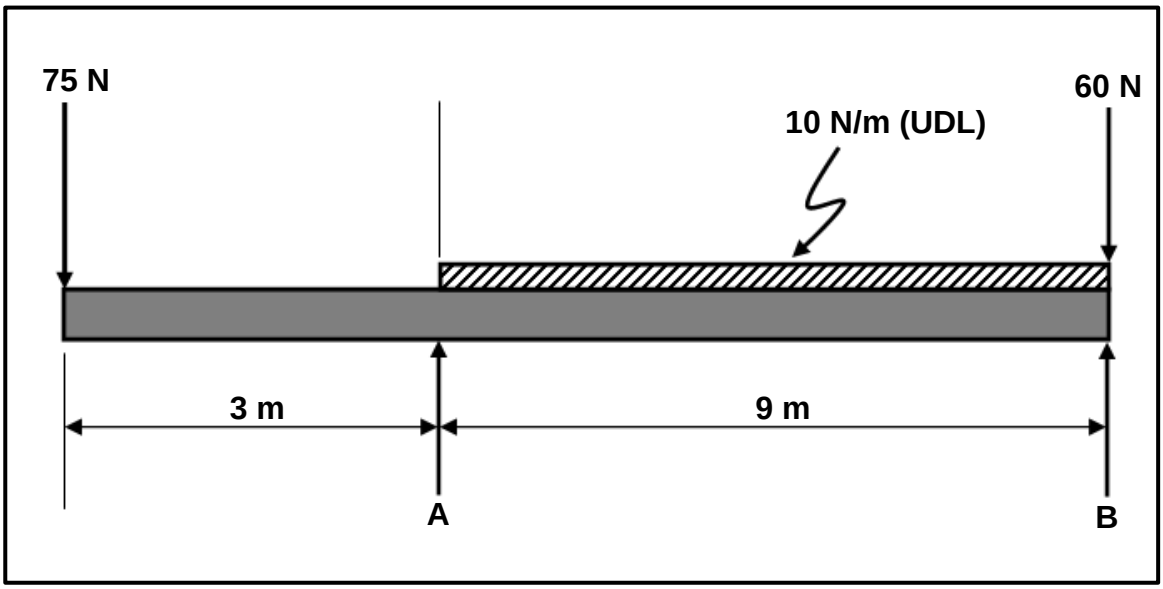


FIGURE 8.2

Calculate the following:

8.2.1 The point load representing the uniformly distributed load (**UDL**) (1)

8.2.2 The magnitude of the reaction force at **A** (4)

8.2.3 The magnitude of the reaction force at **B** (5)

8.3 A load of 45 kN causes a compressive stress of 9 MPa in a square brass bar. The change in length caused by the load on the square bar is 0,15 mm and Young's modulus for brass is 90 GPa.

Calculate the following:

8.3.1 The side length of the resistance surface in mm (4)

8.3.2 The strain (3)

8.3.3 The original length in mm (3)
[33]

QUESTION 9: MAINTENANCE (SPECIFIC)

9.1 Why is it necessary to conduct maintenance on an operating system? (2)

9.2 Name THREE different types of belts used in belt-drive systems. (3)

9.3 State THREE preventative maintenance procedures to ensure that chain drives work properly. (3)

9.4 State TWO properties of EACH of the following composites:

9.4.1 Nylon (2)

9.4.2 Fibreglass (2)

9.4.3 PVC (2)

9.5 State ONE use of EACH of the following composites:

9.5.1 Bakelite (1)

9.5.2 Carbon fibre (1)

9.5.3 Nylon (1)

9.6 Is Vesconite reliable when used as a bush in a drive system? (1)
[18]

QUESTION 10: JOINING METHODS (SPECIFIC)

10.1 Bianca needs to manufacture a two-start square threaded bar. The lead of the square thread is 46 mm and the crest diameter is 85 mm. The clearance angle on the cutting tool must be 3°.

Calculate the following:

10.1.1 Pitch diameter (5)

10.1.2 Helix angle (3)

10.1.3 Leading tool angle (2)

10.1.4 Following tool angle (2)

10.2 FIGURE 10.2 below shows a square screw thread. Label **A**–**D**.

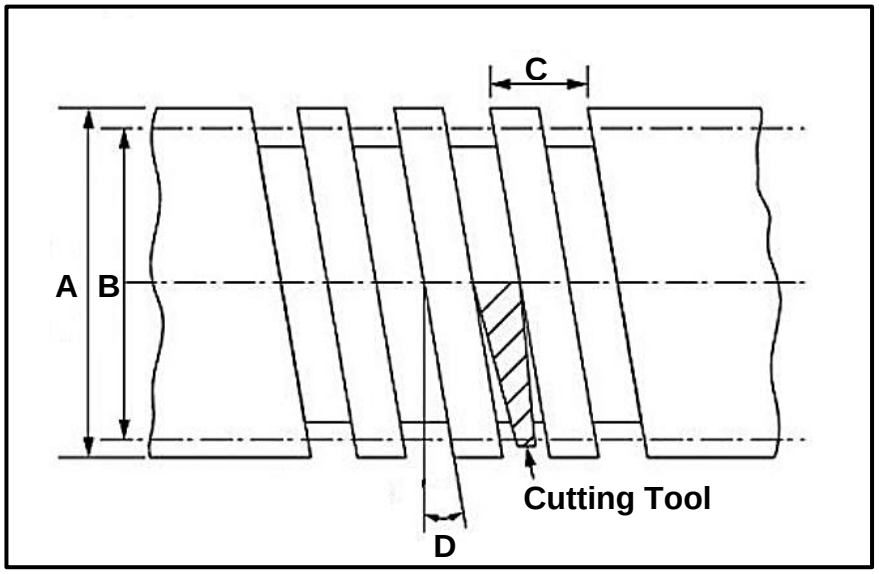


FIGURE 10.2 (4)

10.3 Explain how the sides of cutting tools must be ground in order to cut a square thread. (2)

[18]

QUESTION 11: SYSTEMS AND CONTROL (DRIVE SYSTEMS) (SPECIFIC)

11.1 FIGURE 11.1 below shows a hydraulic press. A force of 85 N acts on the plunger that moves 90 mm. The area of the plunger is 0,25 m² and the area of the ram is 2,1 m².

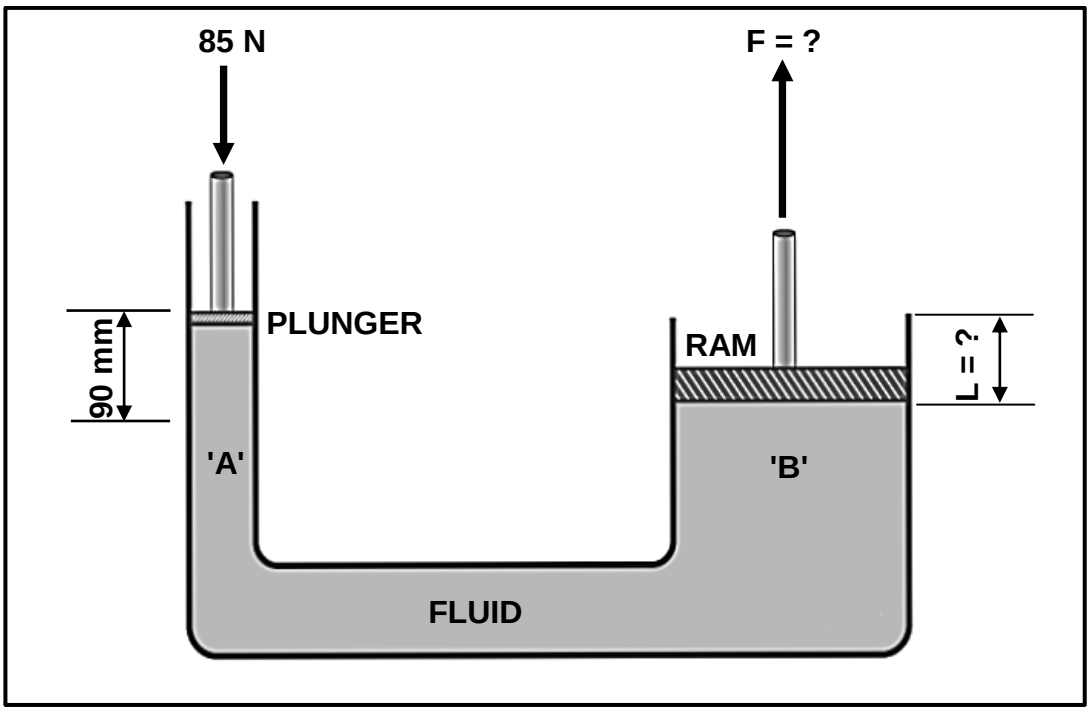


FIGURE 11.1

Calculate the following:

11.1.1 The fluid pressure in the hydraulic system in Pa (2)

11.1.2 The displacement of the ram in mm (L) (3)

11.1.3 The force exerted by the ram (3)

11.2 Name TWO types of hydraulic pumps. (2)

11.3 Identify the type of hydraulic valve in FIGURE 11.3 below.

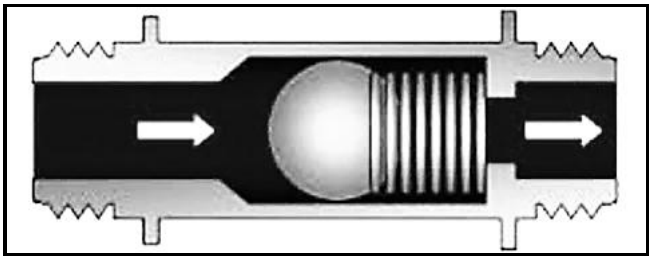


FIGURE 11.3 (1)

11.4 FIGURE 11.4 below shows a V-belt drive system of a compressor. The driver pulley of the belt drive system rotates at 2 700 r/min and has a diameter of 210 mm. The compressor shaft must rotate at 1 000 r/min.

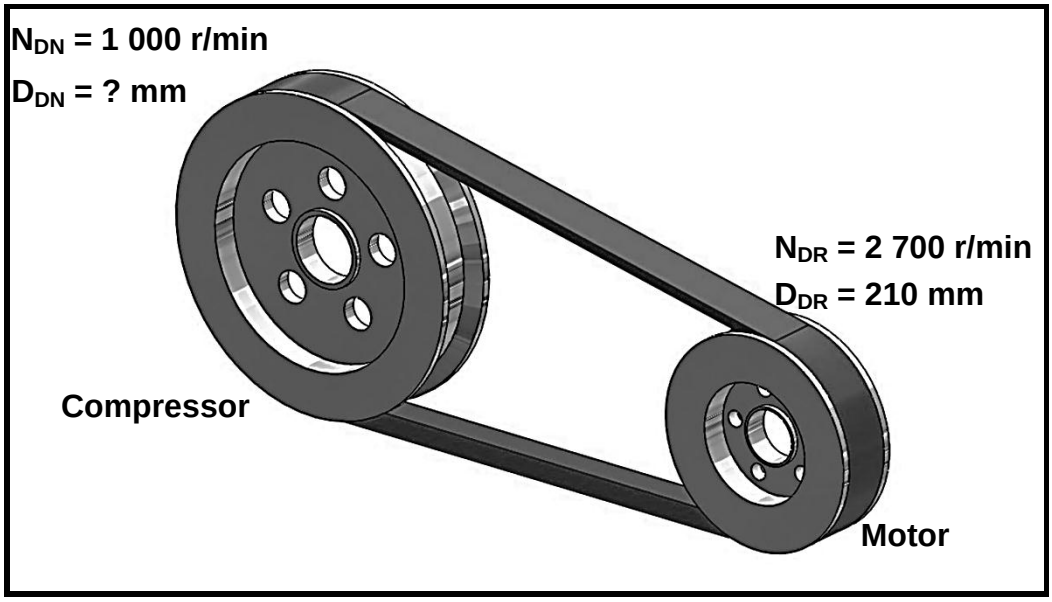


FIGURE 11.4

Calculate the following:

11.4.1 The diameter of the driven/compressor pulley in mm (3)

11.4.2 The power transmitted, in kW, if the effective force in the belt is 400 N (4)

11.5 FIGURE 11.5 below shows a gear drive system on the shaft of an electric motor.

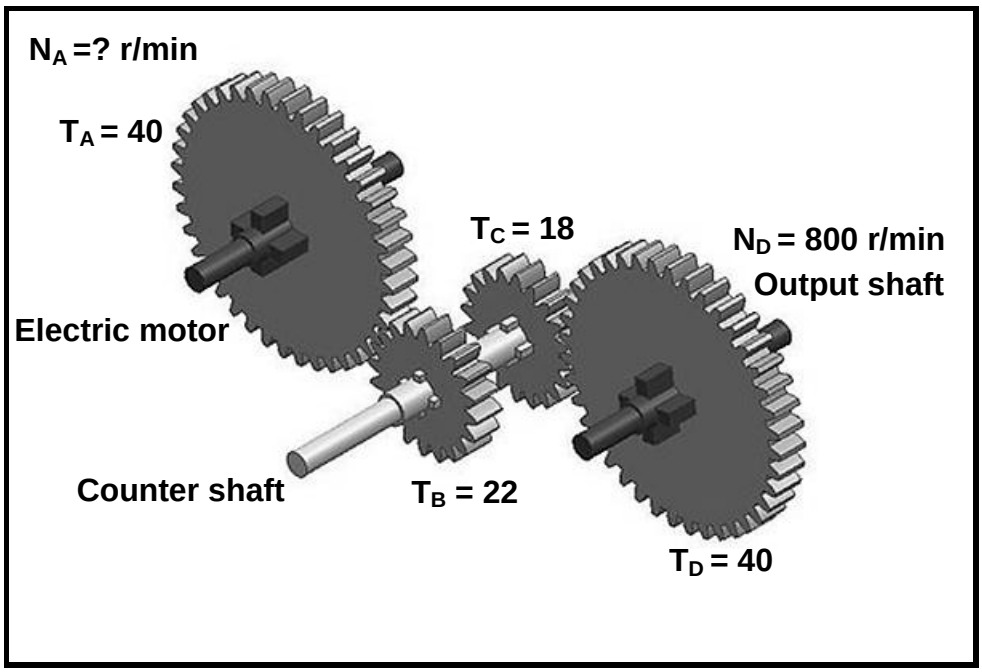


FIGURE 11.5

Calculate the following:

11.5.1 The rotation frequency of the electric motor in r/s if the output shaft rotates at 800 r/min (4)

11.5.2 The speed ratio (3)

11.6 An output shaft of a chain drive rotates at 5 r/s. Calculate the torque if the drive transmits 11 kW of power. (3)
[28]

TOTAL: 200

FORMULA SHEET FOR MECHANICAL TECHNOLOGY: FITTING AND MACHINING

1. BELT DRIVES

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

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

1.3 *Belt mass = Area × Length × Density* *(A = thickness × width)*

1.4 *Speed ratio =* $\frac{\textit{Diameter of driven pulley}}{\textit{Diameter of driver pulley}}$

1.5 *Belt length (flat) = [(D + d) × 1,57] + (2 × centre distance)*

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

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

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

Where:

T_1 = *force in the tight side*
T_2 = *force in the slack side*
$T_1 - T_2$ = *effective tensile force* (T_e)

1.9 *Ratio between tight side and slack side =* $\frac{T_1}{T_2}$

1.10 *Width =* $\frac{T_1}{\textit{Permissible tensile force}}$

1.11 $N_{DR} \times D_{DR} = N_{DN} \times D_{DN}$

2. STRESS AND STRAIN

2.1 $A_{shaft} = \frac{\pi d^2}{4}$

2.2 $A_{pipe} = \frac{\pi\left(D^2 - d^2\right)}{4}$

2.3 $Safety\ factor = \frac{Maximum\ stress/Break\ stress}{Safe\ working\ stress}$

2.4 $Stress = \frac{Force}{Area}$ *OR* $\sigma = \frac{F}{A}$

2.5 $Strain = \frac{Change\ in\ length}{Original\ length}$ *OR* $\varepsilon = \frac{\Delta L}{OL}$

2.6 $Young's\ modulus = \frac{Stress}{Strain}$ *OR* $E = \frac{\sigma}{\varepsilon}$

3. HYDRAULICS

3.1 $Pressure = \frac{Force}{Area}$ *OR* $P = \frac{F}{A}$

3.2 *Volume = Area × Stroke length (l or s)*

3.3 *Work done = Force × distance*

3.4 $P_A = P_B$

3.5 $\frac{F_A}{A_A} = \frac{F_B}{A_B}$

4. GEAR DRIVES

4.1 $Power\ (P) = \frac{2\pi NT}{60}$

4.2 $Gear\ Ratio = \frac{Product\ of\ teeth\ on\ driven\ gear}{Product\ of\ teeth\ on\ driver\ gear}$ *OR* $Speed\ ratio = \frac{N_{input}}{N_{output}}$

4.3 $\frac{N_{input}}{N_{output}} = \frac{\text{Product of teeth on driven gear}}{\text{Product of teeth on driver gear}}$

4.4 $N_A \times T_A = N_B \times T_B$

4.5 *Torque = Force × Radius*

4.6 *Torque transmitted = Gear ratio × Input torque*

4.7 $\text{Module} = \frac{\text{Pitch-circle diameter}}{\text{Number of teeth}}$ *OR* $m = \frac{PCD}{T}$

4.8 $\text{Pitch-circle diameter} = \frac{\text{Circular pitch} \times \text{Number of teeth}}{\pi}$

OR

$PCD = \frac{CP \times T}{\pi}$

4.9 *Outside diameter (OD) = PCD + 2(m)*

4.10 *Addendum = Module* *OR* $a = m$

4.11 *Dedendum (b) = 1,157 × m* *OR* *Dedendum (b) = 1,25 × m*

4.12 *Cutting depth (h) = 2,157 × m* *OR* *Cutting depth (h) = 2,25 × m*

4.13 *Clearance (c) = 0,157 × m* *OR* *Clearance (c) = 0,25 × m*

4.14 *Circular pitch (CP) = m × π*

4.15 *Working depth (WD) = 2 × m* *OR* *Working depth (WD) = 2 × a*

5. PULLEYS

5.1 $N_{DR} \times D_{DR} = N_{DN} \times D_{DN}$

5.2 $\text{Power (P)} = \frac{2\pi NT}{60}$

5.3 $\text{Velocity ratio} = \frac{\text{Diameter of driven pulley}}{\text{Diameter of driver pulley}}$

6. KEYWAYS

6.1 *Width (W) =* $\frac{D}{4}$

6.2 *Thickness (T) =* $\frac{D}{6}$

6.3 *Length (L) = 1,5 × D*

Where:

D = Diameter of shaft

6.4 *Standard taper for taper key: 1 in 100 or 1 : 100*

7. CINCINNATI DIVIDING HEAD TABLE FOR 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											
Gears	*24 × 2*	*28*	*32*	*40*	*44*	*48*	*56*	*64*	*72*	*86*	*100*

7.1 *Indexing =* $\frac{40}{n}$ *(n = number of divisions)*

7.2 $\frac{Dr}{Dn} = \frac{A-n}{A} \times \frac{40}{1}$ *OR* $\frac{Dr}{Dn} = (A-n) \times \frac{40}{A}$

Where:

A = chosen number of divisions
n = real number of divisions

8. DOVETAILS

Where:

R = Radius of precision roller

y = Distance from top edge of dovetail in relation to bottom corner of dovetail

x = Distance from middle of precision roller to bottom corner of dovetail

θ = Dovetail included angle (normally 60°)

h = Height of dovetail

w = Minimum width of dovetail

W = Maximum width of dovetail

m = Distance between rollers

M = Distance over rollers

9. TAPERS

9.1 $\tan\frac{\theta}{2} = \frac{D - d}{2 \times l}$ *(l = Taper length)*

9.2 *Tailstock setover* $= \frac{L(D - d)}{2 \times l}$ *(L = Distance between centres)*

10. SCREW THREADS

10.1 *Mean diameter = Outside diameter – (½ × Pitch)* *OR* $D_m = OD - \frac{P}{2}$

10.2 *Effective diameter (D_{eff}) = Pitch diameter (D_p) = Mean diameter (D_m)*

10.3 *Lead = Pitch × Number of starts*

10.4 *Height of screw thread = 0,866 × Pitch (P)*

10.5 *Depth of screw thread = 0,613 × Pitch (P)*

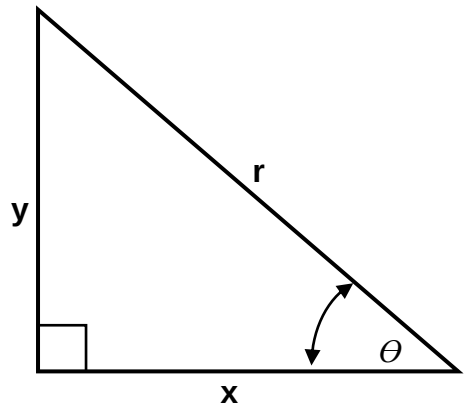
10.6 *Helix angle: Tan* $\theta = \frac{Lead}{\pi \times D_m}$

10.7 *Leading angle = 90° – (Helix angle + Clearance angle)*

10.8 *Following angle = 90° + (Helix angle – Clearance angle)*

10.9 $D_P = D_N - (0{,}866 \times P)$

11. PYTHAGORAS' THEOREM AND TRIGONOMETRY



11.1 $Sin\ \theta = \frac{y}{r}$

11.2 $Cos\ \theta = \frac{x}{r}$

11.3 $Tan\ \theta = \frac{y}{x}$

11.4 $r^2 = x^2 + y^2$