basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

SENIOR CERTIFICATE EXAMINATIONS/ NATIONAL SENIOR CERTIFICATE EXAMINATIONS

MECHANICAL TECHNOLOGY: FITTING AND MACHINING

MAY/JUNE 2024

MARKS: 200

TIME: 3 hours

This question paper consists of 16 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 9,81 m/s^2 or 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 of the following refers to the Occupational Health and Safety Act (OHSA), 1993 (Act 85 of 1993) when responding to HIV/Aids in the workplace?

A It is the duty of employers to make sure that rubber gloves and surgical masks are available in all first-aid kits.
B This Act emphasises the working relationship between employees and employers.
C It explains the minimum standards that employees and employers can expect from one another in the workplace.
D The purpose of this Act is to create an environment of equality in the workplace. (1)

1.2 Which ONE of the following statements refers to *process layout*?

A The machines are arranged in the sequence in which operations are carried out.
B The different stages of production are carried out in different departments.
C The process is ideal for mass production.
D The time period of the manufacturing cycle is shorter. (1)

1.3 What is the function of the pressure gauge in a hydraulic press?

A To be able to observe the working pressure
B To support the jig on the platform
C To stabilise the frame on the support pins
D To hold the work piece in place (1)

1.4 Why is steel soaked at a specific temperature during heat treatment?

A To ensure that the outside of the steel becomes hotter than the inside
B To ensure that the inside of the steel becomes hotter than the outside
C To prevent a loss in the carbon content of the steel
D To ensure uniform penetration of heat (1)

1.5 Which ONE of the following quenching media is used for the normalising of steel?

A Oil
B Liquid salts
C Still air
D Brine (1)

1.6 The metal that is best suited for case-hardening:

A Brass
B Aluminium
C Mild steel
D Cast iron (1)

[6]

QUESTION 2: SAFETY (GENERIC)

2.1 State TWO situations when basic first aid should be given to help and support a person at the workplace. (2)

2.2 FIGURE 2.2 below shows a safety sign at a bench grinder. Explain what is meant by the signs labelled **A–D**.

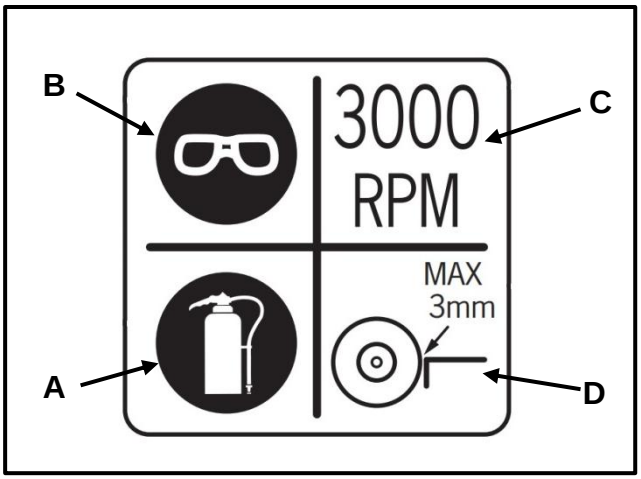


FIGURE 2.2 (4)

2.3 State TWO safety precautions that should be adhered to when using a drill press.

NOTE: All PPE and environmental factors have been taken care of. (2)

2.4 State TWO safety precautions that an operator should adhere to while working on a surface grinder.

NOTE: All PPE and environmental factors have been taken care of. (2)

[10]

QUESTION 3: MATERIALS (GENERIC)

3.1 State whether steel is heated either *below* or *above* the critical temperature during the following heat-treatment processes:

3.1.1 Hardening (1)

3.1.2 Tempering (1)

3.1.3 Normalising (1)

3.2 The hardness of a sampled work piece is tested using a drill press. Which TWO aspects should be observed on the cutting chips? (2)

3.3 Besides the machinability test, name THREE other tests used to determine the different types of steels. (3)

3.4 Name TWO quenching methods used for case-hardening. (2)

3.5 How can the temperature of a work piece be determined during the heat-treatment process? (1)

3.6 State the THREE basic steps that are involved in all heat-treatment processes according to a time-temperature cycle. (3)
[14]

QUESTION 4: MULTIPLE-CHOICE (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 With which part of the centre lathe does the gear of the thread dial indicator engage during screw cutting?

A Tool post
B Lead screw
C Compound slide
D Tailstock (1)

4.2 Which ONE of the following is a safety precaution that must be adhered to before working on a lathe?

A Stand far away when the machine is working
B Make sure all guards are removed
C Remove all jewellery
D Insert new tools on the tool post while the machine is running (1)

4.3 What is meant by the term *absolute programming* when referring to a CNC-milling machine?

A It is the sequence of programming for selecting cutting tools in the machine.
B It uses dimensions with all points of reference being taken from a common point.
C It is the location of each operation in co-ordinate format of the program.
D It is to take the distance of one point to the next on the work piece. (1)

4.4 When does tool change automatically occur during the operation of a CNC milling machine?

A When the machine is being started
B When the work piece in the chuck has been changed
C When the tool change has been programmed
D When tools are replaced with new ones by the operator (1)

4.5 What type of material is used to make the indenter of the Brinell hardness tester?

A Graphite
B Aluminium
C Brass
D Carbide (1)

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

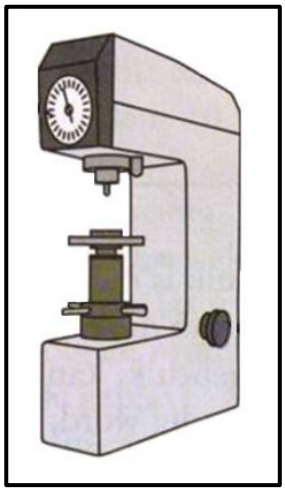


FIGURE 4.6

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

4.7 Which ONE of the following describes the term *tensile stress*? It is an …

A external tensile force acting on matter.
B external force present when an internal tensile load is applied.
C internal force present when an external tensile load is applied.
D internal tensile acting force. (1)

4.8 Describe the type of stress in a rivet that is caused by the forces shown in FIGURE 4.8 below.

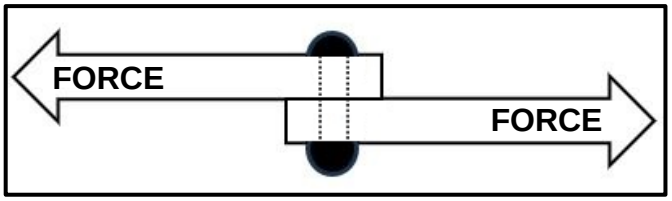


FIGURE 4.8

A Shearing stress
B Form stress
C Compressive stress
D Tensile stress (1)

4.9 What is Vesconite used for?

A Drill bits
B Bearings and bushes
C Vehicle panel parts
D Window frames (1)

4.10 From which raw materials is polyvinyl chloride (PVC) manufactured?

A Salt and oil
B Sand and oil
C Iron ore and oil
D Silicon and oil (1)

4.11 The crest diameter of an ISO metric square thread is also known as ...

A pitch diameter.
B major diameter.
C core diameter.
D effective diameter. (1)

4.12 Which ONE of the following screw threads is mainly used to obtain more locking power?

A Single-start screw thread
B Double-start screw thread
C Triple-start screw thread
D Quadruple-start screw thread (1)

4.13 What is the SI unit for work done (energy)?

A Joule
B Newton
C Pascal
D Metre (1)

4.14 Identify the hydraulic symbol in FIGURE 4.14 below.

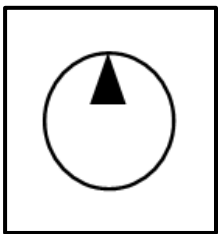


FIGURE 4.14

A Fixed-flow control valve
B Flow control valve
C Filter
D Pump (1)
[14]

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

5.1 Discuss TWO advantages of cutting tapers on a centre lathe using the tailstock set-over method. (2)

5.2 FIGURE 5.2 below shows an internal taper in a bush with an included angle of 7°. The taper should be machined on a centre lathe using the compound slide method. Answer the questions that follow.

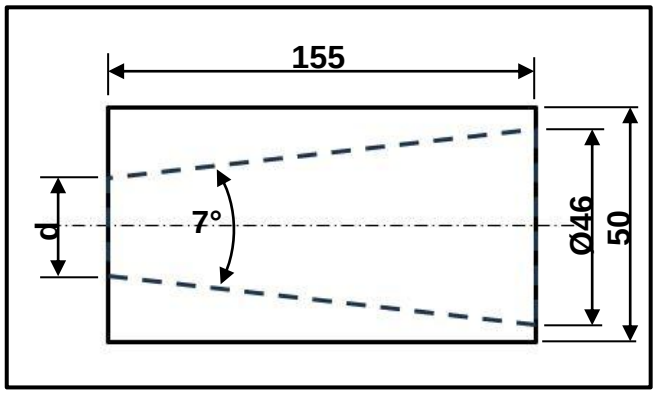


FIGURE 5.2

5.2.1 What type of tool must be used to cut the internal taper? (1)

5.2.2 Calculate the small diameter (**d**) of the taper. (6)

5.3 A shaft with a diameter of 82 mm must be used in a gearbox. Calculate the following dimensions suitable for a parallel key:

5.3.1 Width (2)

5.3.2 Thickness (2)

5.3.3 Length (2)

5.4 State THREE advantages of gang milling. (3)
[18]

QUESTION 6: TERMINOLOGY (INDEXING) (SPECIFIC)

6.1 A machinist is tasked to cut a spur gear with a pitch-circle diameter of 156 mm and a module of 3 on a milling machine.

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 centre lathe.

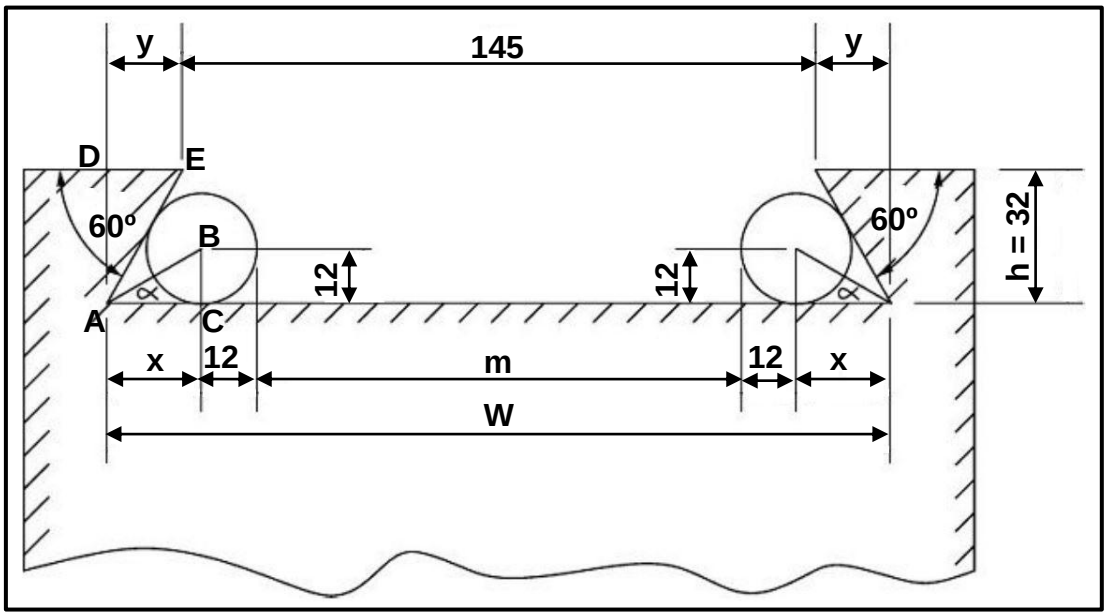


FIGURE 6.2

Calculate the following:

6.2.1 Maximum width (W) distance of the dovetail (6)

6.2.2 Distance (m) between the precision rollers (6)

6.3 Mason is required to mill a spur gear with 163 teeth for a client. The dividing head has a ratio of 40 **:** 1.

HINT: Use A = 160 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 Define the term *hardness*. (2)

7.2 Name TWO types of hardness testers. (2)

7.3 What is the purpose of a microscope when testing the hardness of materials? (2)

7.4 FIGURE 7.4 below shows a tester used to test the mechanical properties of material. Answer the questions that follow.

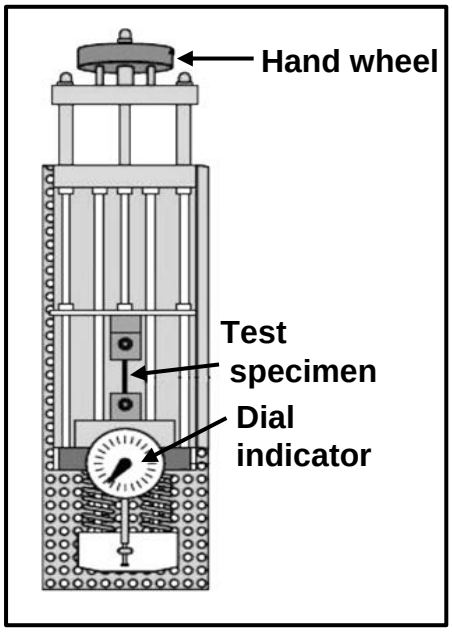


FIGURE 7.4

7.4.1 Identify the tester. (1)

7.4.2 Which component of the tester above is used to apply force to the test specimen? (1)

7.5 Which hardness tester uses a hardened steel ball or a diamond cone indenter? (1)

7.6 What is tested with a moment tester? (2)

7.7 Determine the reading of the depth micrometer in FIGURE 7.7 below.

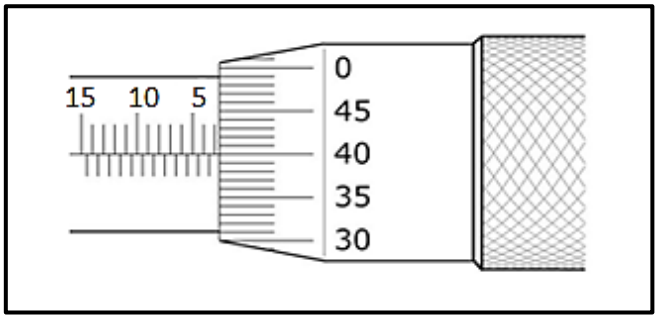


FIGURE 7.7 (2)

[13]

QUESTION 8: FORCES (SPECIFIC)

8.1 FIGURE 8.1 indicates a system of forces with four tensile forces acting onto the same point.

HINT: Draw and complete the diagram in FIGURE 8.1 below. Show ALL the horizontal and vertical components before you do the calculations.

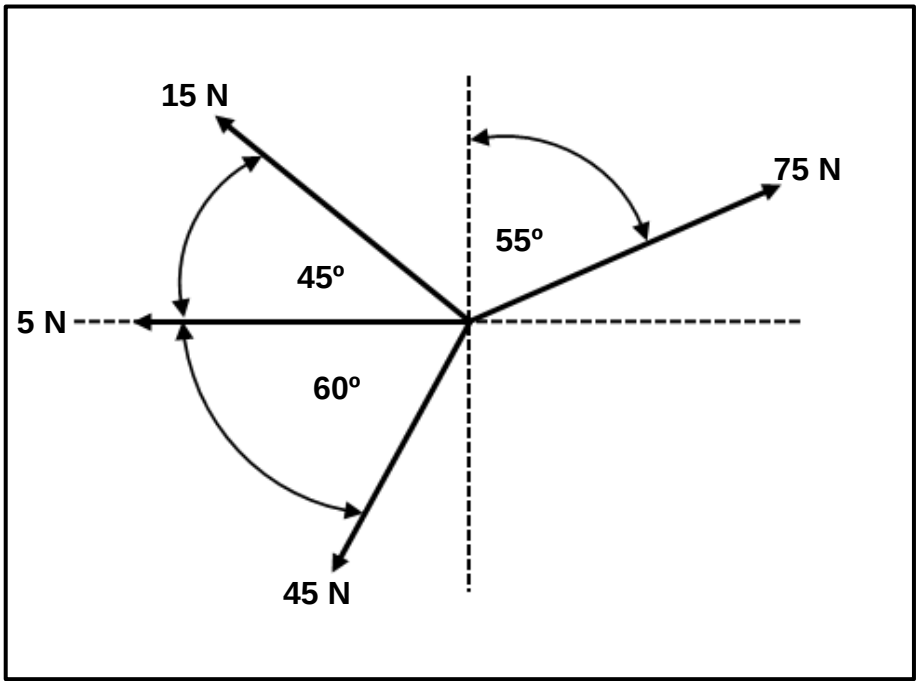


FIGURE 8.1

Calculate the following:

8.1.1 Sum of the horizontal components (5)

8.1.2 Sum of the vertical components (4)

8.1.3 Magnitude of the resultant (2)

8.1.4 Angle and direction of the resultant (3)

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.

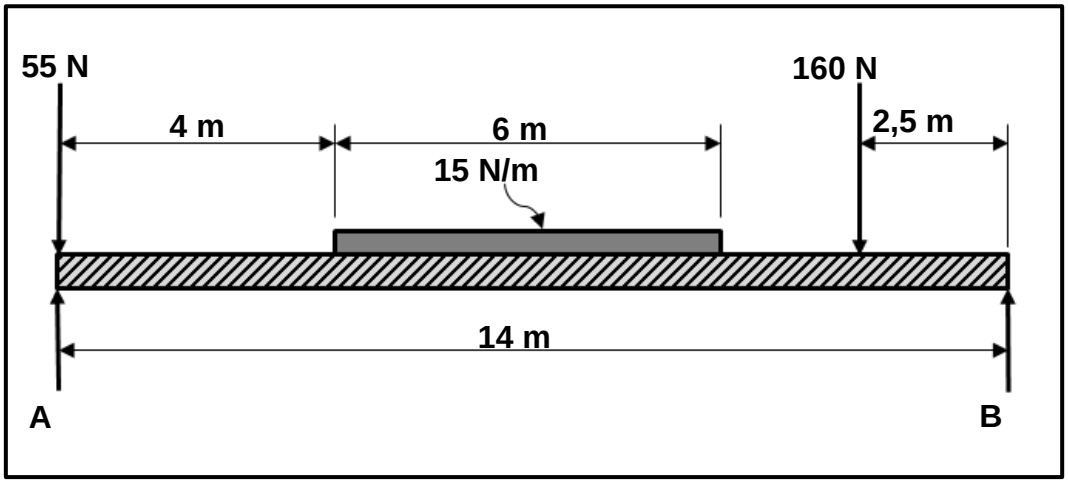


FIGURE 8.2

Calculate the following:

8.2.1 Point load of the uniformly distributed load (UDL) (2)

8.2.2 Reactions in supports **A** and **B** (7)

8.3 A load of 18 kN causes a tensile stress of 56,5 MPa in a brass round bar. The original length of the bar is 275 mm and Young's modulus of elasticity for brass is 90 GPa.

Calculate the following:

8.3.1 The diameter of the brass bar in millimetres if the area is $3{,}19 \times 10^{-4}$ m^2 (4)

8.3.2 The change in length, in millimetres, caused by the load (6)
[33]

QUESTION 9: MAINTENANCE (SPECIFIC)

9.1 State FOUR preventative maintenance procedures for belt drives. (4)

9.2 State TWO drives that you will use if you have to design a drive to transmit high amounts of power. (2)

9.3 State TWO methods to bond polyvinyl chloride (PVC). (2)

9.4 State TWO uses of EACH of the following materials in a mechanical workshop:

9.4.1 Nylon (2)

9.4.2 Fibreglass (2)

9.4.3 Bakelite (2)

9.5 State whether EACH of the following materials is a thermo-hardened/thermosetting or a thermoplastic composite:

9.5.1 Polyvinyl chloride (PVC) (1)

9.5.2 Fibreglass (1)

9.5.3 Carbon fibre (1)

9.5.4 Vesconite (1)

[18]

QUESTION 10: JOINING METHODS (SPECIFIC)

10.1 State THREE examples where multiple-start screw threads are generally used. (3)

10.2 State THREE advantages of multiple-start screw threads. (3)

10.3 A two-start square threaded bar must be manufactured where the lead of the square thread is 46 mm and the crest diameter is 80 mm. The clearance angle must be 3°.

Calculate the following:

10.3.1 Pitch (2)

10.3.2 Pitch diameter (2)

10.3.3 Helix angle of the thread (4)

10.3.4 Leading tool angle (2)

10.3.5 Following tool angle (2)

[18]

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

11.1 FIGURE 11.1 below shows a hydraulic system.

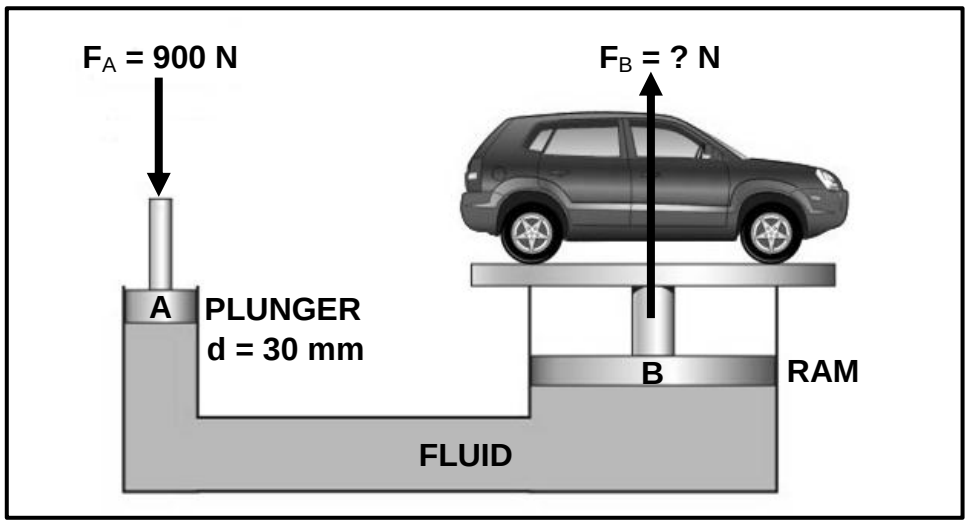


FIGURE 11.1

Calculate the following:

11.1.1 The pressure in the system in MPa (5)

11.1.2 The mass in kilogram (kg) that can be lifted by the system if the area of the ram is 31,42 x 10^{-3} m^2 (4)

11.2 State the function of EACH of the following hydraulic components:

11.2.1 Motor (1)

11.2.2 One-way valve (1)

11.2.3 Reservoir (1)

11.3 FIGURE 11.3 below shows a flat belt drive system. The tensile force of the belt in the tight side is 1 900 N and the force in the slack side is 450 N.

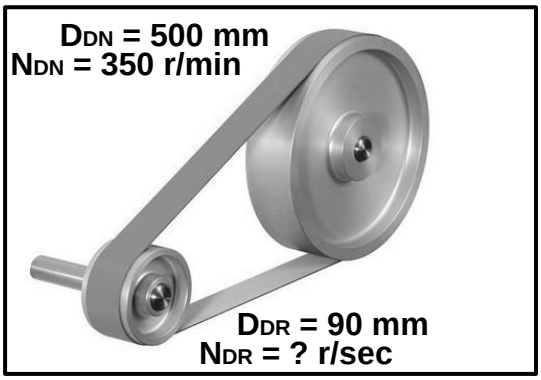


FIGURE 11.3

Calculate the following:

11.3.1 The rotational frequency in r/sec of the driver pulley (3)

11.3.2 The power transmitted by the belt (4)

11.4 One of the main disadvantages of belt drives is its liability to slip. Name TWO measures used to avoid slipping. (2)

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

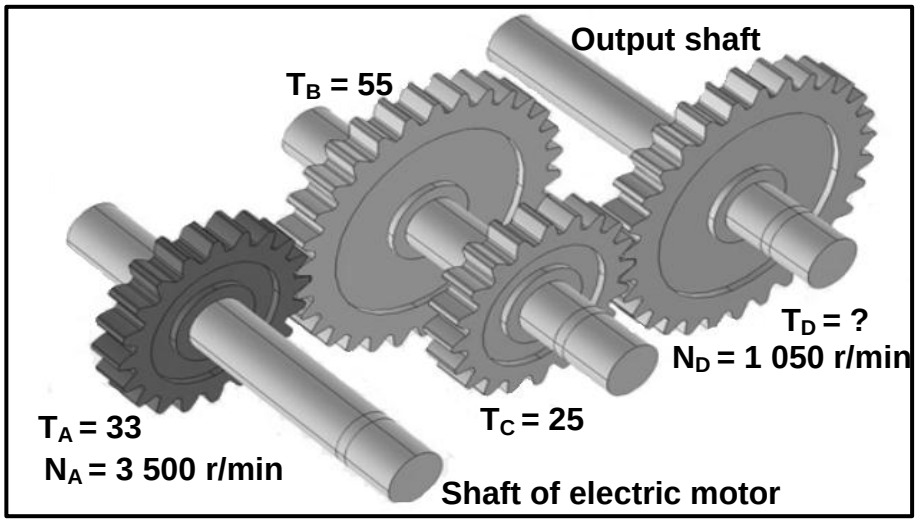


FIGURE 11.5

Calculate the following:

11.5.1 The number of teeth on output gear **D** (4)

11.5.2 The torque on the output gear if the power transmitted is 737,4 kW (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* = $\frac{Diameter\ of\ driven\ pulley}{Diameter\ of\ driver\ pulley}$

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* = $\frac{T_1}{Permissible\ tensile\ force}$

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

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

4.5 $Torque = Force \times Radius$

4.6 $Torque\ transmitted = Gear\ ratio \times Input\ torque$

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

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

OR

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

4.9 $Outside\ diameter\ (OD) = PCD + 2(m)$

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

4.11 $Dedendum\ (b) = 1{,}157 \times m$ *OR* $Dedendum\ (b) = 1{,}25 \times m$

4.12 $Cutting\ depth\ (h) = 2{,}157 \times m$ *OR* $Cutting\ depth\ (h) = 2{,}25 \times m$

4.13 $Clearance\ (c) = 0{,}157 \times m$ *OR* $Clearance\ (c) = 0{,}25 \times m$

4.14 $Circular\ pitch\ (CP) = m \times \pi$

4.15 $Working\ depth\ (WD) = 2 \times m$ *OR* $Working\ depth\ (WD) = 2 \times a$

5. PULLEYS

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

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

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

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 x 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)*

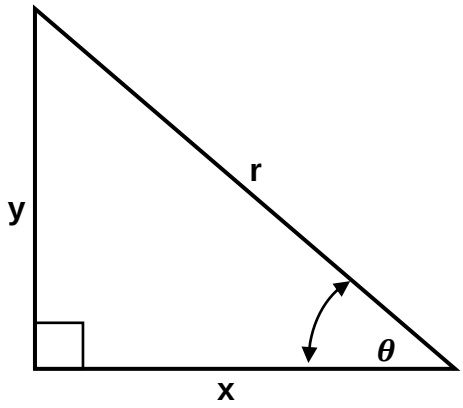
10.6 *Helix angle: Tan* $\theta = \frac{Lead}{\pi \times D_m}$

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