BOARD OF STUDIES
NEW SOUTH WALES

1998 HSC

EXAMINATION REPORT

Engineering Science 2/3 Unit

Including:
- Marking criteria
- Sample responses
- Examiners' comments

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Board of Studies NSW
GPO Box 5300
Sydney NSW 2001
Australia

Tel: (02) 9367 8111

Fax: (02) 9367 8484

Internet: http://www.boardofstudies.nsw.edu.au

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Preface

The Enhanced Examination Report replaces the standard HSC examination report in selected subjects. It contains additional information, and in this report, includes marking criteria, candidate responses and detailed examiners' comments on aspects of questions asked in both the 2 and 3 Unit Examination Papers. Some solutions by candidates have been included to highlight points made by markers.

In 1998 approximately 1,383 candidates sat for the 2/3 Unit Common Paper, and 199 students sat for the 3 Unit Paper. This year as in previous years, the top 2 Unit result was achieved by a 3 Unit candidate.

PROCEDURES FOR HSC MARKING 1998

THE MARKING PROCESS

The complete 2 Unit paper was split into Sections I and II. Section I was marked in Newcastle and Section II and the 3 Unit paper were marked in Sydney. The markers are carefully selected from experienced teachers and university lecturers and are appointed to mark a specific question which relates to their area of expertise.

The Examination Committee presents a set of answers for the Supervisor of Marking for consideration. A meeting, between the Examination Committee, the Supervisors of Marking and the Senior Markers is held to discuss and confirm the best answer for each question. The HSC markers further develop the range of accepted responses and marking scales for each question by pilot marking a range of scripts. The marking scales are examined and confirmed by the Supervisor of Marking before final marking commences.

During the marking, questionable responses are analysed and discussed with the Senior Marker, and an appropriate mark is awarded. The Supervisor of Marking overviews the marking process to ensure the scales are correctly used and that all students receive equity. Marking scales may include checklists and concept lists. As the marking proceeds, each marker keeps a tally of the marks awarded for the question they are marking. These marker tallies are statistically examined each day and are used as a check, along with systematic checkmarking by the Senior Marker, to ensure the accuracy of the marking procedure. During the marking control scripts are circulated for marking to ensure the reliability of the marking to the agreed marking scales. The marking is monitored to ensure that the first candidate marked receives the same consideration as the last.

A correct solution for each question is contained in this report. It is impossible to provide a full range of answers for publication for any one question, as there are often many methods and combinations possible in providing a solution. For example, candidates may commence with an analytical solution, use a part graphical solution, and revert to an analytical solution to calculate an answer. Similarly, candidates may use auxiliary views, rebattment, or independent constructions to find true lengths of lines, all of which may provide the same solution. The marking scales are designed to provide flexibility, and to allow for alternative methods at arriving at a solution and to fairly discriminate between the Engineering Science candidates.

A report is also prepared with marker comments and marking scales, for the information of the Examination Committee. This is used by the Examination Committee to review and refine setting of questions for the following years' examination. This enhanced report includes comments on the responses given by candidates made by Markers and Senior Markers and includes some part solutions given by candidates.

ALLOCATION OF MARKS

Some general principles on the allocation of marks within each question, is given below. They are points used in discussion and may be helpful in understanding how the marking scales are determined.

General:

- A N/A (Not attempted) is awarded when there is no evidence (blank response) to any part of the question.
- A zero is awarded to an answer, which is not blank, and to which no marks are awarded. It is included in the statistics.
- Emphasis is placed on working when marks are allocated.
- Where possible marks are allocated on the basis of degree of difficulty, and to reward each correct response.
- Marks are attributed to correct and accurate use of terminology.
- Conflicting information given in an answer is penalised ie +1 -1 = 0
- Restating or rewording the information given in the question is not acceptable.
- Marks are awarded rather than subtracted (positive response).
- Candidates are expected to write sentences for questions that ask for definitions, descriptions or explanations. If the question asks the candidate to state, or list then keywords are rewarded and a sentence is not expected.

Materials:

- When assessing diagrams, micro or macrostructures or graphs, they should reasonably reflect accepted practice of drawing such diagrams.
- When labels are applied to drawings they should be concise and specifically related to the diagram.
- Emphasis is to be placed on concepts/methods used .

Engineering Mechanics:

- Concept errors are not awarded marks, however, errors made in one section of the paper, and carried forward to the next section, are not penalised twice. In Mechanics, providing the error carried forward does not make the answer any easier, then no penalty is applied.
- No marks are awarded for restating a formula given on the formulae sheet.
- Calculation errors are only applied once in a solution to a question.
- Correct answers where no working is found are given full marks.
- Incorrect answer, no working, no marks.
- g = 10 m/s2 or g = 9.8 m/s2 is acceptable for gravity.
- Graphical solutions are acceptable in deriving solutions in mechanics.
- The use of measurements (angles and distances) from scaled drawings in questions is acceptable.
- When more than one solution is shown, and one is crossed out, the solution not crossed out is marked.
- When one solution is given and crossed out, the solution is marked.
- When two solutions are given, one right and one wrong and an answer is not placed in the space provided then marks awarded are at the discretion of the Senior Marker and Supervisor of Marking.
- It is acceptable for candidates to change the units on the paper, providing it conforms to SI standards. For example, 1200N changed to 1.2 kN. Otherwise, units as indicated in the answer statement must be given.

Graphics:

- Projections in graphics questions should not be erased, as these often display the method used in solving the problem. Marks are awarded for correct methods/concepts.
- Sectioning, linework and general standards related to Graphics are to conform to AS1100.
- Unless requested in the question, labels for plotted points are not required.
- Evidence of calculating true lengths in triangulation problems should be expected. Analytical calculations are acceptable, but not encouraged.
- In intersection problems, end points and change-over points should be clearly shown. Joining points in correct order completes the 'visibility' of the view. Visibility is an important component of all orthogonal drawings.
- Evidence of recognised technical drawing construction methods is required for all solutions to Graphics problems.

Additional comments are included in the comments with each question.

Advice to Candidates:

You will notice on reading the enhanced report, that examiners and markers recommend that more time be spent in examining a range of components of the Prescribed Topics. It is obvious from responses that many students have not examined in any depth, all aspects of these topics. For example, when studying the bicycle, as well as analysing the overall machine, examine component parts, eg spokes, handlebars, rims, brake components, centre bracket components etc.

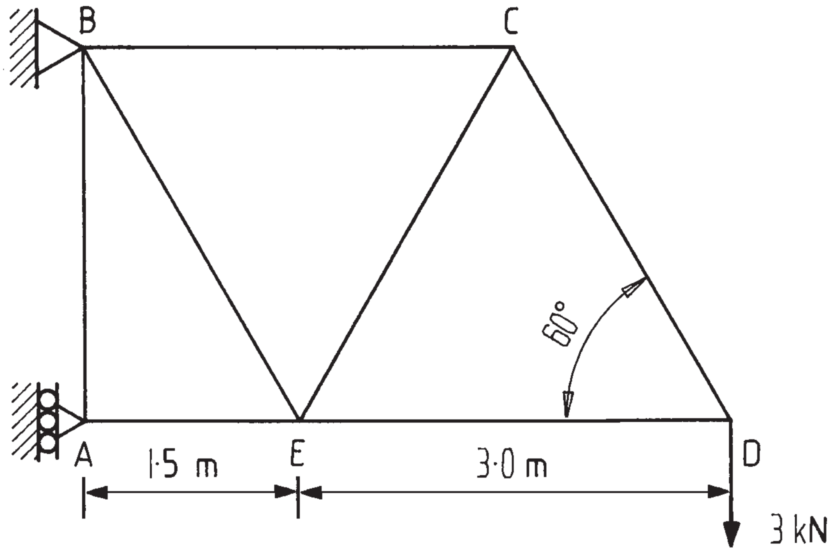
Looking back over a number of past papers, components become the theme for many questions, particularly in Section II of the examination paper. Physical examination, sketching a shape description, sectioning to reveal threads and details, microstructural examination, formal drawing of aspects of components, discussion on manufacture, properties, service properties, materials used, mechanical operation or requirements, will ensure a better prepared candidate.

2/3 Unit (Common)

QUESTION 1

This was a good question which tested a broad range of concepts in statics. Errors were many and varied with only the better candidates achieving full marks. The average student was able to obtain some marks in each part of the question while often displaying limited knowledge of the concepts involved.

Details of a timber truss are given below on the diagram. The truss has a mass of 120 kg acting through joint E. A vertical force of 3 kN acts through a steel cable at joint D.



(a) Determine the reactions at the supports A and B.

$$\circlearrowright + \sum M_B = 0 = (1.5\text{x}1200) + (4.5\text{x}3000) - (2.6\text{x}R_A)$$

$$R_A = 5885 \text{ N} \rightarrow$$

$$+\uparrow \sum V = 0 = R_{V_B} - 3000 - 1200$$

$$R_{V_B} = 4200 \text{ N} \uparrow$$

$$\sum H = 0 = R_{B_H} = 5885 \text{ N} \leftarrow$$

$$R_B = \sqrt{4200^2 + 5885^2} = 7230 \text{ N}$$

$$\theta = \tan^{-1}\frac{4200}{5885} = 35.5^\circ$$

Magnitude of reaction at A **5.89** kN. Direction →

Magnitude of reaction at B **7.23** Direction **35.5°**

Before taking moments, students recognised the need to calculate the distance AB, by trigonometry or by scaling the drawing, as 2.6m. Most students appeared to have a reasonable understanding of moments and achieved at least part marks for this question. Some students, including the following solution, omitted the mass of the truss from the moments equation. Hint: Draw all external forces acting on the truss.

The following solution was typical of those candidates that omitted the mass of the truss.

$\circlearrowleft + \Sigma M_{RB} = 0$

$0 = -(R_{AH} \times 2.6) + (3 \times 4.5)$

$\therefore R_{AH} = 5.2\,kN \rightarrow$

$\xrightarrow{+}\ R_{BH} = -R_{AH}$

$= -5.2\,kN \rightarrow$

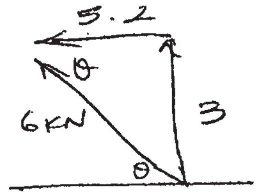
$= 5.2\,kN \leftarrow$

$\uparrow + \Sigma F_V = 0$

$0 = R_{BV} - 3$

$\therefore R_{BV} = 3\,kN \uparrow$

For R_B:



$\tan\theta = 3/5.2$

$\therefore \theta \doteq 30°$

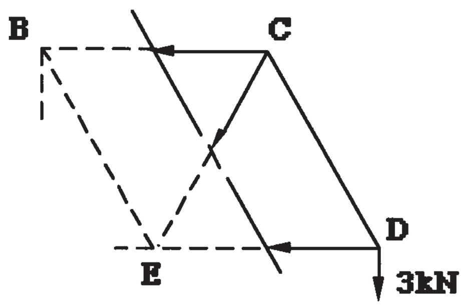
The nature of the reaction forces was not understood by many students with common responses of RA and RB as horizontal and opposite forces, as in the example above. The support at B, being a fixed support, has a reaction that includes horizontal and vertical components.

Other common errors included: incorrect calculation of the length of AB; confusion of mass (kg) and weight (N) and use of incorrect units.

Students should note that compass directions are more appropriate when used in top views.

(b) Determine the magnitude and nature (tension or compression) of the force in member BC.

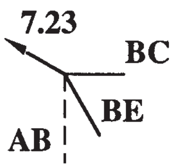
Method of Sections:



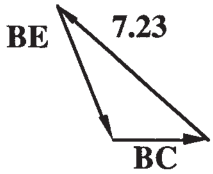
$\circlearrowleft + \ \sum M_E = 0 = (3000x3) - (BCx2.6)$

$BC = 3464\ N$

$= 3.46\ kN$



Method of Joints: (B) (AB redundant)



BC = 3.46 kN

Force in BC 3.46 kN

Nature of force in BC Tension

The majority of students (approx 60 - 70%) attempted this question by using the method of sections. Students had a poor understanding of the concept behind this method. Often the question was poorly set out with no free body diagrams of the “half truss” and often no section plane was indicated. Most students had difficulty determining the appropriate point for a moment equation (E). The most common errors were taking moments about D or A and conveniently omitting member EC as shown in the example below.

$$\circlearrowright + M, \; M_D, \quad BC \times 1{\cdot}5 \times \tan 60^\circ = 120 \times 9{\cdot}8 \times 3.$$
$$BC = 1{\cdot}357\,kN$$

Students who used method of joints often were more successful, compared to those using a Maxwell diagram.

The nature of the force in BC (tension) was found by most students, even those who did not attempt to find the magnitude of the force. External members can be analysed logically in pin-jointed trusses by asking, “What would happen if BC were removed ?” BC must be in tension otherwise the frame would rotate about E and C would move away from B. (BC could be replaced by a ‘wire’)

(c) The steel cable at joint D has a tensile yield stress of 250 MPa. Using a factor of safety of 1.5, determine the minimum diameter of steel cable that should be used to withstand the 3 kN force.

$$\text{F of S} = \frac{\sigma\,\text{yield}}{\sigma\,\text{working}}$$

$$\sigma_w = \frac{250}{1.5}$$

$$= 166.7 \text{ MPa}$$

$$\sigma = \frac{P}{A}$$

$$A = \frac{3000}{166.7\text{x}10^6}$$

$$= 18\text{x}10^{-6} \text{ m}^2$$

$$A = \frac{\pi d^2}{4}$$

$$d = \sqrt{\frac{4\text{x}18\text{x}10^{-6}}{\pi}}$$

$$= 4.79\text{x}10^{-3} \text{ m}$$

Minimum diameter 4.79 mm

Few students obtained full marks for this question. The greatest single error appeared to be the factor of safety. The formula was given in the formula sheet but not used.

Many students would have benefited from a more systematic (step by step) approach as shown in the sample answer, rather than trying to solve the problem in one or two steps. This caused frequent errors in both transposition of formula, calculation and units.

To ensure a material is used in a safe manner, engineers use a safety factor to reduce the chance of the material failing or undergoing plastic deformation due to the stress applied. The true yield stress is therefore proportionally reduced by 1.5 to find the safe working stress. This is then used in calculating the required information. The following example was a common error, where the yield stress was multiplied by 1.5. In the example below, the student has incorrectly multiplied the yield stress by the factor of safety, therefore reducing the final diameter.

$$\sigma = \frac{P}{A}$$

$$1.5 \times 250\text{MPa} = \frac{3000}{x\text{mm}}$$

-1

$$x\text{mm} = \frac{3000}{375\text{MPa}}$$

$$= 8\text{mm}$$

$$A = \pi r^2$$

$$8 = \pi r^2$$

$$r^2 = \frac{8}{\pi}$$

$$r^2 = 2.546$$

$$r = 1.595$$

$$d = 2r$$

$$= 2(1.595)$$

$$= 3.192$$

Although the stress equation was generally well understood by the majority of students, many errors were made including: not using correct units or compatible units; multiplying the diameter by the factor of safety; calculating the radius and calling it the diameter.

Many students would have benefited from a more systematic, step by step approach. The candidate below has attempted to solve the problem in one or two steps. Frequent errors in transposition of formula, calculations and units occur in this type of question.

4.5 KN

2.39

$\frac{4500}{250{,}000{,}000} = 1.8 \times 10^{-5} \times 1000000 = 18$

$\sqrt{\frac{18}{\pi}} = r$ $\quad r = 2.39$

This student has multiplied the yield stress by 1.5 correctly, but calculated the radius rather than the diameter.

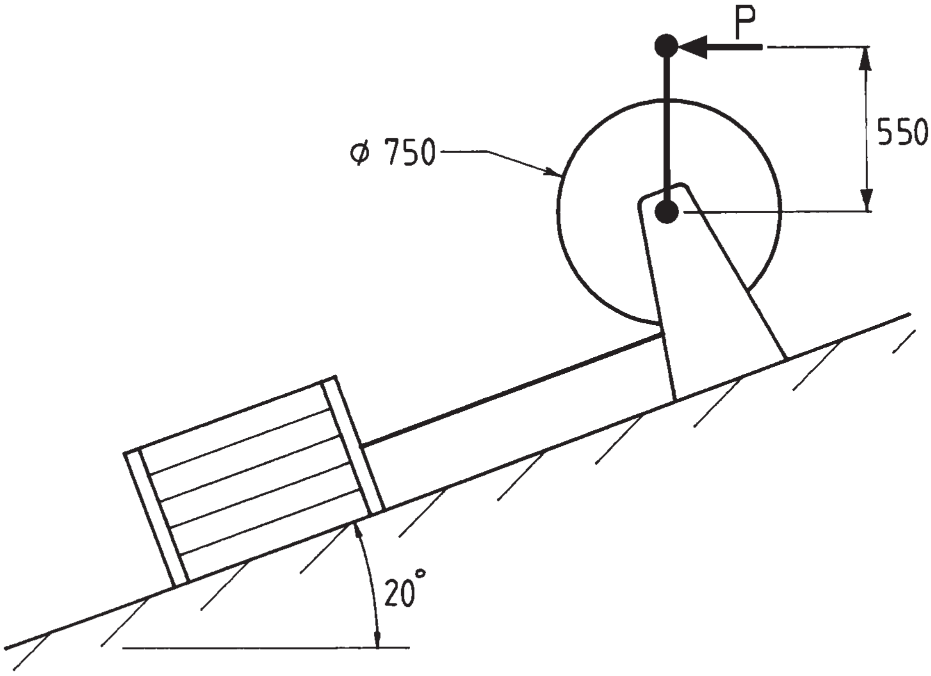
It should be noted that using $A = \frac{\pi d^2}{4}$ rather than $A = \pi^2$ is a more appropriate formula for engineering mechanics when diameters are involved.

QUESTION 2

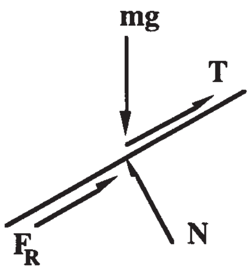
Details of a winch mechanism used to raise and lower crates on an inclined plane are given on the diagram below. The mass of each crate is 300 kg.

The coefficient of static friction between the crate and the plane is 0.2.

The coefficient of dynamic friction between the crate and the plane is 0.14.



(a) (i) Determine the minimum tension in the rope required to prevent the crate sliding down the plane



$+$ $\sum F = 0$

$N - mg\cos 20° = 0$

$N = 3000\cos 20°$

$= 2819N$

$F_R = \mu N$

$= 0.2x2819$

$= 563.8N$

$+$ $\sum F = 0$

$T + F_R - mg\sin 20° = 0$

$T = 3000\sin 20° - 563.8$

$= 1026 - 563.8$

$= 462.3N$

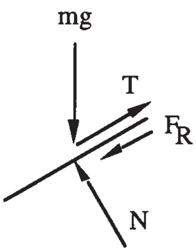
Tension in rope **462.3** N

This question examined a wide range of mechanics, including an inclined plane, friction and tension in a rope.

Students demonstrated a reasonable understanding of the problem.

Common errors included: neglecting the weight component down the plane; applying the coefficient of static friction (0.2) to a vertical force (mg) rather than the normal force (mg cos 20˚); combining the static and dynamic coefficients of friction (0.2 + 0.14 = 0.34); choosing the wrong sense for the frictional force. The frictional force is a reactive force that opposes motion. In this part of the question, the frictional force is assisting to prevent the crate sliding down the plane by the action of gravity. The frictional force is therefore acting up the plane on this occasion.

(ii) Determine the tension in the rope if the crate is moving up the plane with a constant velocity.



$N = 2819\text{ N}$

$F = \mu\text{N}$

$= 0.14\text{x}2819$

$= 394.66\text{ N}$

$+$ $\sum \text{F} = 0$

$\text{T} - \text{F}_r - \text{mg}_{\text{Down Plane}} = 0$

$\text{T} - 394.6 - 1026 = 0$

$\text{T} = 1420.6\text{ N}$

Tension in rope **1.42** kN

The use of a coefficient of dynamic friction was generally understood, although it was evident that many students did not understand the difference between static and dynamic friction. Many used the coefficients in reverse or added the two together.

The sense of the frictional force was again a common source of errors. The sense in this part of the problem was required to now act **down** the plane to oppose the motion up the plane.

Most students successfully converted the units from newtons to kilonewtons.

The example below was a correct solution that used 9.8m/s2 for acceleration.

$v = \text{constant}$
$\therefore a = 0$
$\therefore \Sigma F = 0$

$T = \underline{1.39\,kN}$

$0 = T - F_F - mg\sin 20$
$T = \mu_d N + mg\sin 20$

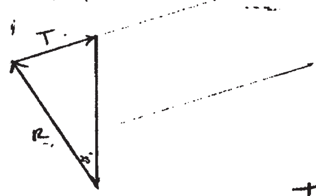
Tension in rope ....1.39.........

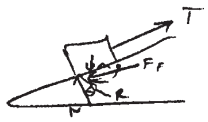
$= (0.14)(300)(9.8)(\cos 20) + (300)(9.8)(\sin 20)$
$= 386.777 + 1005.54$
$T = \underline{1392.3167}$

Hint: draw a free body diagram to assist in analysing the problem.

Very few candidates attempted this question graphically. Many had difficulty in determining the angle of friction. The following is a correct graphical solution to the problem

iction acts down plane:
∴ 1cm = 1000N





$\theta = \tan^{-1} 0.14$
$= 8°$

Tension in rope ....1.45..... kN

$T = 1.45\,cm$
$= 1450\,N$
$= 1.45\,kN$

(b) **For a different set of conditions, a tension of 1.2 kN in the rope moves a crate up the plane with a constant velocity.**
(i)Determine the force, P, that needs to be applied at the handle of the winch to cause this motion.

$$\sum M_C = 0$$

$$(Px550) - (1.2x\frac{750}{2}) = 0$$

$$P = \frac{1.2x375}{550} = 0.818kN$$

Force P **818** N

This is a simple moments application and was answered well by most candidates.

Common errors included: not reducing the drum diameter of 750 mm to a moment arm equal to the radius of 375 mm; applying the moment created by the force P into a movement along the plane.

Students who attempted this question by means of a velocity ratio and a mechanical advantage generally experienced difficulties.

(ii) If the winch has an efficiency of 85%, determine the work required to turn the winch five full revolutions.

Force on handle approach:

$$\begin{aligned} 1 \text{ rev} &= 2\pi d \\ &= 750\pi \\ &= 2356.2 \text{ mm} \\ 5 \text{ rev} &= 11\,781 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{input} &= \frac{1200}{0.85} \\ &= 1\,411.7 \text{ N} \end{aligned}$$

$$\begin{aligned} W &= Fs \\ &= 1\,411.7 \text{x} 11\,781 \\ &= 16\,632 \text{ Nm} \end{aligned}$$

Tesion in cable approach:

$$\begin{aligned} 1 \text{ rev} &= \pi d \\ &= 750\pi \\ &= 2\,356.2 \text{ mm} \\ 5 \text{ rev} &= 11\,781 \text{ mm} \end{aligned}$$

$$\begin{aligned} \mathit{Input} &= \frac{1200}{0.85} \\ &= 1\,411.7 \text{ N} \end{aligned}$$

$$\begin{aligned} W &= Fs \\ &= 1\,411.7 \text{x} 11\,781 \\ &= 16\,632 \text{ Nm} \end{aligned}$$

Work **16.65** kJ

This part contained many subsections and proved to be difficult for many students.

Many students had difficulty in finding a circumference and often did not distinguish between a radius and a diameter for substitution into the formula C=?d. Errors were compounded further when it was necessary to find the distance equivalent to five revolutions.

Students displayed limited understanding of efficiency. If a machine is not 100% efficient, it is necessary to increase the size of the input to overcome the losses in the machine. An efficiency of 85% required the output to be divided by 0.85 rather than increasing the output by 15% ie multiplying output by 1.15.

A large percentage of incorrect responses involved applying the force P to the circumference of the drum instead of applying it to the circumference of the handle. This incorrect linking of force and displacement in W = Fs was a very common error.

The use of compatible units required a conversion of displacement from mm to m, for the Work to be calculated as Nm (equivalent to a joule). The answer then required a further conversion from joules to kilojoules. These conversions are often a source of basic errors.

An alternative solution could have used the tension of 1.2 kN applied on the drum. This was not recognised by most candidates.

Examples of good solutions are given below:

$W = Fs \times \frac{100}{85}$

$818.2 \times 5(\pi \times 1100) \times \frac{100}{85} \qquad = 16632.35$

Work ....16.63.... kJ

$\eta = 85\%$

$W = ? = \frac{Fs}{\eta}$

$s = 5(2)(\pi)(550)$

$s = 17278.76\text{mm}$

$\underline{s = 17.28\text{m}}$

$F = P = 818.18\text{N}$

$W = Fs$ (for 100% Efficiency)

$\therefore W = \frac{Fs}{\eta}$

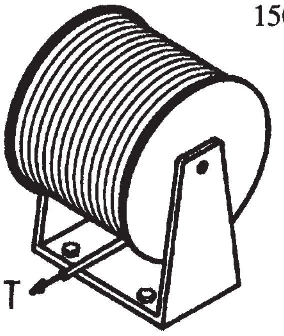
$= \frac{(818.18)(17.28)}{0.85}$

$W = 16631.96\text{J}$

Work ....16.63.... kJ

Students who attempted to solve this by using velocity ratios, mechanical advantage and efficiency experienced difficulties.

(c) The winch mechanism has a mass of 160 kg and is held to the inclined plane by 4 identical bolts. The maximum shearing force on the bolts, caused by the tension T in the rope, was found to be 4.65 kN. Determine the minimum diameter of the bolts used, if each has a maximum shear stress of 150 MPa.



$$\text{Force/bolt} = \frac{\text{Total Force}}{4} = \frac{4.65}{4}\ \text{kN}$$

$$= 1.165\ \text{kN}$$

$$\sigma = \frac{L}{A}$$

$$150\text{x}10^6 = \frac{1162.5}{A}$$

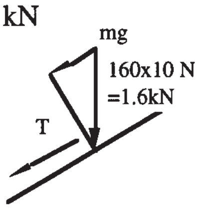
$$= 7.75\ \text{mm}^2$$

$$A = \frac{\pi d^2}{4}$$

$$d^2 = \frac{4\text{x}7.75}{\pi} = 9.87$$

$$d = \sqrt{9.87}$$

$$= 3.14\ \text{mm}$$



Weight included:
Force created by weight

$$= mg \sin 20^\circ$$

$$= 1.6 \sin 20^\circ$$

$$= 0.55\ \text{kN}$$

Therefore total force down slope:

$$4.65 + 0.55 = 5.2\ \text{kN}$$

$$\text{Force/Bolt} = 1.3\ \text{kN}$$

$$\sigma_s = \frac{L}{A} = \frac{1300}{A}$$

$$d^2 = \frac{1300 \text{ x } 4}{150\pi}$$

$$d = 3.3\ \text{mm}$$

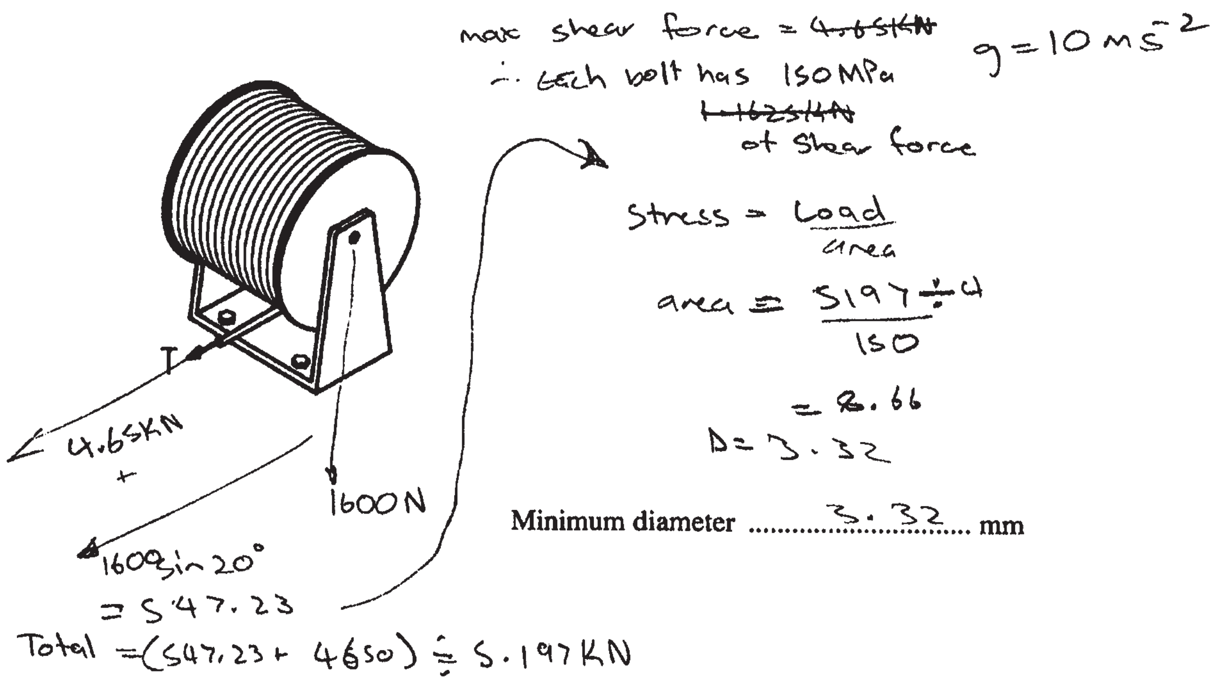
Minimum diameter **3.14** mm

The use of the winch on the inclined plane was poorly understood. The weight component down the plane was often not recognised as contributing to the shear force on the bolts. Shown above are two solutions. The solution that includes the weight force component of the drum acting down the plane, is the best solution.

The question stated that the tension was creating a shear force on the bolts. The sharing of the force between the four bolts required either the force to be divided by 4, or the area to be multiplied by 4. An incorrect concept displayed by some students was to increase the maximum shear stress from 150 MPa to 600 MPa.

Incompatible units in the stress equation resulted in many students experiencing difficulties in calculating the correct area. Students had difficulty in applying the formula to find the area of a circle.

The following sample is of a good response. Note that the candidate has added forces to the pictorial drawing to analyse the problem. The weight force component is also included.



A common poor response mixed the data in the question:

$$\tau = \frac{F}{A}$$

total force. inclined plane.

$$= 1600 + 4.65 \times 10^3$$

$$= 6250$$

$$\cancel{150 = 6250}$$

$$150 \times 10^6 = \frac{6250}{A}$$

$$A = 4.167 \times 10^{-5}$$

$$\text{each area} = \frac{4.167 \times 10^{-5}}{4}$$

$$= 1.0417 \times 10^{-5}$$

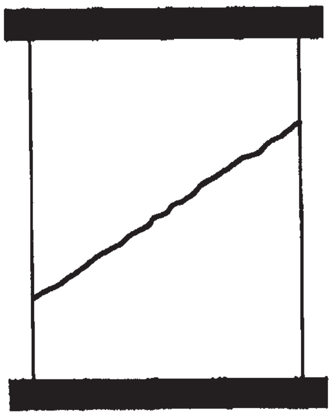
$$A = \frac{\pi D^2}{4} \qquad 1.0417 \times 10^{-5} = \frac{\pi D^2}{4}$$

$$\therefore D =$$

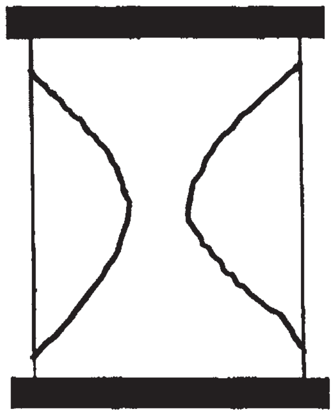
Hint: Use a free-body diagram to assist in analysing a problem, where applicable. Most students who do, usually score well.

QUESTION 3

(a) (i) Two concrete specimens are tested to destruction in a compression test. Using the diagrams below, draw the TWO different types of failure that could occur.



SPECIMEN 1



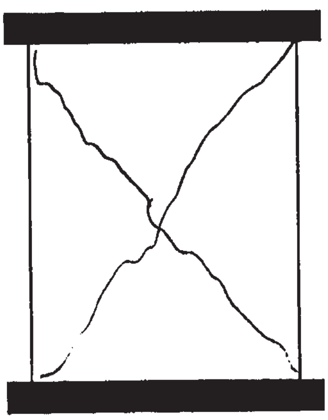
SPECIMEN 2

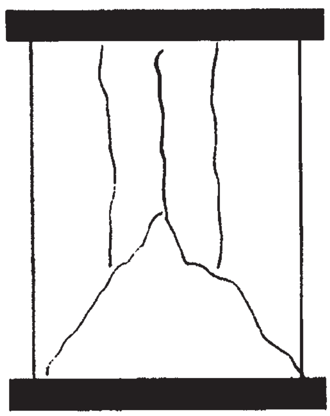
Illustrations were generally of a reasonable standard with the hour-glass failure the most common of the correct responses.

The shear failure diagram frequently did not show sufficient angle (greater than 30˚ preferred).

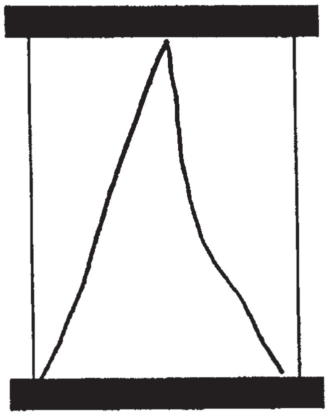
Shear cone fracture diagrams were sometimes upside down or the cone was incorrectly drawn through to the top plate.

Good responses:





A poor response showing the shear cone through to the top plate.



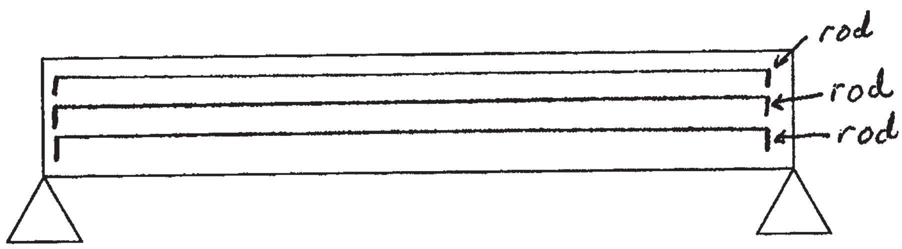
(ii) A concrete beam is supported as shown below.

On the diagram, indicate the approximate position of a reinforcing rod to minimise tensile cracking.

Candidate's responses often did not indicate an understanding of tensile cracking as a result of deflection, and the rods were frequently located too high or too close to the centre of the beam (neutral axis).

In pre-tensioned concrete the steel reinforcement is generally parallel to the bottom of the beam. In post-tensioned beams the conduits for the tendons can be curved upwards to the ends of the beam, maximising the effect of the steel tendons and strength of the beam.

This poor response demonstrates a lack of understanding of the need for reinforcing to increase the strength of the composite structure.



(iii) There are two methods of pre-stressing the beam. Name and describe ONE of these methods.

Name: **Pre Tensioned**

Description: **Tension is placed in rod/cables. Concrete poured and allowed to set.**

External tensioning is then released.

or

Name: **Post Tensioned**

Description: **The beam is cast with conduits/cavities running from end to end. Cable is put through conduit and then tensioned. The conduit is filled with grout.**

In pre-stressing the tension is placed in the steel prior to the concrete being poured into the mould. In post-stressing the concrete is poured into the mould and when set, the steel tendons are inserted in the conduits before the beam is placed into tension. In both cases, the steel forces the concrete into compression making a stronger composite body.

Often both processes are referred to as pre-stressing because the stress is placed in the beam 'pre' using the beam.

Hint: Most processes or descriptions of this type involve at least four major steps. They are usually 2 mark questions in the examination paper.

(b) Powder metallurgy is often used in the manufacture of bronze bearings.
Give TWO advantages that this process has over machining the bearing from solid bar stock.

Advantage 1 **Facilitates self lubricating bearings / Bearings can be porous.**

Advantage 2 **Minimisation of machining (elimination).**

High production rate

Dimensional accuracy

Reduced metal waste

Some students confused the term ‘bearing’ with ball or roller bearings in their responses. Common incorrect responses included reference to ‘grainflow’ or ‘microstructure’.

While many of the general advantages of powder metallurgy were seen as correct responses, students should understand that controlling porosity and reduction of machining more specifically relate to the production of these bearings and are advantages for the specific use mentioned in the question.

Good response:

Advantage 1 Bearing can be made porous (self lubricating)

Advantage 2 less or no waste material.

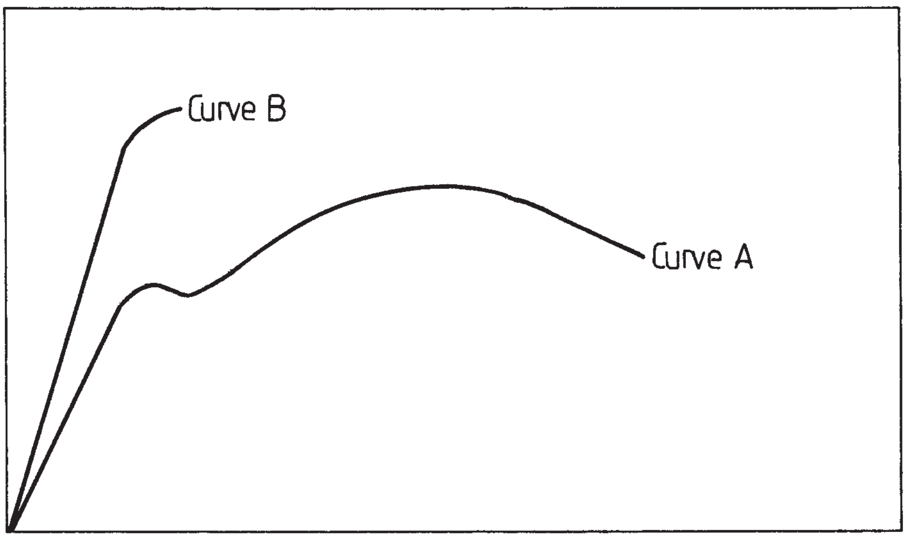
Poor response:

Advantage 1 grains are formed with the flow of the bearing.

Advantage 2 bearing is stronger less fracture or failure points.

QUESTION 3. (Continued)

(c) The diagram below represents the tensile stress strain curves for mild steel (curve A) and a hardened and tempered steel (curve B).



In the table below, indicate the steel with the higher value for each of the mechanical properties given. Give a reason for each answer by referring to the curves given above. A sample answer has been provided.

Mechanical Property	Steel (A or B)	Reason
Tensile Strength	B	Higher UTS shown on diagram
Ductility	A	Curve shows greater strain/elongation/plasticity
Toughness	A	Larger area under the curve

The concept of 'Ductility' was generally understood by candidates with suitable reasons being given, whereas 'Toughness' was more poorly understood.

Good response:

Mechanical Property	*Steel* (A *or* B)	*Reason*
Tensile strength	B	Higher UTS shown on diagram
Ductility	A	Much more strain before fracture
Toughness	A	Greater area under curve.

(d) Name a suitable mass production method for EACH of the following products.

Flexible, narrow-necked PET bottle · · · · · · · · · · · · · · · **Blow Moulding**

Thin polyethylene wrapping film · · · · · · · · · · · · · · · · · **Film Extrusion / Calendering**

Stoneware toilet bowls · **Slip Casting**

Glass fibre · **Crown process or Continuous Filament process**

Most candidates correctly identified Blow moulding and Slip casting as the correct responses for parts 1 and 3.

Candidates frequently missed correct answers for production methods for **Thin polyethylene wrapping film** and **glass fibre**, with glass fibre proving the most frequently unanswered or wrongly answered. Some candidates confused glass forming processes with polymer forming processes.

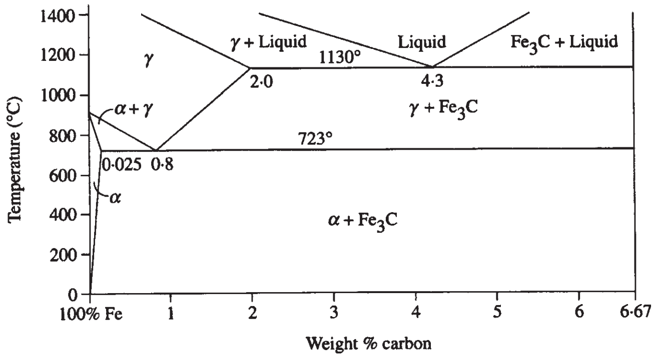
Good response:

Name a suitable mass production method for EACH of the following products.

- **Flexible, narrow-necked PET bottle** ....Blow moulding....
- **Thin polyethylene wrapping film** ....Calandering....
- **Stoneware toilet bowls** ....Slip casting....
- **Glass fibre** ....Continious fillament method....

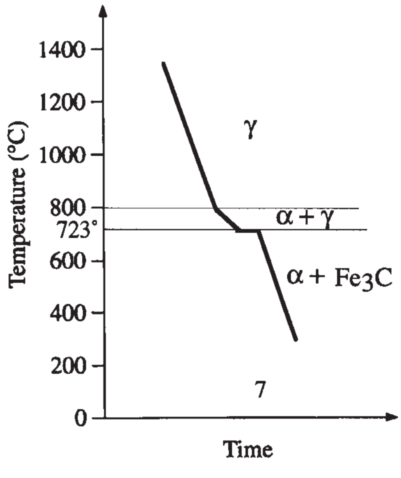
QUESTION 4

A portion of the iron-carbon equilibrium diagram is given below.

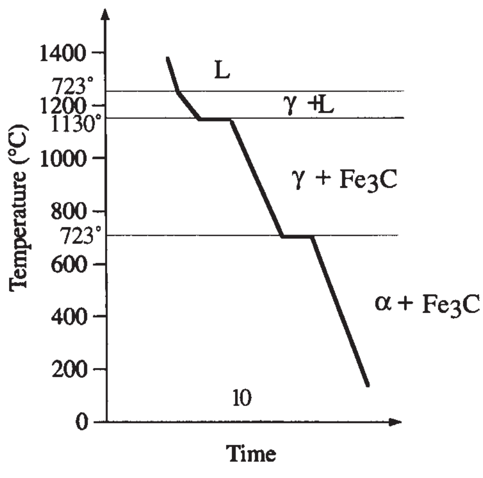


(a) (i) Using the axes provided below, sketch the equilibrium cooling curves and label the phases present for the following alloys, cooled from 1300∞C.

- **0.5% carbon**
- **3.5% carbon**



0·5% CARBON



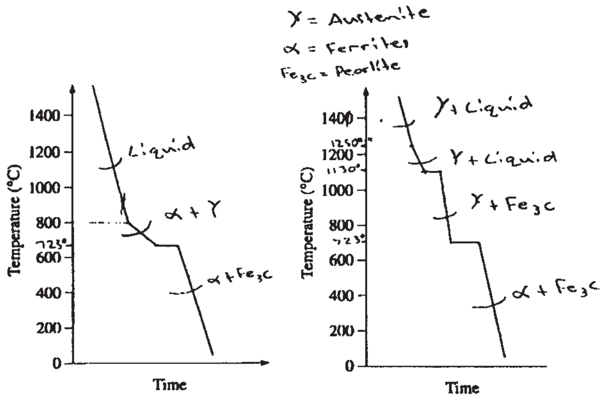
3·5% CARBON

This question was reasonably well answered with most students being able to draw an equilibrium cooling curve.

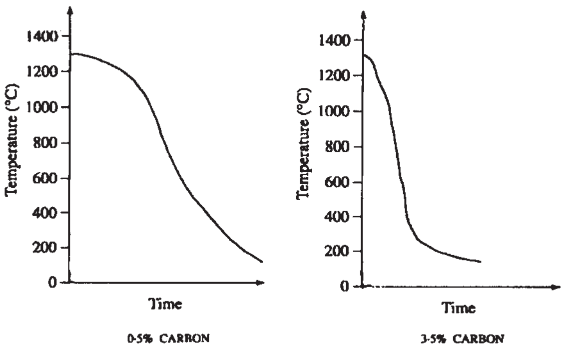
Common errors included: not showing isothermal arrests; poor plotting of temperatures from the phase diagram onto the cooling curve axes; using solid+liquid instead of reading off the phases from the equilibrium diagram; not labelling the phases; and very poor freehand drawing of the cooling curves.

Students should answer this type of question by: drawing the vertical composition line on the phase diagram using a ruler; accurately drawing a horizontal line through arrest points i.e. where the vertical line crosses the phase boundaries on the phase diagram; accurately drawing the horizontal arrest points lines on the cooling curve axes; draw a cooling curve showing the arrest points - slope from left to right; and to label all phases from the phase diagram on the cooling curve.

Good response:



Poor response:



(ii) Name the solid phase present, under equilibrium conditions, in a 2.5% carbon alloy at 1200°C, and determine its composition at that temperature.

Name γ or Austenite Composition 1.7% Carbon

This question was poorly answered. Candidates demonstrated little understanding of how to determine the composition of a solid phase at a prescribed temperature.

Common mistakes included: incorrectly naming the solid phase as pearlite, ferrite or gamma+liquid. The composition was often stated in words and not as a percentage.

The composition can be determined by drawing a horizontal line (lever) at 12000°C. Where the lever line crosses the solidus line, a vertical line is dropped to the composition axes. The composition of austenite can then be read from this axis.

(b) (i) The equilibrium diagram provided shows two phases which are interstitial solid solutions. Name these TWO phases.

1. α, (Ferrite)

2. γ, (Austenite)

Students generally did not know how to identify a solid solution from the phase diagram.

Common incorrect answers included cementite (which is an interstitial compound) and pearlite.

Students should learn how to identify solid solution phases from diagrams. These are always one (single) phase areas and have a range of compositions (solid solubility).

(ii) State the maximum solid solubility of carbon in FCC iron.

2.0%

This question was not well answered with students failing to read 2% from the phase diagram as the maximum solubility of carbon in austenite. Common incorrect answers were 0.025%, 0.8%, 6.67% and 4.3%.

(iii) Iron-carbon alloys form interstitial solid solutions rather than substitutional solid solutions. State ONE reason for this.

Difference in size between the carbon and iron atoms
(Smaller C atoms fit between the larger Fe atoms)

Not many students realised that the carbon atom is smaller than the iron atom and therefore fits into the interstices (gaps, voids, holes) between the iron atoms. It is the iron atoms that make the space lattice structure (FCC or BCC). The key phrase which markers were looking for was “difference in size”.

The carbon atoms are small enough
to fit between the matrix of iron

(c) Explain the term allotropic change. Give an example from the ironñcarbon phase diagram to illustrate your answer.

Allotropic change: A change of crystal (lattice) structure

Example: FCC change to BCC for pure iron and vise versa

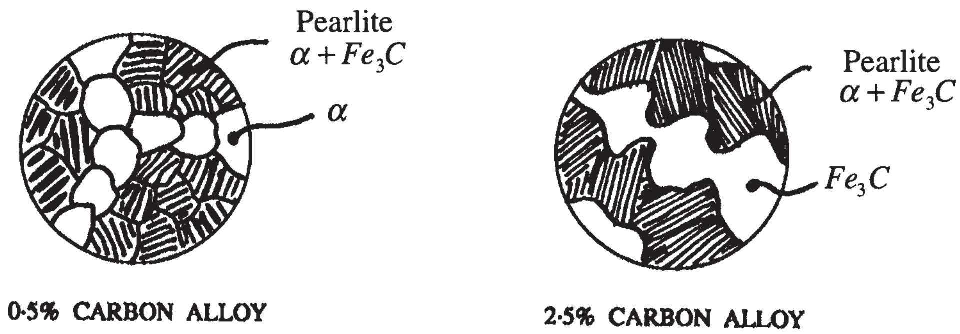
$$\delta \rightleftharpoons \gamma \rightleftharpoons \alpha$$

This proved to be a difficult question for most candidates.

An allotropic change (or polymorphic change) refers to the change in crystal lattice, for example, when iron changes from BCC to FCC at 913˚ C. Note that there are two parts to the question with half marks given to the explanation and half for stating an example.

This is a change in the crystal structure of the iron. eg $\gamma \rightarrow \alpha$

(d) **Alloys of 0·5% carbon and 2·5% carbon in iron are cooled under equilibrium conditions to room temperature. Draw and label the resultant microstructures of these two alloys.**



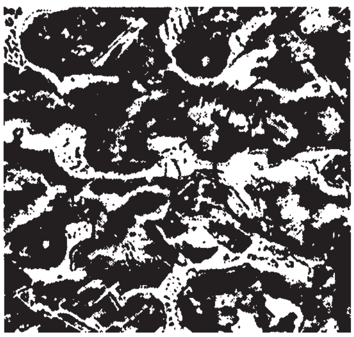


Photo micrograph of white Cast iron

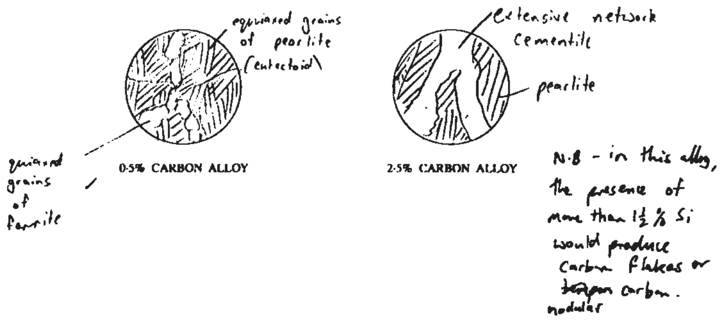
This question was well answered with most students making an attempt to sketch the alloys and label the phases.

Common errors included: interpreting the 2.5% carbon cast iron to contain graphite when there is no mention of a graphitising agent (silicon) being added to the alloy; not labelling the diagrams which resulted in a loss of half marks; not showing pearlite as a lamellar structure; and using the same drawings for both microstructures.

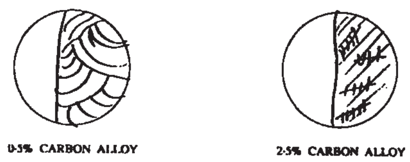
Students should also trace the cooling on the given phase diagram so that they can determine the number of phases at the required temperature.

A photomicrograph of white cast iron is included above for reference purposes. It shows white areas of Cementite in a matrix of unresolved Pearlite (Grey). To ensure a white cast iron is formed, low silicon is required and faster cooling rates are used. It is called a white cast iron because of the appearance of its fracture surface (white).

Good response:



Poor response:

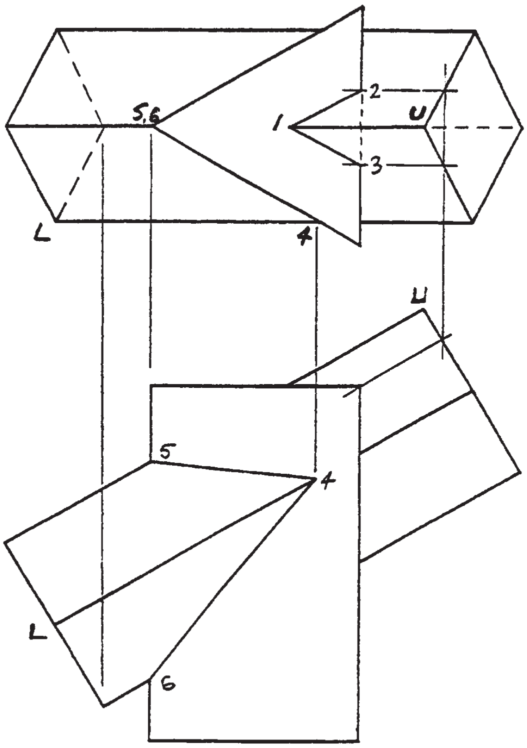


Many candidates still have difficulty in sketching metal structures. Metals are polycrystalline with no voids. Too often “grains of rice” or “islands of despair” are drawn, as though one grain is unrelated to another. The above poor responses have little resemblance of metal microstructures. Macrostructures and microstructures are fundamental in interpreting and describing the structure of a material and students would be well advised to spend more time in this area.

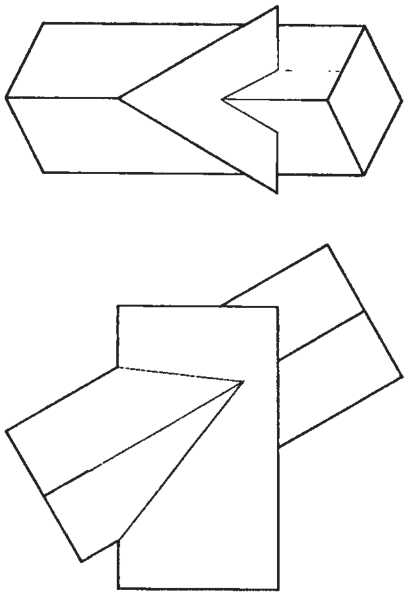
QUESTION 5

(a) The incomplete front view and incomplete top view of a square prism intersecting with a triangular prism are given below in third-angle projection.

Complete the top view and the front view.

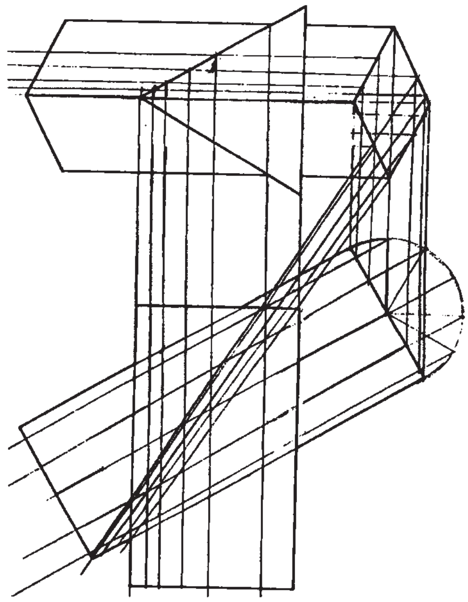


A good response that shows all visible outline, but does not show hidden detail in the top view.



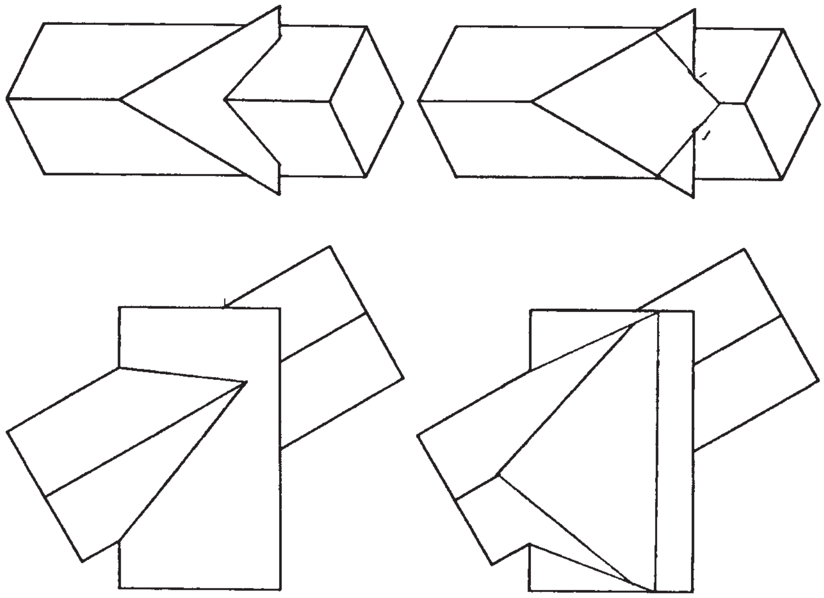
This question was generally well answered, although many candidates showed a lack of care when projecting between views. Line work quality was good and a few candidates included hidden detail in their solutions. The majority of those that did complete hidden detail were usually incorrect with some merely joining the ends of lines in the vain hope that they would indicate correct hidden detail. The correct use of line type and the principles of visibility need careful attention by students. Unless otherwise stated, completion of views would include visible and hidden lines of intersection in this type of question.

In the example given below, dark construction and projection lines have been drawn that have no relation to the actual intersecting solids. Drawing lines that have no relationship to a method are not rewarded with marks.

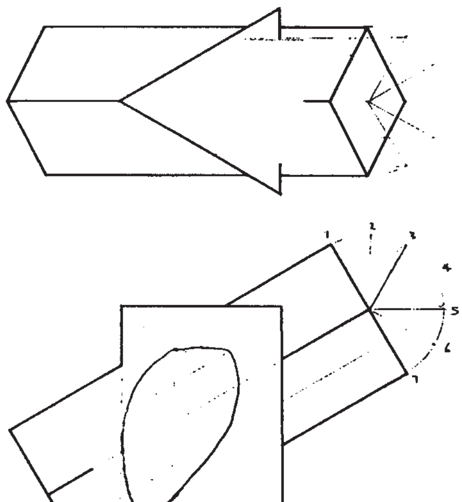


Points 2 and 3 (see original solution on the previous page) were missed by many candidates due to an obvious lack of knowledge of the use of vertical cutting planes and associated projection methods. This section of the syllabus should be given special attention by candidates because of its broad application to a number of areas in Graphics. It can apply not only to intersection of solids, for example, but also to fillet curves and rod ends as well.

Candidates also erroneously used the ends of existing lines to obtain a line of intersection in the top view rather than using a correct projection method.



Quite a number of candidates read more into the question than was necessary. This resulted in excessively complex plotting methods being used which in turn led to curved lines of intersection being drawn in the front view. Careful reading of the question to determine exactly what is required by the examiner is a must. Marks are directly related to the requirement specified in the question.

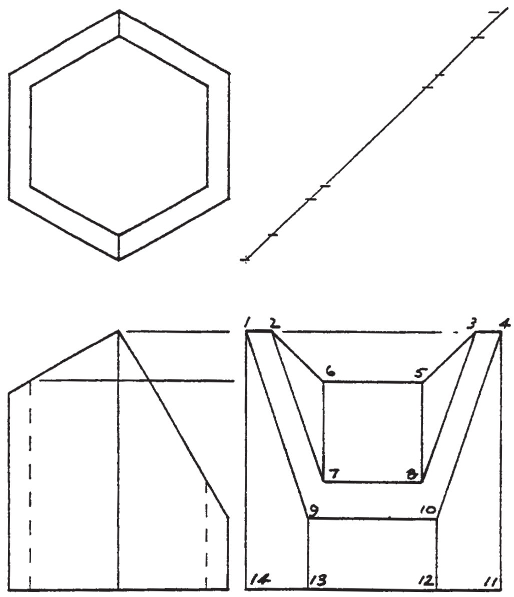


The use of cutting planes in obtaining lines of intersection needs revision as well as the rules governing lines of intersection. The following points need to be noted:

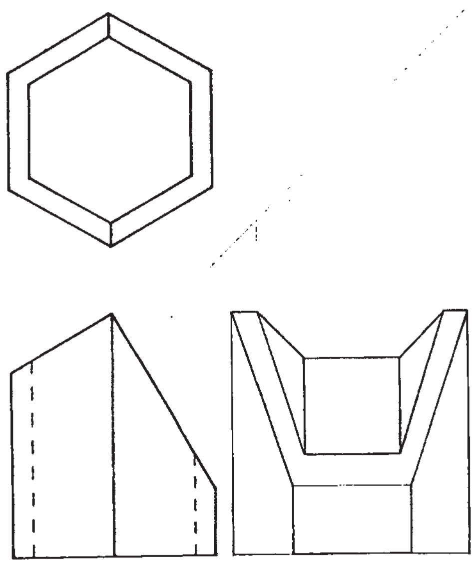
a flat surface intersecting a flat surface: straight line of intersection;
a flat surface intersecting a curved surface: curved line of intersection;
a curved surface intersecting a curved surface: may give a curved line of intersection.

(b) **The top view and front view of a truncated hexagonal pipe are given below in third-angle projection.**

Project the right-side view of the pipe. Do NOT include hidden outline in your solution.



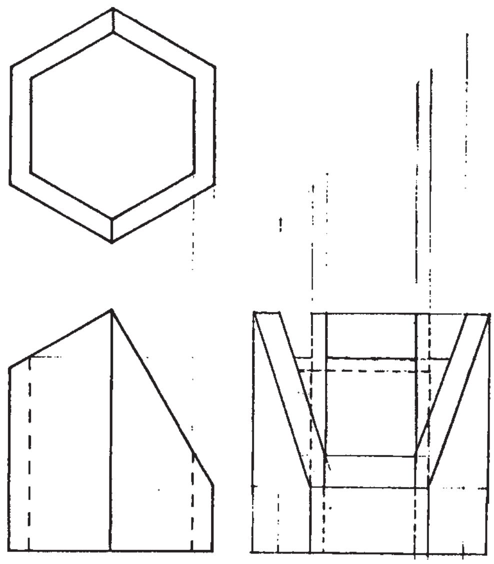
Perfect response:



Overall, this question was well answered, although some incorrect projection methods were evident. The quality and differentiation of lines seemed inferior to that given in Question 5(a).

This possibly may have been due to an excessive number of lines drawn by many candidates. Standards of linework need special attention from students, as it aids in their accuracy, particularly in this type of orthogonal problem where projection is involved.

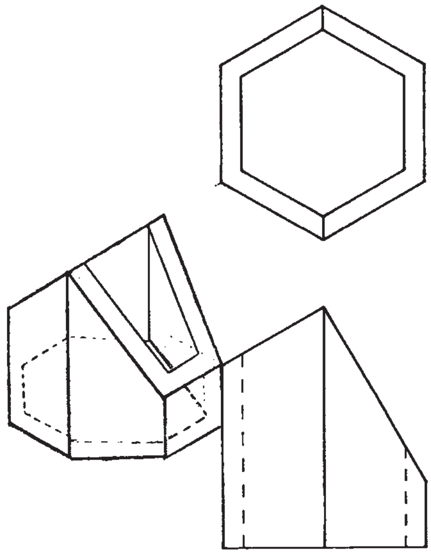
The three surface areas contained in the front view were completed to varying degrees of success. The inside surface at the back caused many visualisation and interpretation problems for students with many either omitting necessary long edges or including excessive detail. Hidden detail was often shown despite clear and specific instructions in the question.



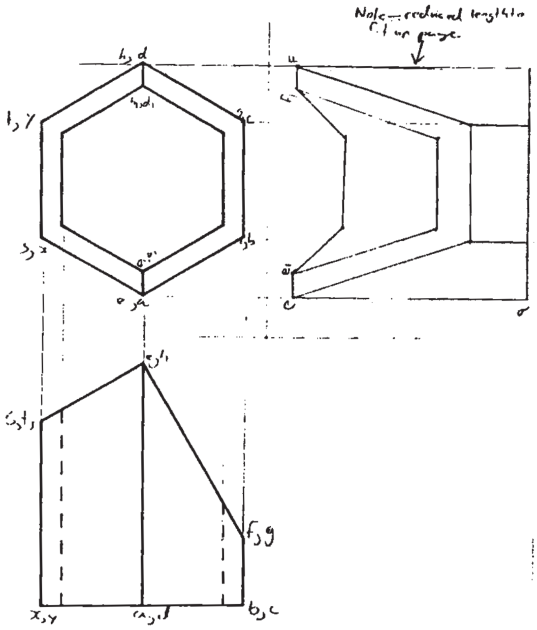
The ‘inner wall’ top surface area was generally recognised as being a single surface once correctly found. However, many showed this as having vertical rather than tapered sides as derived from a correct interpretation of the hexagonal shape of the pipe. Sectioning of the wall top was erroneously completed by some students although they may have merely followed the “truncated” terminology and mistaken this as an instruction to show it as a section.

The ‘outside wall’ area at the front of the right side view was the best completed part of the view. Candidates showed good visualisation and interpretation as well as correct insertion of long edges etc.

From a broad perspective, many candidates experienced confusion with the overall concept of what a right side view consists of with some even showing a pictorial view or a developed surface with curved edges despite there being none in the object.

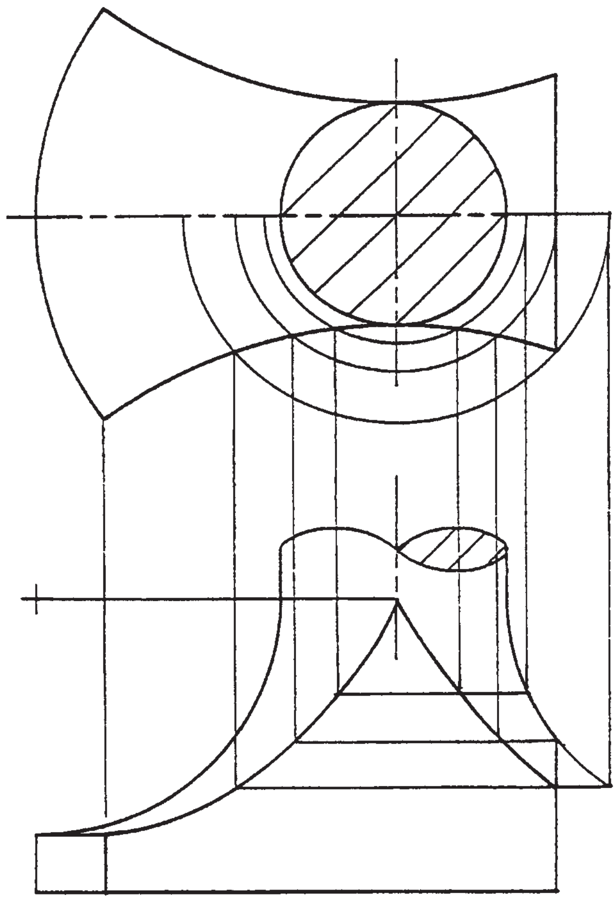


Many positioned the right side view to the left of the front view or projected incorrectly from the top view.
The principles of orthogonal projection and the placement of views needs careful revision by students.

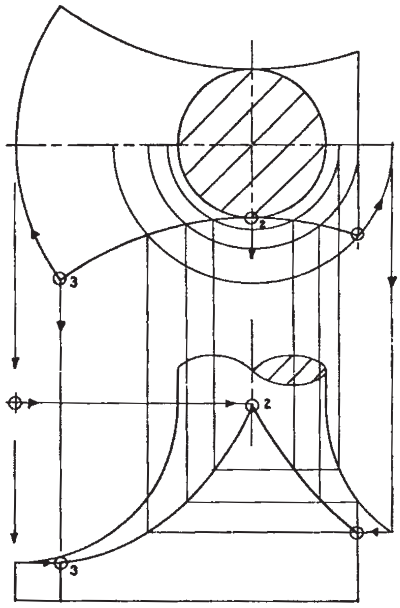


QUESTION 6

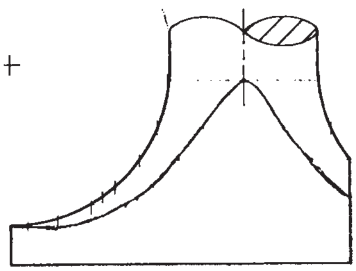
**(a) The top view and incomplete front view of a rod end are given below in third-angle projection.
Complete the front view.**



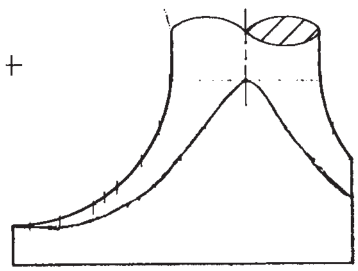
A high percentage of candidates were able to plot intermediate points but were unable to find the three limiting points. Good drawing practice should locate limiting points first.



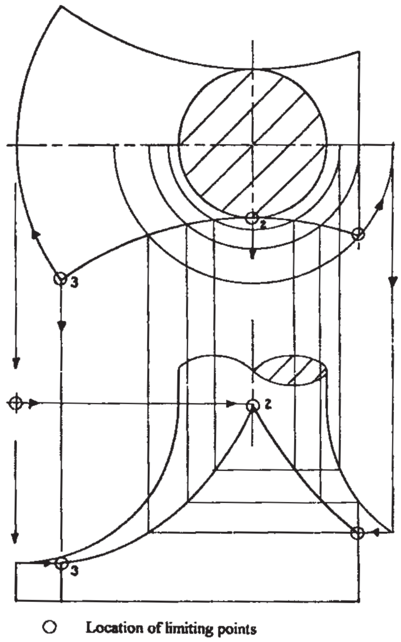
The horizontal and vertical lines, on the left side of the front view, were missed by a majority of candidates.



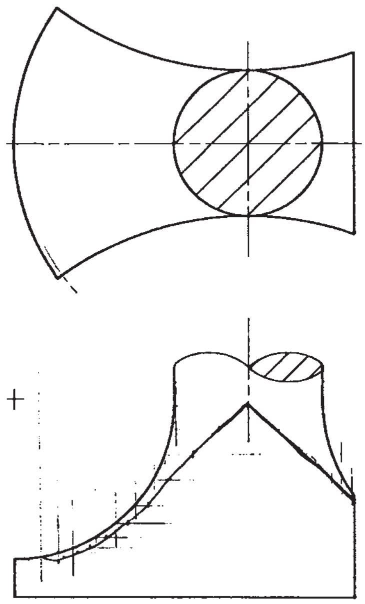
Many candidates located the top point but failed to recognise that the curve should show a sharp point at the top.



The top point is best located by projecting horizontally from the given centre.



Candidates should be aware that drawing of random section planes, which do not line up with adjacent views, will not gain marks. Plotted points must be indicated clearly.

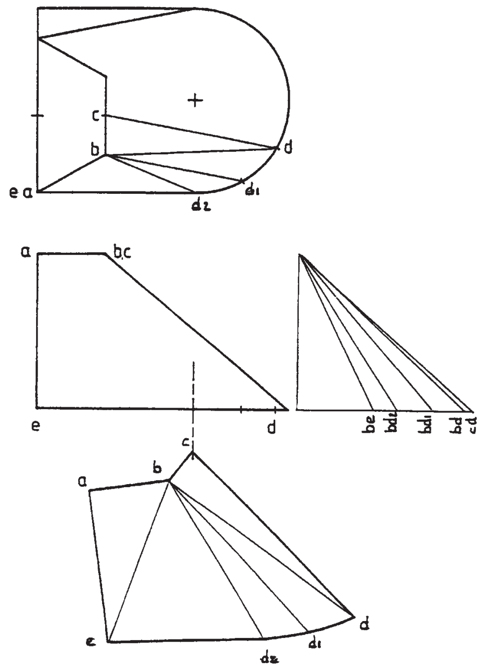


Continuous thick lines should be used for outlines, in this case the curve of intersection. Some candidates wasted time by taking too many section planes. Careful selection of section planes will give a quick, accurate solution.

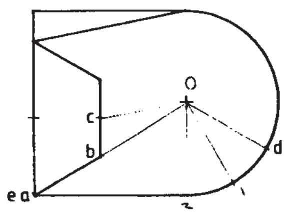
Freehand curves were drawn poorly by a majority of students.

(b) **The top view and front view of a transition piece are given below in third-angle projection.**

Develop a surface pattern for the section abcde. Point, a, and part of the seam are given to start the pattern.



Triangulation in the top view was not well understood, as shown in the example given below.

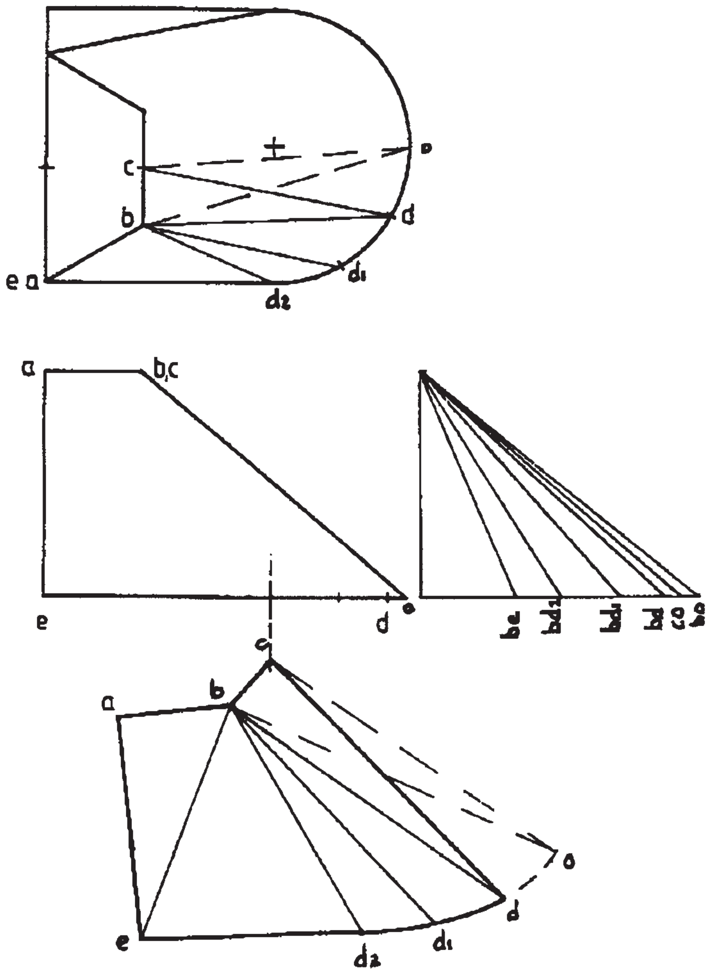


Candidates should work systematically around the pattern to avoid leaving out sections.

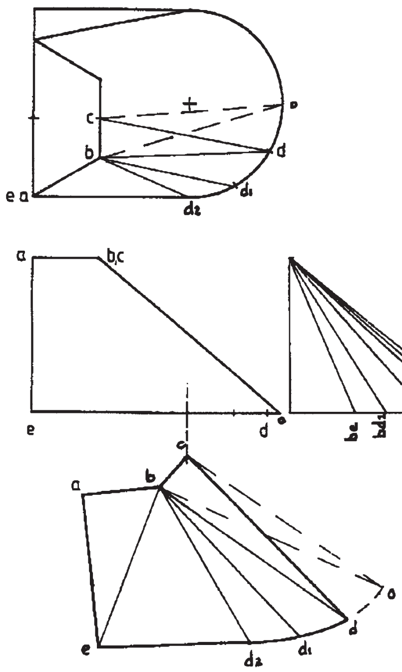
Look at both views when deciding whether a true length needs to be determined. Many candidates joined the curved section, in the development, with straight lines. The positioning of point ‘c’ caused confusion amongst many candidates.

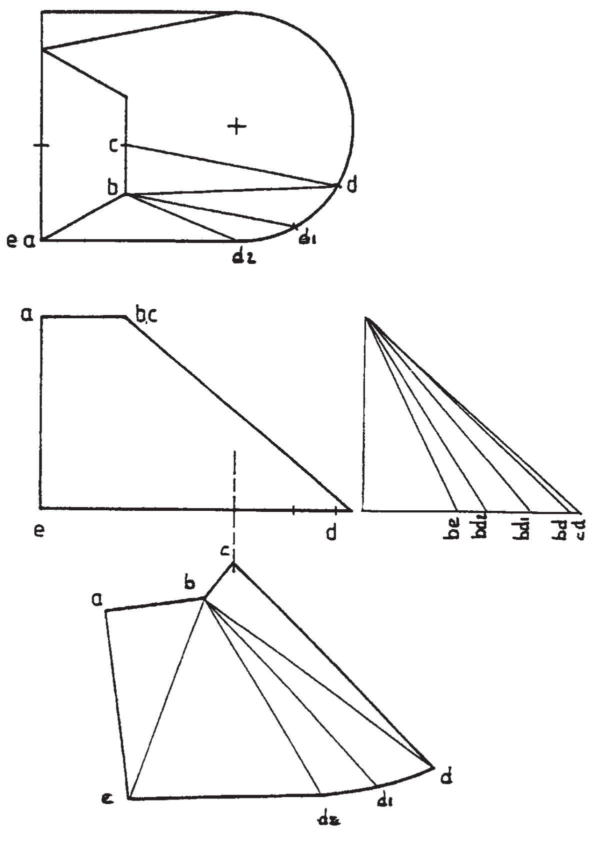
The concept of obtaining true lengths was generally well understood. Many candidates had difficulty in translating this information to the developed surfaces. Few students recognised that the vertical triangle ‘aed2’ was a true shape in the front view. (see solution above)

The following solutions show a number of acceptable ways a solution could be obtained. They are included to promote discussion on the merits of various ways of triangulating a transition piece. Please note that triangle bcd is not flat.



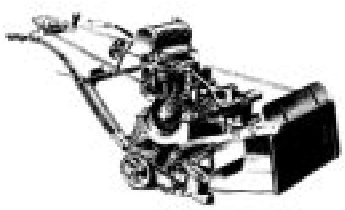
In the example below, the student has recognised that x is the end of the flat area, bcx.



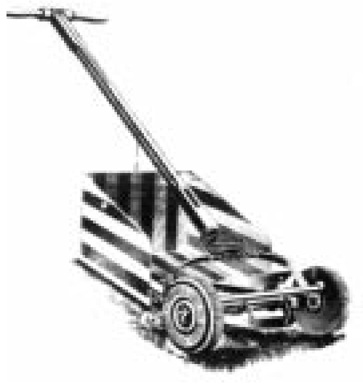


QUESTION 7

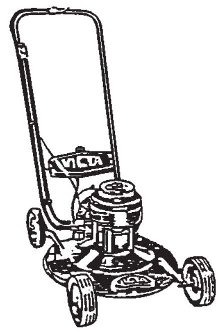
(a) Five examples of lawnmowers are given below.



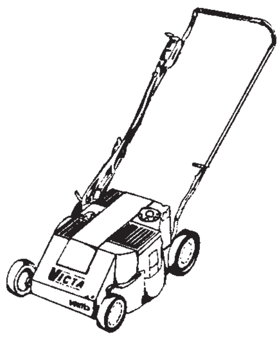
1907 RANSOME
Fig.1



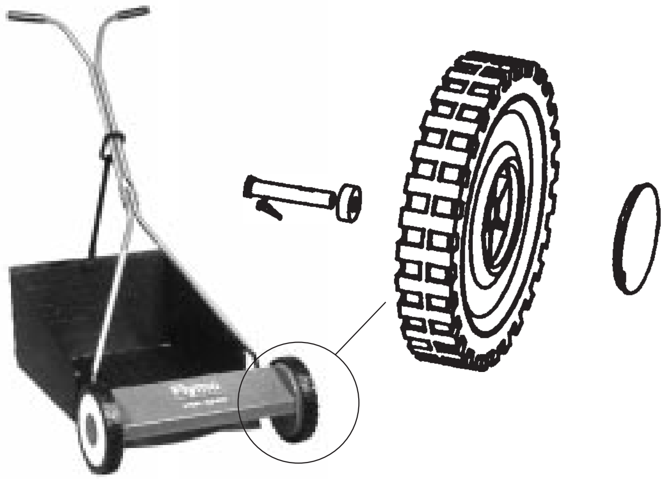
1910 MOWER
Fig.



1950s VICTA 2-STROKE
2Fig. 3



1980s VICTA VORTEX
Fig. 4



1998 MOWER
Fig. 5

(i) State TWO social and/or environmental consequences that have resulted in the change from the mower in Figure 2 to the mower in Figure 3.

1. **Air Pollution, Noise Pollution**

2. **Greater use of fossil fuels**

Most candidates answered this question successfully. They were able to indicate a variety of consequences, although most highlighted the issues of noise and air pollution.

Other candidates touched on areas such as the use of limited resources, increases in leisure time and other environmental factors. Social issues were the most poorly addressed. Answers such as ‘change to a more affluent society after WWII’ or ‘too much effort’ failed to elaborate on the ‘consequences that resulted’.

Social consequences can best be summed up by looking at the changes that have occurred to our daily lives through the introduction of any piece of new technology.

(ii) State TWO social and/or environmental factors that have influenced the change from the mower in Figure 3 to the mower in Figure 4.

1. The need to reduce noise pollution

2. Standards requiring better guarding of moving parts

The majority of candidates successfully sorted out ‘factors’ which ‘influenced’ the changes in design and also indicated a variety of environmental factors (pollution, conformity to Local Council, EPA laws and resource management). Safety issues (ergonomics, personal protection) were paramount. eg ‘Social - fig 4 has a quieter operation - community aspect’.

Some candidates placed no importance on the term ‘influenced’ and simply recounted technological changes that had occurred, without relating them to any social or environmental issue. eg ‘Widespread use of plastic products’; ‘Better production methods.’

On occasion, where students used one or two word responses, their answers were ambiguous and definitely needed qualifying. eg ‘Safe.’ In what fashion did the candidate wish this term to be used? Students should be encouraged to write a sentence for all questions requiring ‘explanation’ or ‘discussion’.

(iii) The mower in Figure 1 used an indirect drive to rotate the cutting blades. The mowers in Figures 3 and 4 used a direct drive to rotate the cutting blades. List TWO advantages of the direct drive over the indirect drive. Do NOT use cost as an advantage.

1. **Fewer moving parts to be maintained**
2. **Less friction between moving parts therefore greater efficiency**

Candidates related their responses to this question in terms of the number of components used in each system and linked that notion to either maintenance, noise or safety. Typical good responses included qualification of the terms used. eg “Less exposed moving parts, improving safety”. Those candidates who performed poorly in this question often simply distinguished different features of the mowers pictured. These students often responded in terms of overall efficiency of the mower or the ease of turning and cutting with the mower. These candidates clearly misinterpreted the question and did not understand the different drive mechanisms and the features associated with each mechanism. eg “Less effort needed” ; “Quicker”; “More efficient”. As with other parts of this question, short answers need to be qualified to gain full marks.

(iv) During the 1990s, the push-cylinder mower in Figure 5 has re-emerged as a popular design. State TWO social and/or environmental reasons for its recent popularity. Do NOT use cost as a reason.

1. **Exercise for operator, less noise pollution**
2. **Less air pollution, smaller lawns**

This portion of the question was well answered. Candidates demonstrated a sound knowledge of factors affecting our society at present. The range of possible answers was considerable, however answers tended to be in terms of an awareness of the environment, physical exercise or maintenance.

(b) (i) The table below lists various components of push-cylinder mowers. Complete the table by suggesting a suitable material used for the components listed.

Component	*1910 mower (Figure 2)*	*1998 mower (Figure 5)*
Handle	**Wood, Wrought iron**	Low-carbon-steel tube
Wheel	**Cast iron**	**HD Polyethylene** **Polypropylene**
Bearing	Bronze bush	**Nylon**
Grass catcher	**Canvas**	**Fibre reinforced polyethylene** **Galvanised mild steel**

In general most candidates demonstrated an awareness of the materials that have historically been used in early mowers, and either knew, or could deduce from the photos, the materials of the 1910 mower. The same did not apply to the 1998 mower. Very poor responses were given for the wheel and the grass catcher, demonstrating a poor understanding of the use of specific polymers in various lawnmower parts. Candidates were not specific in identifying polymers and metals, with generic classification terms being used repeatedly eg 'Plastic', 'Polymer', 'Metal', 'Fabric'. The question asked for a suitable material, and in the example given, gave a specific material.

Students would be well advised to physically examine and discuss examples of 'Integrated Topics' required in the course. eg Bicycles, Lawnmowers etc.

(ii) Explain how a design feature of the mower in Figure 5 makes it safer to use than the mower in Figure 2.

The cutting blades have been enclosed by a guard.

Extremely well answered. Almost every candidate correctly indicated that enclosing the blades of the mower (Fig 5) made it safer than the mower indicated in Fig. 2.

QUESTION 8

(a) A bicycle and rider accelerate from rest at 2 m/s^2 for a period of 10 seconds. The bicycle and rider then travel at a constant velocity before decelerating at 3 m/s^2 until they become stationary. The total distance travelled is 1 kilometre.

(i) Determine the maximum velocity achieved by the bicycle and rider during the journey.

$v = u + at$

$= 0 + 2 \times 10$

$= 20$ m/s

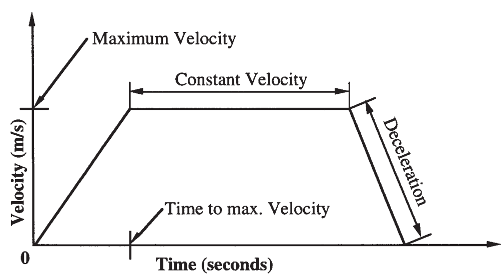
Maximum velocity **20** m/s

The majority of candidates answered this question well. Some candidates introduced irrelevant data and some used more complex equations than were required.

To assist in the analysis of the question, underlining or highlighting key points in each question, listing data that is relevant for each question part and writing the appropriate formula before substituting data, would help many candidates to perform better.

(ii) On the axes provided below, sketch the graph (not to scale) representing the journey. Label on your sketch the:

- maximum velocity
- time taken to reach the maximum velocity
- region representing constant velocity
- region representing deceleration.



The majority of students were able to draw the shape of the graph and indicate the maximum velocity and the time taken to reach it. Regions indicating constant velocity and deceleration were not clearly indicated by all students. Some candidates were unaware that constant velocity is represented by a line which is parallel to the horizontal axis (time). Other candidates incorrectly represented uniform acceleration and deceleration by curved lines.

Candidates would be well advised to: draw and label graphs neatly; indicate all supplied and derived data (20ms-1 from (a) (i)) on the graph; represent uniform acceleration and deceleration on a graph using straight lines; representing constant velocity as a line parallel to the time axis.

(iii) Determine the distance travelled during the period of deceleration.

$$v^2 = u^2 + 2as$$
$$s = \frac{v^2 - u^2}{2a}$$
$$= \frac{0 - 400}{-6}$$
$$= 66.7 \text{ m}$$

OR

$$v = u + at$$
$$t = \frac{20}{3}$$
$$= 6.67 \text{ s}$$

$$s = \left(\frac{u+v}{2}\right)t$$
$$= \frac{20}{2} \times 6.67$$
$$= 66.7 \text{ m}$$

Distance travelled **66.7** m

The majority of candidates answered this question well. Some candidates incorrectly utilised time (10s - given) as velocity in the equation $v^2 = u^2 + 2as$ and others failed to square the initial velocity in the formula $v^2 = u^2 + 2as$.

(iv) Determine the total time taken by the rider and bicycle to complete the 1 kilometre journey.

(iv) Determine the total time taken by the rider and bicycle to complete the 1 kilometre journey.

Total Distance = 1,000 m

For acceleration $v^2 = u^2 + 2as$

$$s = \frac{20^2}{4} = 100 \text{ m}$$ **t = 10s** ..... given in question

For Deceleration $s = 66.7$ m .... from part (iii)

$$t = \frac{66.7}{\frac{20}{-2}}$$
$$= 6.67 \text{ s}$$ **t = 6.67 s**

For constant V $s = 1000 - 100 - 66.7$

$$= 833.3\text{m}$$
$$t = \frac{833.3}{20} = 41.67 \text{ s}$$ **t = 41.67 s**

Therefore Total Time = $10 + 6.67 + 41.67$

$$= 58.3 \text{ s}$$

Total time 58.3 s

The majority of candidates answered this question satisfactorily. Some failed to include the displacement component from the acceleration region together with the displacement component from the deceleration region, in calculating the displacement during the constant velocity. Some students failed to correctly calculate the displacement for the acceleration region with 200m a common incorrect answer. Most candidates had little trouble calculating the displacement for the deceleration region. The 'total time' often was not calculated, even though the time of the three sections of motion had been calculated. Others mixed the time and distance in the one equation.

(b) Bicycle A is travelling in a north-easterly direction at 8 m/s. Bicycle B is travelling in a westerly direction at 3 m/s.

Determine the velocity and direction of bicycle B relative to bicycle A.

$$v = 8\sin 45^\circ \quad = 5.66$$

$$h = 8\cos 45^\circ \quad = 5.66$$

$$h + 3 = 5.66 \ + \ 3 \ = 8.66$$

$$R = \sqrt{8.66^2 + 5.66^2}$$

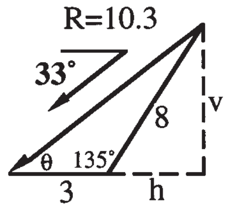
$$= 10.34 \text{ m/s}$$

$$\sin^{-1}\theta = \frac{v}{10.34}$$

$$= \frac{5.66}{10.34}$$

$$\theta = 33.3^\circ$$

Or by the Cosine Rule



Note: Graphical solution is also acceptable

$$\cos 135° = \frac{3^2 + 8^2 - c^2}{2x3x8}$$

$$c^2 = 106.9$$

$$\therefore \quad c = 10.34$$

$$\frac{8}{\sin\theta} = \frac{10.3}{\sin 135°}$$

$$\sin\theta = \frac{8\sin 135°}{10.3}$$

$$\therefore \quad \theta = 33.3°$$

Relative velocity **10.34** m/s

Relative direction **33°**

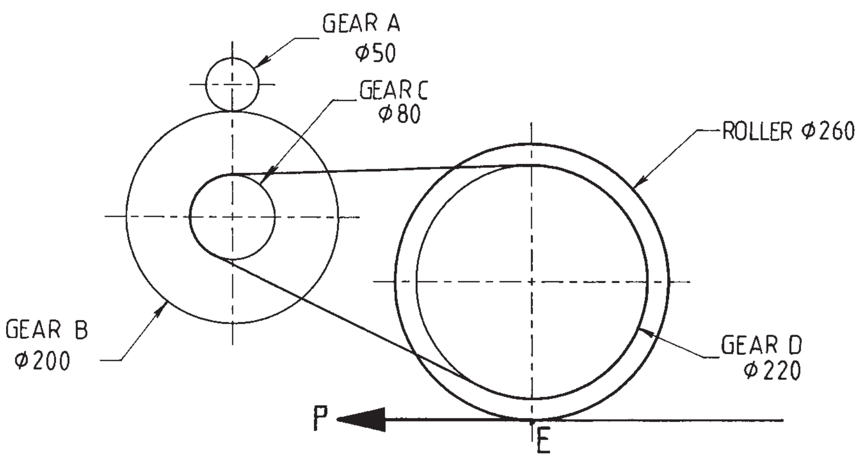
This question proved difficult for many students. The concept of relative velocity was not well understood. Most attempted to solve this question using graphical solutions or by using the cosine rule. Very few candidates tried to solve this question using components. Graphical solutions were given a 5% margin for error.

The common errors were: incorrect vector addition/subtraction; sense incorrect for the resultant, indicating lack of understanding of the question B relative to A, and not vice versa. The sense of the Resultant was given in many formats including polar coordinates, true bearing, angle to the horizontal, angle to the vertical and angle to the NE vector. Many who used the cosine rule incorrectly used 450 instead of 1350 as the included angle opposite the resultant. Many also failed to apply the sine rule to calculate the angle of the Resultant.

Candidates should note: graphical solutions are often the easiest; graphical solutions need to be to an appropriate scale; the sense and the direction of the resultant needs to be clearly indicated.

QUESTION 9

The drive mechanism for a lawnmower is given. Gear A on the motor shaft rotates at 2400 r.p.m. and drives Gear B. Gear C uses a chain to drive Gear D on the roller. The diameter for each gear is given.



(a) (i) Determine the overall velocity ratio of A:D.

$$VR = \frac{\text{Driver}}{\text{Driven}} \times \frac{\text{Driver}}{\text{Driven}}$$

$$= \frac{50}{200} \times \frac{80}{220} \qquad \text{VR} \qquad A : D :: 11 : 1$$

$$= \frac{1}{11} \quad \text{or} \quad 0.09$$

V.R. **11:1**

The part discriminated between candidates. Full marks were allocated where the correct reduction ratio was determined. ie. VR = 11 : 1. Unnecessary marks were lost by some candidates when an increased ratio was given ie. VR = 1 : 11. The correct ratio may be calculated using radii, diameters or circumferences, providing they are used consistently.

(ii) Determine the speed, in revolutions per minute, of Gear D.

Gear A = 2400 rpm

Gear D = ^{2400} 218.2

Speed of Gear D 218.2 r.p.m.

Most students understood the Gear A to Gear B, and Gear C to Gear D ratios and gained marks. Problems arose when students used the ratio of Gear B to Gear C which is clearly incorrect. A few students tried to apply a circular motion formula to this question.

Most students realised that the drive mechanism produced a reduced rpm at Gear D. Students are reminded that they can still gain full marks for part (ii) even if their VR from part (i) is incorrect; provided that they apply the ratio consistently.

(iii) The motor delivers 1.5 kW of power to the motor shaft. Determine the power transmitted to the gear on the roller if the system has an efficiency of 90%.

$$\text{efficiency} = \frac{\text{output}}{\text{input}}$$

$$\text{output} = 0.9 \times 1.5$$

$$= 1.35$$

Power **1.35** kW

Most students scored well using efficiency correctly. However a common mistake was to divide by 0.9 instead of multiplying by 0.9. This gave an increased output instead of a reduction in output.

(b) For a different motor output, the roller travels a distance of 80 m in 90 seconds. The tangential driving force P, at point E, is 500 N. Determine the power transmitted by the system.

$$P = Fv$$
$$= 500 \text{ x } \frac{80}{90}$$
$$= 444.4 \text{ W}$$

$$W = Fs$$
$$= 500 \text{x} 80$$
$$P = \frac{W}{t}$$
$$= \frac{40\,000}{90} = 444.4 \text{ W}$$

Power **444.4** W

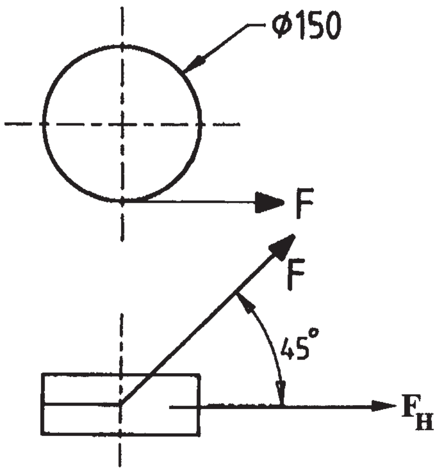
The selection of the appropriate formula was the major hurdle for students in this part. Students tended to either be successful or do poorly. Many students missed 'for a different motor output', and included the 90% efficiency (from part a (iii)) in their calculations. It is important for candidates to read the question carefully.

(c) The starter cord of a lawnmower is connected to the recoil-start mechanism as shown below.

Determine the minimum force F, on the starter cord if a torque of 5·9 N m is required to start the motor. The mechanism is 90% efficient.

Solution 1

$$T = F_H \text{ x } r$$
$$5.9 = F_H \text{ x } 0.075$$
$$F_H = 78.7$$



$$F = \frac{F_H}{\cos 45^\circ} = \frac{78.7}{\cos 45^\circ}$$
$$= 111.29 \text{ N}$$

$$\text{Efficiency} = 90\%$$
$$\text{Input} = \frac{\textit{Output}}{\textit{Efficiency}}$$
$$= \frac{111.29}{0.9}$$
$$= 123.7$$

Solution 2

$$T = F \text{ x } 0.075 \text{ x } \cos 45^\circ \text{ x } 0.9$$
$$5.9 = F \text{ x } 0.075 \text{ x } \cos 45^\circ \text{ x } 0.9$$
$$F = 123.7 \text{ N}$$

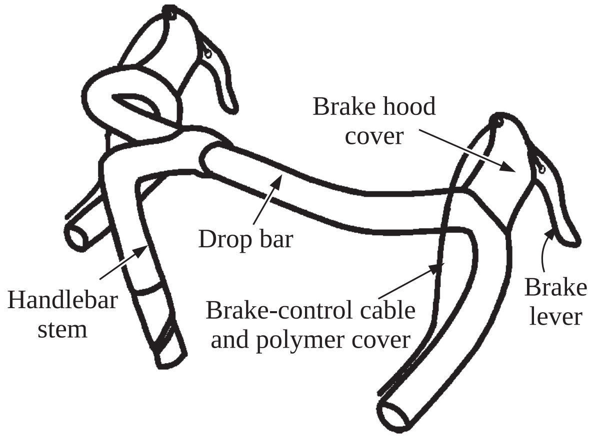
Force F **123.7** N

To score well in this part, students needed to recognise the three major steps required in the solution. The three steps were: using a moment equation and substituting correctly; calculating F from its horizontal component; and applying the correct efficiency.

Marks were also allocated for consistent units, and were lost when students forgot to apply the 90% efficiency. Most students who answered the question correctly used the method shown in Solution 1.

QUESTION 10

A pictorial drawing of a bicycle handlebar is shown below.



(a) The brake hood cover is manufactured by injection moulding from high-density polyethylene.

(i) Describe the injection moulding process.

Granulated plastic is heated to a viscous state, and forced through a nozzle, into a mould where it solidifies.

(ii) An alternative material for the brake hood cover is polystyrene formed by compression moulding. What effect does temperature and pressure have in this process?

Temperature and pressure promote polymerisation.

Very poorly answered. The majority of candidates showed lack of understanding of the compression moulding process. Candidates appear unaware that a measured amount of polymeric powder is used and that polymerisation occurs under the influence of heat and pressure.

(iii) Name and describe a process that may be used to form the polymer cover for the brake-control cable.

Name of process **Extrusion**

Description

Granulated plastic is heated to a viscous state and forced through a die directly onto the wound cable carrier which is also fed through the die.

Generally a good response. Common errors included ‘forced into a mould’, implying injection moulding, and ‘pulled through a die’ implying drawing (metal wire). The wire cable is inserted in the cover, ready for use.

Students would be well advised to physically examine a Bowden Cable and other Integrated Topic components looking at their historical development, materials used, manufacture, properties and function.

(b) (i) The drop bar and the handlebar stem are made from 0.7% carbon steel tube. State ONE advantage and ONE disadvantage of using this steel compared to an aluminium alloy. Do NOT use cost as a consideration.

Advantage **Increased stiffness**

Disadvantage **Increased weight**

Approximately half of the candidates were unable to give a satisfactory response in this part. General and unacceptable terms such as ‘strong’ or ‘durable’ were common. A qualified answer such as ‘increased’ or ‘greater’ are required in this type of question to gain full marks. The disadvantage response proved difficult.

(ii) The drop bar of the bicycle is plated with a thin layer of chromium. State TWO reasons why the drop bar is plated.

1. **Increased hardness**
2. **Improved surface finish**

It must be stressed that when a comparison response is needed, the answer must be qualified in some way. General responses like ‘looks good’, ‘pretty’ or ‘rusts’ are vague and inadequate to gain a mark.

(iii) Name a cold-working process that would be used in forming the shape of the drop bar from extruded 0.7% carbon steel tube.

Form bending

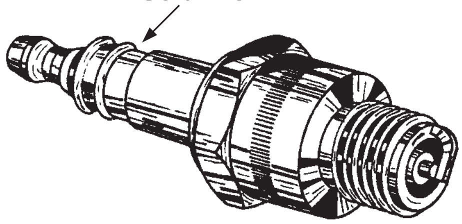
The forming process was poorly answered. Many students named a tube forming process like piercing or extrusion instead of naming the cold working process to bend the tube into shape. Some gave ‘forging’ as an answer, which is an inappropriate process to be used on a tube. The carbon content stated in the question is much higher than that normally used for this application.

(iv) Give ONE reason why a cold-working process is used rather than a hot-working process to form the drop bar.

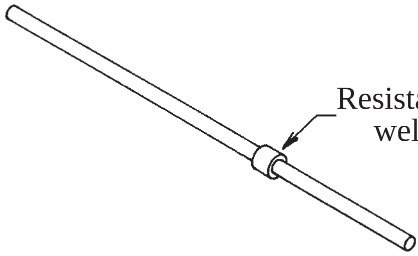
Cold working increases the stiffness and toughness of the bar.

The majority of candidates were unable to relate the process of cold working to the properties required of the drop bar. Explanations such as ‘easier’ or ‘cheaper’ is irrelevant to the use of the drop bar. Some students answered in terms that ‘hot working produces...’ This does not inform the examiner of what students know about the cold working process.

(c) A spark plug and the central electrode are shown below.



Spark plug



Central electrode

(i) State TWO service properties of the ceramic used in the spark plug.

1. **Electrical insulation**
2. **Heat resistance**

A service property is a property required of the material in use. Many students gave general properties of ceramics, such as "hard and brittle", which were out of context of the use of the spark plug.

(ii) Suggest a clay-bodied ceramic that may be used.

Alumina, Porcelain

Candidates displayed a poor knowledge of a suitable material. For this application, the ceramic needs to have a homogeneous structure with high thermal shock properties. Alumina (Al2 O3) can be highly compressed, very fine and pure ceramic, that when sintered is extremely resistant to thermal shock.

Background Notes: A spark plug insulator is manufactured by isostatic pressing, where the alumina powder is placed in a rubber mould, and then compressed under high pressure to form the shape of the insulator. It is then removed and sintered. Sintering ensures that the powder bonds by solid state diffusion, forming a polycrystalline structure with minimal void space. The product is dense and coherent. The surface is then coated with glaze and fired to form a glass on the surface to assist with electrical insulation and to prevent moisture or oil penetrating the void space and breaking down the electrical properties.

Many students gave Kaolinite as an answer. This is a clay and a major raw ingredient for clay based ceramics, but as such would not be suitable for the insulator in service.

(iii) The central electrode is a two-part component which is resistance welded. Describe this welding process.

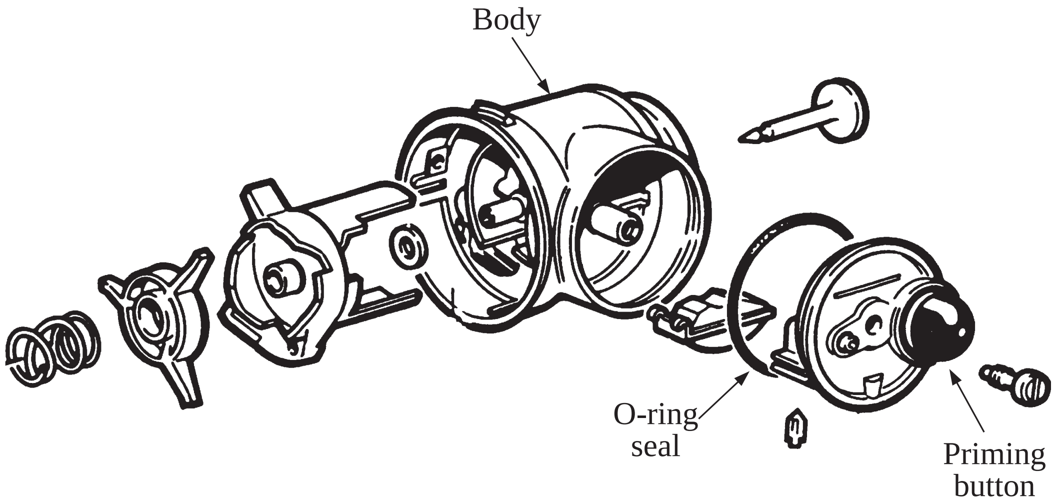
The rod ends are brought together and a high amperage electric current is used to produce localised heating at the ends.
This localised heating, along with localised pressure, causes the ends to fuse together.

The rod ends are brought together and a high amperage electrical current is used to produce localised heating at the ends. The rod ends melt and they are forced together for fusion (welding) to occur.

Candidates had little understanding of the resistance welding process, and often described electric or stick welding. Resistance welding involves no filler rod to join the parent metals. The electricity provides the localised heat to allow fusion to occur. This process is particularly useful in joining dissimilar metals.

QUESTION 11

A pictorial assembly diagram of a lawnmower carburettor is shown below. The body is made from 30% glass-filled polyester. The priming button and the O-ring seal are made from neoprene rubber.



(a) (i) List TWO service properties of the composite material used for the body.

1. Resistance to solvents, particularly fuel

2. Dimensional stability at operating temperature

Generally this question was well answered by the candidates; who displayed a good knowledge of the properties of polymer based composites, although many candidates did not relate the polymer properties to the properties of the component.

The term ‘service properties’ was poorly understood by many candidates. Service properties are those required by that component to function efficiently while in use.

The service properties need to relate specifically to the material in question (polymer-glass composite in this case). eg. ‘Resistant to solvents’ rather than ‘corrosion resistant’ which relates more to metal.

Candidates are encouraged to practice analysing the service properties and manufacturing properties of commonly known components.

(ii) What is the purpose of adding 30% glass fibre to the polyester material used to make the body?

The glass fibres enable the composite material to maintain accurate shape and size during cooling from elevated forming temperatures.

Candidates displayed a good knowledge of the properties that the glass fibres contributed to the composite material. Many candidates were able to qualify the effect that the glass had on the properties identified, eg 'increased rigidity' as opposed to 'rigid'. Some candidates were able to relate the improved properties to the specific component which showed a deeper understanding of the topic.

this adds ridgidity to object
aswell as allowing good dimensional
accuracy

(iii) Name the process and the additive used to change the properties of rubber to make it suitable for the O-ring seal.

Name of process Cross linking / Vulcanisation

Additive Zinc Oxide or Magnesium Oxide

A very well answered question with the majority of candidates able to correctly name the process and the additive. Some students offered additional information as to the mechanism of vulcanisation or its effect on the properties of the rubber. Candidates are reminded that if additional information is incorrect it may incur some loss of marks.

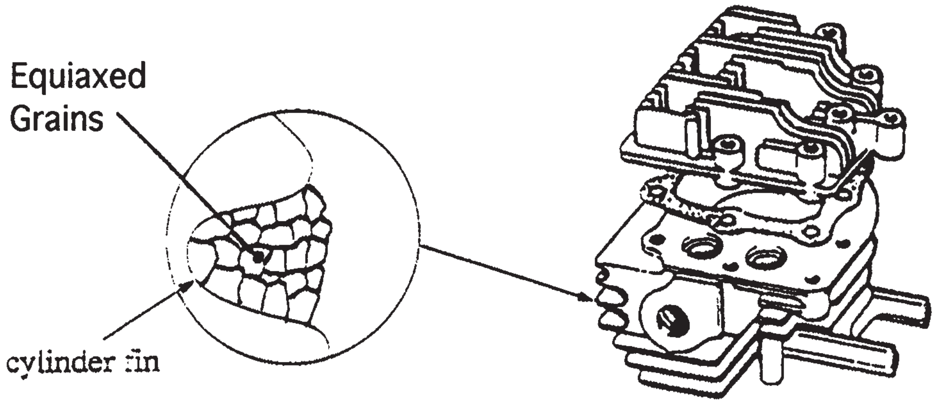
(iv) Over a period of time in service, the rubber in the priming button is exposed to the atmosphere. State the effect that this exposure could have on the properties of the rubber.

The rubber will lose its flexibility and become harder and more brittle.

Many candidates misinterpreted the question and failed to respond in terms of the specific properties of the rubber. Candidates are advised to read the question carefully and take note of the important words or phrases in the question. (Underlining those words or phrases may help draw attention to those terms when answering the question).

It could crack and deteriorate
reducing its flexability.

(b) The cylinder body and cylinder head of a lawnmower engine are shown below. The cylinder body is manufactured by sand casting of cast iron.

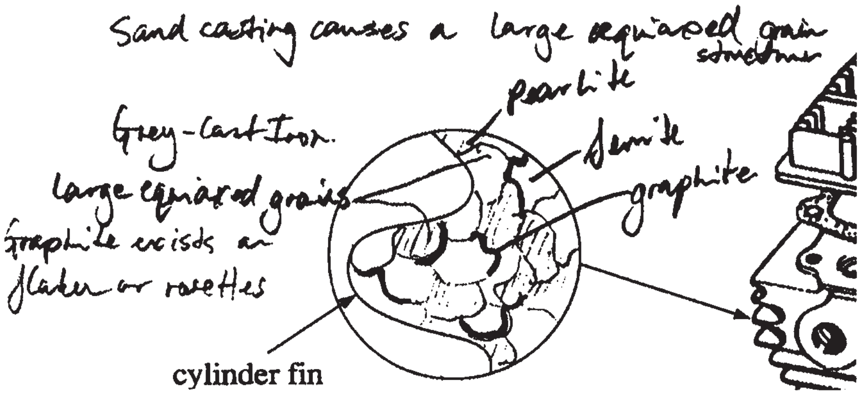


(i) On the enlarged portion of a cylinder fin, sketch and label the grain structure that results from sand casting.

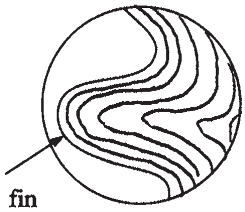
Overall this question was answered poorly with most candidates unable to draw the typical 'as-cast' structure produced in a sand mould where the sand acts to insulate the cast metal and allows it to cool slowly. Many candidates answered in terms of a cast iron microstructure and often showed little knowledge of a suitable type of cast iron. Candidates are reminded that microstructures and macrostructures must be drawn carefully, showing some appreciation of the correct grain size and shape. They must also show the essential features very clearly. (eg grains drawn as circles in an unknown matrix should be avoided.)

Many candidates gave answers which showed that they were unfamiliar with the lawn mower engine cylinder body and particularly the cooling fins, their shape, size and function.

Better solutions were drawn showing evidence of casting. Below is a good answer that indicates slow cooling and the student has displayed his knowledge of the microstructure of grey cast iron.

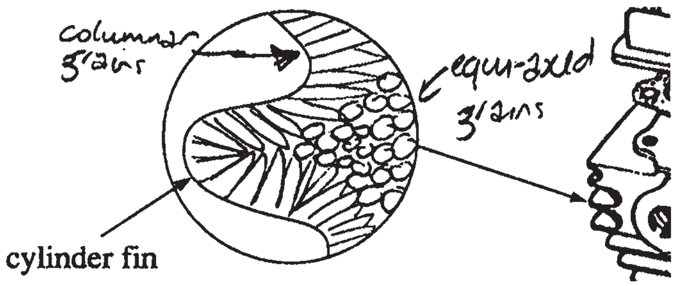


Some candidates wrongly included grain flow in their response and were clearly confusing the macrostructure produced by forging with that produced by sand casting. eg



Although the profile of the fin shown in the paper was a little different to a thin piece of metal to assist in heat loss, some candidates attempted to show a cast structure. Elongated columnar grains would be expected in thin metal cooling fins particularly if cast in a metal mould. The structure below was accepted for part marks.

The grains need to be shown as being polycrystalline. This sketch implies that there are void spaces in the structure. Equiaxed grains are found where cooling is equal in all directions, and is a particular feature of sand cast structures.



It is strongly recommended that candidates familiarise themselves with the various components in each of the integrated topics.

(ii) **Cylinder heads are manufactured by die casting of aluminium alloys.**
State TWO advantages of die casting over sand casting.

1. **Better accuracy and surface finish and so less machining needed.**
2. **Reusable moulds allow increased production rates.**

Most candidates answered these questions well and demonstrated a clear understanding of the process, and its advantages over sand casting.

(iii) **During some sand casting processes, sand cores may be used.**
State two reasons for using sand cores.

1. **In hollow castings cores reduce the amount of metal needed and also reduce stresses which may occur during shrinkage.**

2. **Sand cores are easily removed after cooling and reduce the need for machining.**

This question was well answered by the majority of candidates. It should be noted here that responses that are brief and direct are usually best, eg. "to make internal cavity shapes".

1. if object is to be hollow in the centre
2. save material rather than just machining it out

(c) (i) Brazing is used to join the frame of a low-carbon-steel bicycle. State TWO reasons for the use of a flux during the brazing process.

1. Cleans the surfaces to be joined and prevents oxides forming.

2. Assists the flow of the spelter.

The knowledge of the functions of flux was generally well understood with some candidates displaying a deeper level of knowledge including the role fluxes play in beginning capillary action from spelter and in surface alloying between the parent metals and the spelter.

1. To help the flow of the brazing metal into gaps
2. to clean the surface area

(ii) State the main difference between hard soldering and gas welding.

Gas welding involves the melting of the parent metals while in hard soldering the parent metal is heated to below its melting point.

This question was generally poorly answered with the majority of candidates responding in terms of different levels at applied heat without specifically mentioning melting at parent metals.

Hard soldering, which includes brazing, was not well understood as the joining process which utilised solders at much higher melting points than soft soldering.

Again candidates are encouraged to underline key words in the question (such as "main difference") and specifically address them in their response.

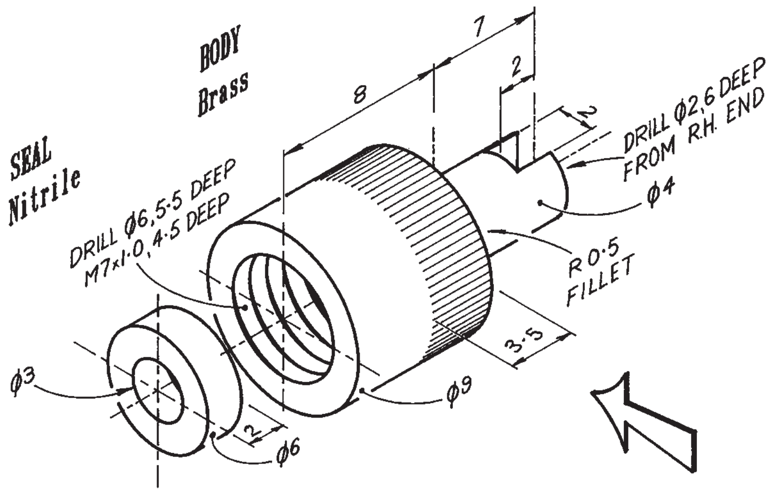
(ii) State the main difference between hard soldering and gas welding.

The parent metal is not melted in hard soldering whereas in gas welding it is and alloys with the filler rod.

QUESTION 12

The shape and size details of a bicycle valve cap are given below in the exploded pictorial drawing. The valve cap is also used to remove the valve from the stem.

Draw, to a scale of 5:1, a half-sectional front view of the assembled parts when viewed from the direction of the arrow. The centre line is given for the drawing.



This question examines aspects and disciplines in Engineering Drawing including: interpreting and reading pictorial representation of engineered components; assembly drawing; detail drawing; sectioning of components; and application of AS1100 drawing standards.

The mean was slightly above half marks for this question, with very few candidates receiving full marks or zero.

The marking scale is designed to objectively and consistently recognise and reward all correct responses made by candidates. In designing the marking scale, the correct solution is broken into a number of components, or features, and these are then examined for: representation of the shape concept; size; relationship with other features; and representation according to the AS1100 drawing standards.

As an example, the drill hole of 6mm diameter and 5.5mm length, in the question, would be broken down into the following four responses for marking:

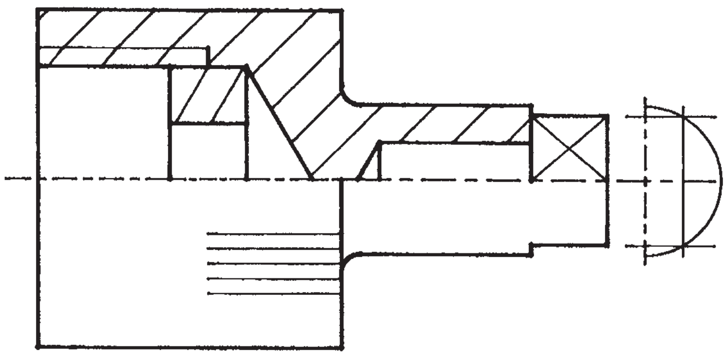
Drill hole outline, Shape of the end of the drill hole, diameter 6, length 5.5, 600 angle for the drill end.

All components are treated in this manner by allocating a tick to each aspect of the component. This system allows every step which is taken by the student to complete the response to the question.

Once the ticks for each component are totalled, a conversion scale is used to convert the number of ticks obtained to a final mark. For example, a candidate who totals 24 correct responses would score a final mark of 8.5 for the question this year. The conversion process allows candidates to achieve full marks and marks in respect to the correctness of the solution. Below is included the marking detail.

Main Body		Shape , O9 , L8	✓ ✓ ✓
	Drill Hole	Shape , O6 , L5.5, 60	✓ ✓ ✓ ✓
	Thread	Shape , Depth 0.5, L4.5, Thin Black	✓ ✓ ✓ ✓
	Seal	Shape , O3, T2, Position	✓ ✓ ✓ ✓
	Knurl	Concept, I.3.5	✓ ✓
	Fillet	Shape , R0.5, Shape	✓ ✓ ✓
Neck		Shape , O4, L7	✓ ✓ ✓
	Drill Hole	Shape . O2 , L6	✓ ✓ ✓
	Slot	Shape , Aux View, L2, Flat	✓ ✓ ✓ ✓
		LH End, Hole Shoulder	✓ ✓
Sectioning		½ Section Concept, Body, Seal	✓ ✓ ✓
		Thin Black, Hatching Concept	✓ ✓

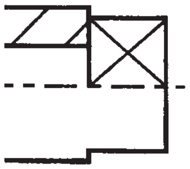
Shown below is the correct solution.



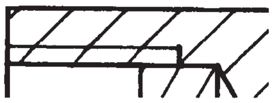
The candidates' responses to this question indicated a reasonable knowledge of general assembly drawing, however some aspects of the question were poorly answered. Many candidates failed to display an understanding of the practical manufacture, assembly and use of machined parts. This was evident by the failure to assemble the seal into the end of the drilled hole; poor understanding of the drilling and tapping of holes; and not sectioning the body as one complete solid piece of metal. This could be redressed by examining a wide range of components / parts of the integrated topic area, discussing their manufacture, measuring and sketching views, sectioning and assembly.

The concept of half-sectioning was poorly understood. Many candidates included full sections, and often included hidden detail. This meant that features such as the knurl were not shown, and therefore marks could not be awarded.

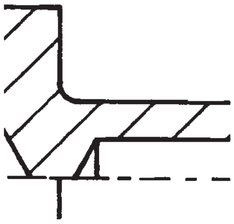
Candidates’ understanding of the drawing standards was generally poor. Areas of concern included: Representation of a flat surface. This area is shown by using thin black diagonals, as shown on the half slot on the right hand end of the solution.



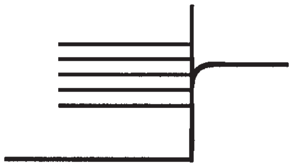
Representation of an internal thread. Appropriate thick and thin lines are required. In this case the thread is internal, and the minor diameter of the thread is thick, because it forms the edge of the hole. The major diameter is thin.



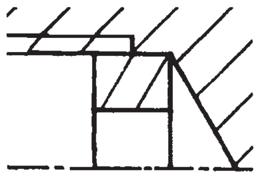
Representation of the drill end. This should have an included angle of 1200 to represent the surface left by the drill in a blind hole.



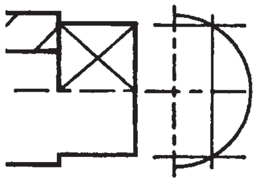
Representation of commonly used machine features, eg straight knurling.



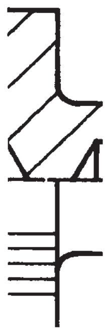
Sectioned surfaces. It is important that different components be distinguished from each other. Some candidates still include too many lines, too close together, wasting valuable examination time. Many also failed to hatch the threaded area.



Candidates generally failed to construct an auxiliary side view of the neck (right hand end), from which the height of the slot in the front view could be projected.



Candidates also generally failed to correctly interpret the fillet curve; a small radius (0.5mm) curve between the main body and the neck. Some candidates also lost time and accuracy by not using a circle or radius gauge for these small curves.



Areas where markers felt there has been a pleasing improvement in candidate responses include: overall shape and sizes of most features, including lengths and diameters; interpretation of the pictorial drawing; drawing the object to the stated Scale of 5:1; and the higher accuracy of the drawings.

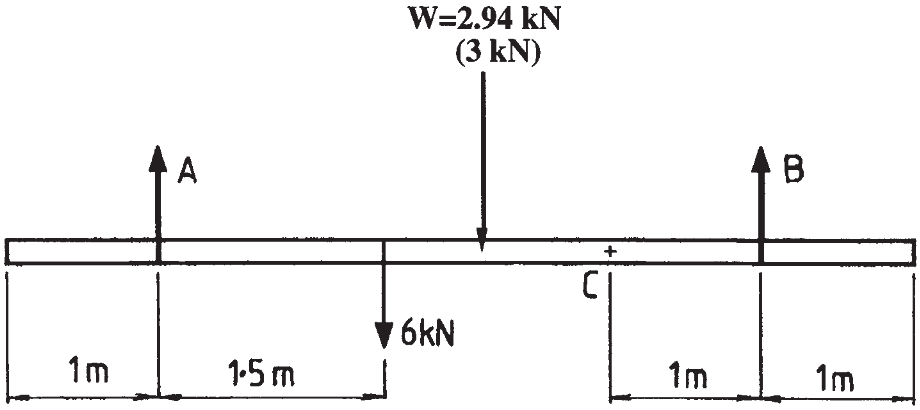
Advice to candidates for this type of question includes: take care with the size of the components so that they are drawn accurately; learn AS1100 drawing standards for things like threads, knurls, flats, nuts, bolts and hatching; do not erase any construction lines; use two different clutch pencils for drawing, eg 0.25 and 0.5 so that variation in line thickness can be easily distinguished. For some students 0.25 and 0.7 may be more suitable for their drawing 'hand'; and separate the examination booklets (Sections I and II) to make the drawing easier.

From a teaching point of view, students should be given a practical 'hands-on' approach so that they may better understand drilling, tapping of a hole, and then cutting the piece in half to view the appearance before sketching or drawing the component. It has been repeated a number of times in this report, that students need to examine as many real components of the topic areas as possible. It is obvious by students' responses through the paper, that many students have not examined or discussed the components as what would be expected.

3 Unit (Additional)

QUESTION 1

(a) Details of a 6 m long steel beam are shown below. The beam is suspended by two steel cables, A and B. The beam has a mass of 50 kg/m.



(i) Determine the forces in cables A and B.

$$\circlearrowright + \sum M_A = 0$$
$$= (1.5 \text{x} 6) + (2 \text{x} 2.94) - 4\, R_B$$
$$R_B = 3.72 \text{ kN} \uparrow$$

$$+\uparrow \sum F_V = 0$$
$$= R_A + R_B - 6 - 2.94$$
$$R_A = 5.22 \text{ kN} \uparrow$$

Force in cable A **5.22** kN

Force in cable B **3.72** kN

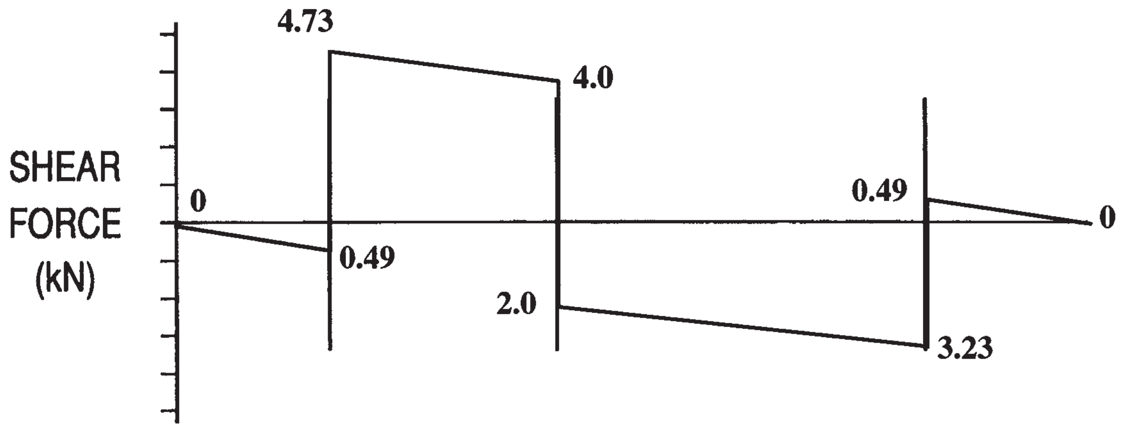
This part of the question examines the candidateís understanding of proportioning the applied loads to the reactions using a moment equation. A significant number of students did not include the self-weight of the beam (50 x 9.8 x 6 = 2940N) in the moment equation.

When taking the sum of the moments of all the forces for an object, it is important to:

- Ensure that all the applied and reactive forces are identified;
- Choose an appropriate point about which to sum the turning moments. (usually a point where one unknown force is acting - in this case either point A or B);
- Ensure that every entry into the moment equation consists of a force multiplied by the relevant distance;
- Use correct perpendicular distances;
- Take the self-weight of the beam to act at the centre of the beam for this moment equation.

A large number of candidates made mistakes in one or more of these areas.

(ii) Draw and label the shear force diagram for the beam.

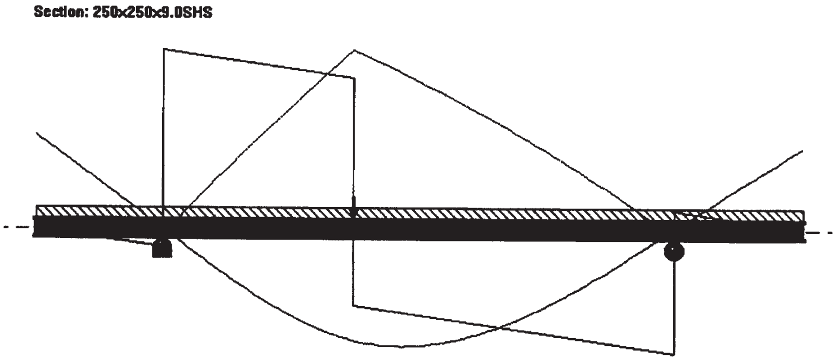


A significant number of candidates again had difficulty in dealing with the self-weight of the beam. This 'uniformly distributed load' (UDL) gives the shear force diagram a slope. The sign of the shear force is considered irrelevant unless this value is being used to calculate the sign of the Bending Moment.

There are different techniques for plotting the shear force diagram but the following points are worth remembering:

- A free end (no support) will always have a S.F.= 0 at that point;
- A concentrated load will produce a step in the S.F. diagram. The value of the step being equal to the value of the concentrated load. There are three steps in this solution and their values should be equal to RA, 6kN and RB.

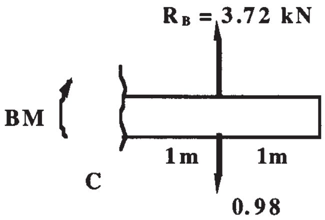
Only a minority of candidates were able to draw the diagram with correct values.



In the example above, a computer generated calculation for the beam in the question, shows shear force, bending moment and deflection information.

(iii) Determine the bending moment at point C, 2 m from the right-hand end.

(iii) Determine the bending moment at point C, 2 m from the right-hand end.



$$\sum M_C = 0$$

$$0 = BM - (3.72 \times 1) + (0.98 \times 1)$$

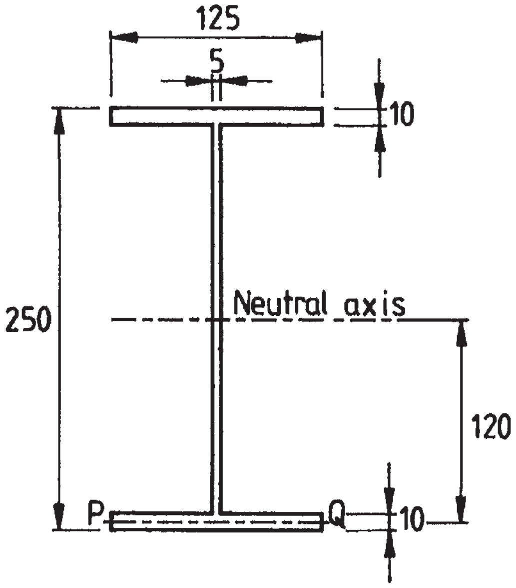
$$2.74 \text{ kNm} = BM$$

Bending moment at C **2.74** kN m

This part requires candidates to calculate the bending moment by taking a section of the beam when it is cut at point C. Either the left or right hand sections can be used. It is usual to take the section with the least number of external forces. The free body diagram for the right end is drawn above.

The method of calculating the bending moment is to sum the turning moments about point C. The self-weight of this section can be assumed to act at the mid-point of the section.

(iv) For a different loading, the bending moment at point C is 3.65 kNm. A cross-section of the beam at point C is shown below. Determine the stress in plane PQ.



$$I = \frac{b_1 d_1^3}{12} - 2\left(\frac{b_2 d_2^3}{12}\right)$$
$$= \frac{125 \times 250^3}{12} - 2\left(\frac{60 \times 230^3}{12}\right)$$
$$= 4.1 \times 10^7 \ \text{mm}^4$$
$$= 4.1 \times 10^{-5} \ \text{m}^4$$

$$\sigma = \frac{My}{I}$$

$$= \frac{3.65 \times 10^3 \times 120 \times 10^{-3}}{4.1 \times 10^{-5}} \quad \textbf{OR} \quad = \frac{3650 \times 120}{4.1 \times 10^7}$$

$$= 10.68 \text{ MPa} \qquad = 10.68 \text{ MPa}$$

Stress in plane PQ **10.68** Mpa

This part of the question requires the candidate to show an understanding of the calculation of stress (σ) due to a Bending Moment as well as the Second Moment of Area (I) for the section. Candidates must be careful in their choice and use of consistent units at the initial stages of the calculations as later conversion is difficult. One set of consistent units is Newtons and metres which will give an answer in Pascals. Another set of consistent units is Newtons and millimetres which will give the answer in Megapascals.

Candidates must be able to calculate the I of a complex shape, such as this beam, using the equations for basic shapes. In this case the basic shape used is the rectangle.

$$\mathbf{I}_{\text{beam}} = \mathbf{I}_{\text{total shape}} - \mathbf{2}\ (\mathbf{I}_{\text{side rectangles}})$$

The most common errors involved:

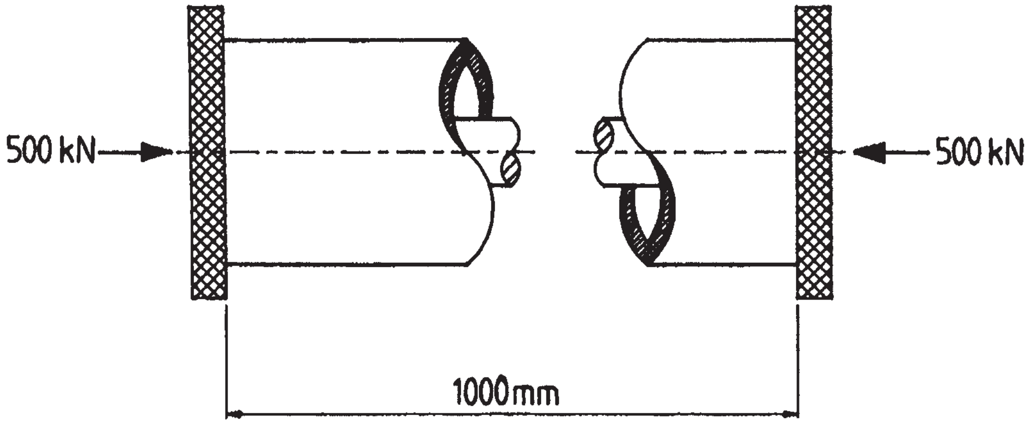
- incorrect mixture of units such as 3.65 kNm with a value for y in millimetres;
- the incorrect value for y;
- an inability to calculate Second Moment of Area for the section.

(b) An aluminium tube and a solid steel bar, as shown below, are compressed by a force of 500 kN.

$E_{\text{aluminium}}$ = 70 GPa   Cross – section area $_{\text{aluminium}}$ = 700mm2

E_{steel} = 70 GPa   Cross – section area $_{\text{steel}}$ = 180mm2

Determine the forces in the tube and the bar.



$$500\text{x}10^3 = L_A + L_S \rightarrow L_s = 500\text{x}10^3 - L$$

$$\varepsilon_A = \varepsilon_S$$

$$\text{Therefore} \quad \frac{L_A}{A_A E_A} = \frac{L_S}{A_S E_S}$$

$$\frac{L_A}{7\text{x}5^4\text{x}70\text{x}10^9} = \frac{500\text{x}10^3 - L_A}{1.8\text{x}10^{-4}\text{x}200\text{x}10^9}$$

$$\frac{L_A}{49\text{x}10^{-4}} = \frac{500\text{x}10^3 - L_A}{36\text{x}10^{-4}}$$

$$36L_A = 49(500\text{x}10^3 - L_A)$$

$$85L_A = 24500\text{x}10^3 \text{ N}$$

$$L_A = 288.2 \text{ kN}$$

$$L_S = 500\text{x}10^3 - L$$

$$\text{Therefore} \quad L_S = 500 - 288.2$$

$$L_S = 211.8 \text{ kN}$$

Force in tube **288.2** kN

Force in bar **211.8** kN

For a composite section that is stressed, the starting point is to recognise that the load is shared.

$$\mathbf{500 \times 10^{3} = L_{\text{Aluminium}} + L_{\text{Steel}}}$$

and the strain is the same in both parts.

$$\varepsilon_{\text{Aluminium}} = \varepsilon_{\text{Steel}}$$

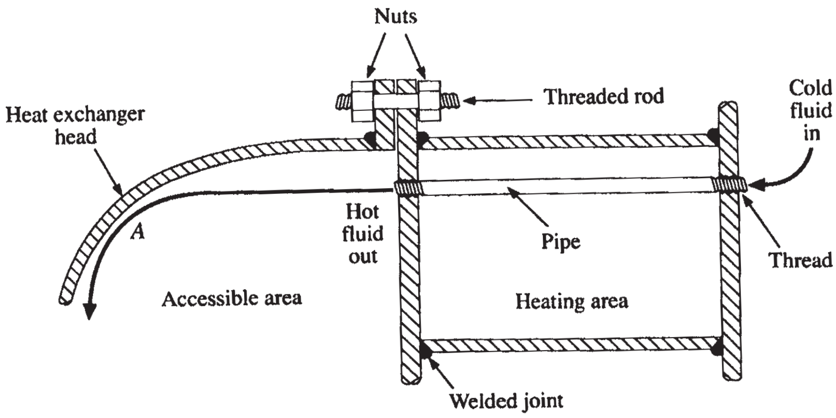
The forces in each part must add up to 500 kN. Some students incorrectly stated that the applied load is 1000 kN.

Many candidates had difficulty in using consistent units (Pascals, Newtons and metres).

It is important that students are able to confidently manipulate equations that contain numbers with indices.

QUESTION 2

(a) A simplified heat exchanger, made from low-carbon steel, is shown below. A fluid flows through the pipe at high velocity. The fluid strikes the heat exchanger head, at point A, which redirects the flow. The heat exchanger operates under high pressure and temperature.



(i) Corrosion occurs at point A on the heat exchanger head.

1. Name and describe this type of corrosion.

Erosion corrosion - Mechanical wearing away of materialby turbulent flow of gases or liquids.

Many candidates correctly identified erosion corrosion as the most likely form of corrosion at point A. Stress corrosion was also acceptable due to the cold-working of the heat exchanger head.

2. Suggest a possible method of reducing corrosion at point A.(The fluid velocity cannot be reduced.)

Surface coating on the Heat Exchanger Head
Use of a more wear resistant material.

This part of the question was well answered.

(ii) State TWO other types of corrosion that can occur in the heat exchanger. Give reasons for your answers.

Stress Cells - area of higher stress (due to cold-working, bending) on the heat exchanger head become anodic.

Oxygen Absorption - (differential aeration) - condensed water acts as the electrolyte and differing levels of dissolved oxygen in the water causes some areas to become anodic.

Galvanic Cells - (concentration cells) - same reason as above

Composition Cells - occur where dissimilar phases are in contact eg the ferrite and pearlite in the low carbon steel, in the presence of an electrolyte.

(iii) State a method used to reduce corrosion within the heating area.

Surface coat with a corrosion resistant material
Galvanise
Use a more wear resistant material

Parts (ii) and (iii) were generally well answered but it is important that students understand the common types of corrosion, where they occur and suitable methods of prevention.

eg. Stress corrosion - Occurs in higher stress areas that are usually caused through cold working. It may be minimised by removal of the work hardening through heat treatment or by redesigning the part to remove the areas of stress.

(iv) A silver and zinc galvanic cell, with respective electrode potentials shown below, is connected to a voltmeter.

Electrode potentials	
$Ag \rightarrow Ag^{+} + e^{-}$	$-0{\cdot}800$ V
$Zn \rightarrow Zn^{2+} + 2e^{-}$	$+0{\cdot}762$ V

1. Determine the value, in volts, shown on the voltmeter.

$$\begin{aligned} \mathbf{E_{cell}} &= \mathbf{E_{(anode)} - E_{(cathode)}} \\ &= \mathbf{0.76 - (-0.8)} \\ &= \mathbf{1.562} \end{aligned}$$

1.562 V

To determine the voltage of a galvanic cell, candidates need to understand that the voltage is the difference in potential values of the two electrodes.

$0{\cdot}8 + 0{\cdot}76 = 1{\cdot}56$

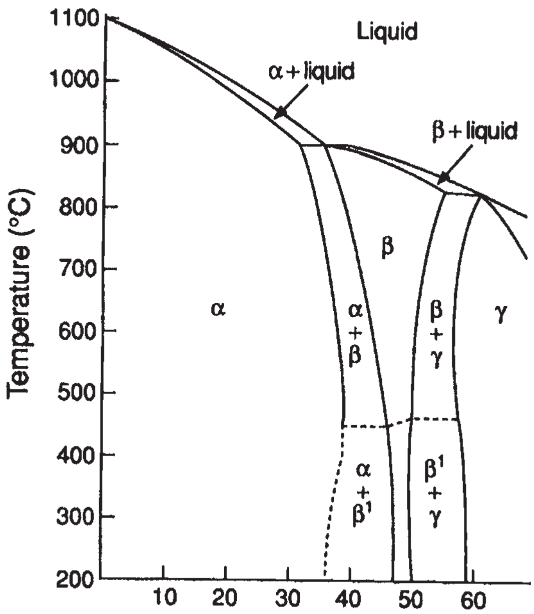
2. Which of the two metals will act as the anode? Explain your answer.

Metal **Zinc**

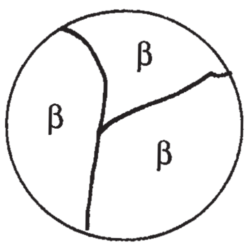
Explanation **Zinc has the higher electrode potential, therefore it becomes the anode and corrodes**

In studying corrosion, candidates need a knowledge of electrode potential, how to combine them and how to distinguish, from an electrochemical table, which metal will be the anode and cathode depending on their position in the table. Students also need to understand the principles of sacrificial anodes (cathodic protection) by identifying which metals will be anodic and therefore protect metals that are cathodic. They also need to understand the common mechanisms of corrosion. eg. anodes corrode by giving up electrons that flow to the cathode.

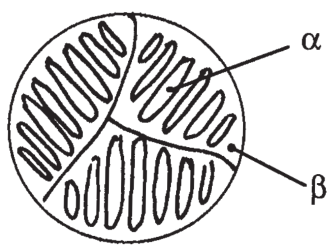
(b) The copper-rich portion of the copper-zinc phase diagram is given below.



(i) An alloy of 60% Cu-40% Zn is cooled under equilibrium conditions to room temperature. In the spaces provided, sketch and label the microstructure of this alloy at 850˚C and 500˚C.



850°C



500°C

This question was poorly answered. Many candidates successfully sketched and labelled the 850˚C structure but had little idea of the 500˚C structure. Very few candidates identified the 500˚C structure as a Widmanstatten structure. The most common responses were equiaxed grains of α and β^1 which demonstrated little understanding of the relationship between the two phases. Better candidates recognised that was a precipitate but often sketched it along the grain boundaries.

(ii) During equilibrium cooling of an alloy of 60% Cu– 40% Zn, β phase occurs in the microstructure. Explain the effect of this phase on the properties of the alloy at room temperature.

β (β') **phase is harder and more brittle than the** α **phase and imparts these properties to the alloy. The** β **also increases the UTS of the alloy.**

(iii) Alloys of 70% Cu–30% Zn are readily cold-worked, while alloys of 60% Cu– 40% Zn often require hot-working, during manufacturing processes. Explain the reason for this, in terms of phases present.

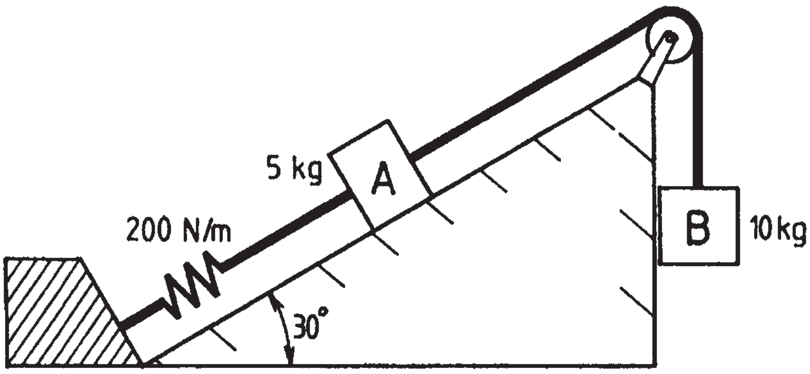
70% - 30% contains single α **phase which is soft and ductile at room temperature.**
60% - 40% contains hard and brittle β **phase which is not readily workable at room temperature but is workable at an elevated temperature.**

Many candidates simply stated that β was a hard and brittle phase and often failed to suggest reasons why 70/30 brass could be cold worked while 60/40 brass required hot working. Students should understand that a single phase alloy is normally more easily worked than a multi-phase alloy. If a 60/40 brass is elevated in temperature so that it contains only equiaxed grains of β then it will be easier to work than the Widmanstatten structure that is found at room temperature.

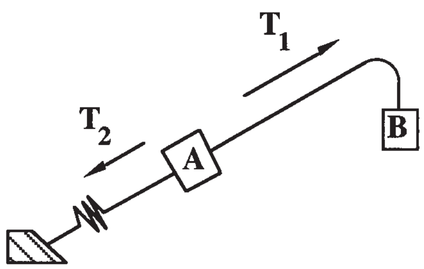
QUESTION 3

Two masses, A and B, are connected by a rope passing over a frictionless pulley as shown below. Mass A, resting on a frictionless inclined plane, is acted upon by a spring of stiffness 200 N/m. Mass B is initially held stationary such that the spring has an extension of 0.75 m from its unstretched position.

Ignore extension of the rope.



(a) Determine the instantaneous acceleration of the masses when the 10 kg mass is released.



$$\sum F_B = T_1 - m_B g = m_B a \qquad \text{..........¨}$$

$$\sum F_A = T_2 - m_a g\sin\theta - T_1 = m_a a \qquad \text{..........¡}$$

Subt ¨ into ¡ to find a

$a = 5.1\ \text{m/s}^2$

acceleration **5.1** m/s^2

This question involves the concept of a net or unbalanced force that causes motion of an object. Care needs to be taken to include all forces acting on each object. Net force equations are developed for each object for motion along the plane for A and in the vertical direction for B.

Since the objects move together as they are connected by a rope, the two equations are simultaneous and can be solved to find values for acceleration and tension as required. Most students were able to calculate the 150N spring force but many were not able to include it in the force equation. This simplified the question and candidates lost marks accordingly.

(b) What will be the extension of the spring once the masses have come to rest?

$$\text{Resultant Force} = m_A g \sin\theta$$
$$F_R = 98 - 24.5$$
$$= 73.5\text{N}$$
$$\text{From } F = kx$$
$$x = \frac{F}{k}$$
$$x = \frac{73.5}{200}$$
$$= 367.5$$

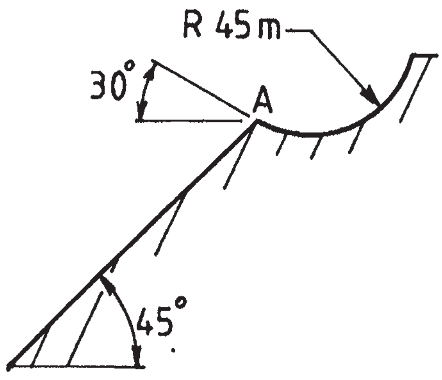
extension 367.5 mm

This part of the question involves a static situation as the masses have come to rest. A free body diagram of the 5kg mass helps in the analysis of the question.

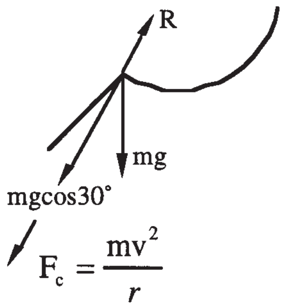
The unknown force F can be found by summing forces along the plane. Using the spring constant (200N/mm), the extension can be found.

QUESTION 4

Details of a ski jump are given below on the diagram. A skier has a mass of 80 kg, and attains a linear velocity, at the take-off position A, of 25 m/s, upward at an angle of 30° to the horizontal.



(a) Determine the magnitude of the normal force exerted by the ski jump on the skier at point A.

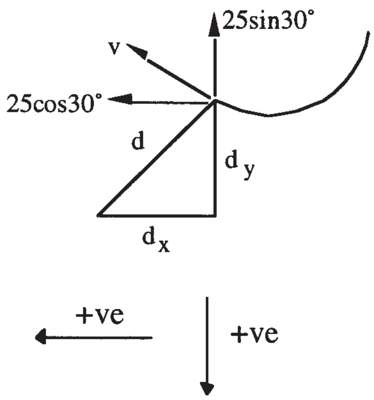


$$F = mg\cos30° + \frac{mv^2}{r}$$
$$= 80 \times 9.8\cos30° + \frac{80 \times 25^2}{45}$$
$$= 1790\ \text{N}$$

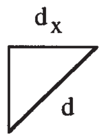
Normal force **1.79** kN

The normal force acting on the skier is the normal component of the reaction force and consists of two parts; one from the component of the weight and the other from the circular motion. Most candidates were able to identify the part from the circular motion but many were not able to combine the two.

(b) Determine the distance down the slope, from point A, where the skier will land.



$$d_x = vt$$
$$= 25\cos30°t \quad \text{........∴.}$$
$$d_y = -ut + \frac{1}{2}gt^2$$
$$= -25\sin30°t + \frac{1}{2}(9.8)t^2 \quad \text{........¡}$$
$$\text{since } d_x = d_y \quad (45° \text{ slope})$$
$$\text{sub } ¨ = ¡$$
$$-25\sin30°t + \frac{1}{2}(9.8)t^2 = 25\cos30°t$$
$$\text{Therefore } t = 6.97 \text{ secs}$$



subt for d_x
$$d_x = 25\cos30°(6.97)$$
$$d = d_x \cos45°$$

Distance **213.4** m

Of the candidates who attempted this question, most had difficulty with this part. A correct solution relies on the ability to work using components and an appropriate sign convention. Equally important is the realisation that, in projectile motion, the horizontal distance and the vertical distance are covered within the same time.

Using the sign convention in the solution above (positive in the direction of displacement), the horizontal (d_x) and vertical (d_y) displacements can be derived from the equation

$s = ut + \frac{1}{2} at^2$ and are given below.

$$d_x = (25 \cos 30^\circ) \text{ x } t$$

$$d_y = (-25 \sin 30^\circ) \text{ x } t + (0.5 \text{ x } 9.8 \text{ x } t^2)$$

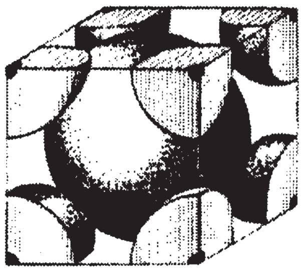
Because these occur within the same time, they can be equated and solved to find t = 6.97 seconds. Substitution back into the original equation together with trigonometry will give the distance down the slope.

Some important points to note include:

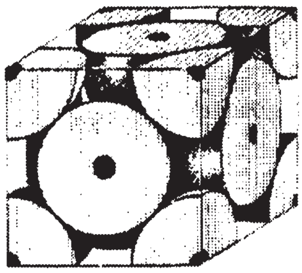
- Other sign conventions could be used;
- The vertical initial velocity is negative and the vertical acceleration is positive according to the sign convention adopted in this solution;
- There is no horizontal acceleration.

QUESTION 5

(a) The schematic drawings of the lattice structures of metal A and metal B are given below.



METAL A



METAL B

(i) With reference to the structures given, explain why metal B is softer and more ductile than metal A.

Metal B - has higher atomic density, (closer packed structure), (higher coordination number). Metal B, therefore, has greater number of slip planes allowing increased ductility and softness.

Candidates needed to identify features of the structures that result in the mechanism of slip, giving the softer and more ductile properties that are found in metal B.

(ii) Determine the coordination number for each of the above structures.

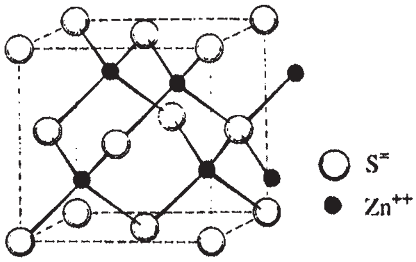
Coordination number is the number of near, equidistant atoms relative to any atom in the lattice structure.

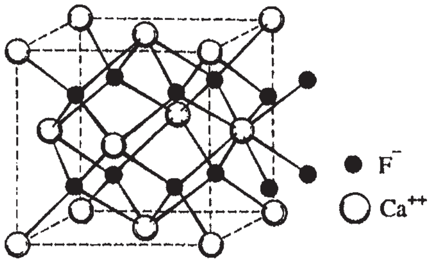
Metal A 8

Metal B 12

A simple concept regarding the number of near and equidistant neighbouring atoms. This part was well answered.

(b) The unit cells of the crystal structures of zinc blende, ZnS, and fluorite, CaF2 ,are shown below. The interstitial sites of the basic unit cells are occupied by cations in the zinc blende structure and by anions in the fluorite structure.





(i) Explain why double the number of interstitial sites are occupied in the fluorite structure compared to the zinc blende structure.

Fluorine is a smaller atom and half the valency of calcium therefore twice as many Fluorine anions are needed to fill structure.

Many candidates had difficulty in understanding the concept of valency.

(ii) The anions in the zinc blende and the cations in the fluorite have the same lattice arrangement. Name the lattice arrangement.

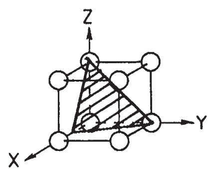
FCC

(iii) Give one reason why zinc blende is hard and brittle.
Ionic bonding

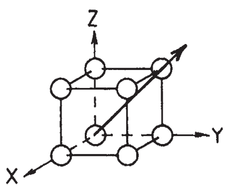
Candidates had difficulty identifying Ionic Bonding as the reason for the hard and brittle structure. Ionic bonds have a very strong electrostatic attraction which is very difficult to break.

(c) The simple cubic lattice structure is shown below.

(i) Sketch and clearly label, on the given diagram, the plane that has Miller indices of (211)



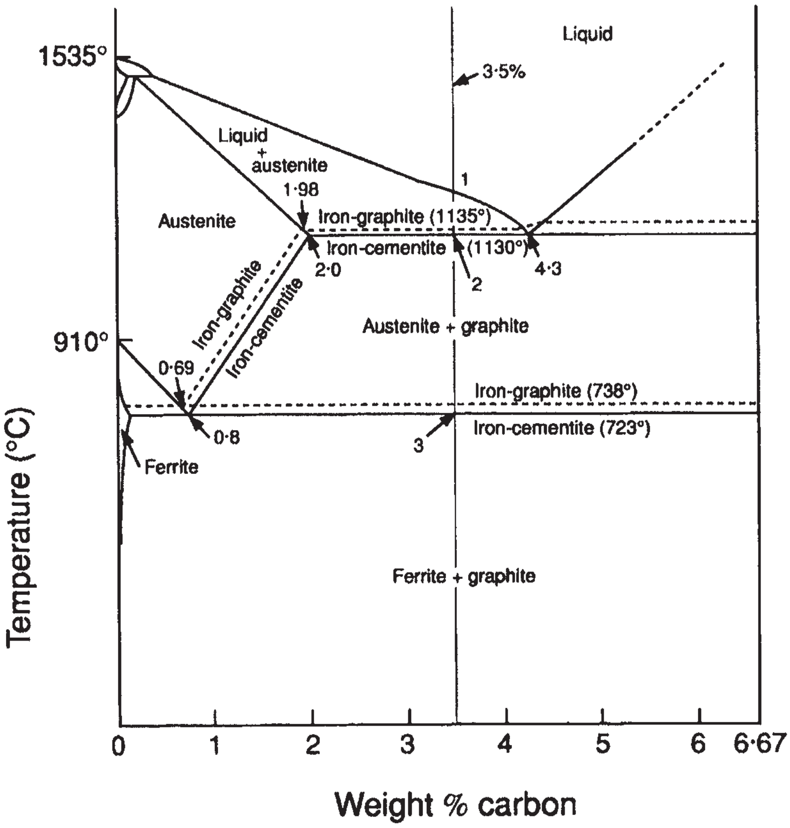
(ii) Sketch and clearly label, on the given diagram, the (011) direction



This question was relatively well answered though some students were confused in part (ii) when the bracket convention ( ) for a plane was used but a ëdirectioní was required. Subsequently responses were divided between the (011) plane and the [011] direction.

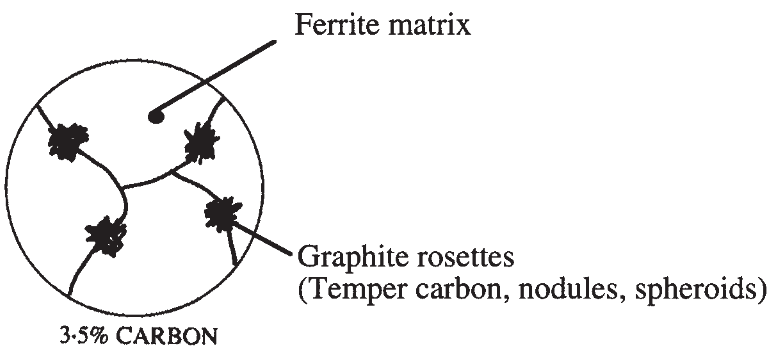
QUESTION 6

(a) The iron–graphite phase diagram is given below.



An alloy of 3·5% carbon in iron is cooled to produce white cast iron. The casting is then annealed at 850˚C for 48 hours, and then furnace cooled to room temperature.

(i) Sketch and label the microstructure resulting from this heat treatment process.



A number of students confused the microstructure associated with the malleable cast iron with that of a tempered steel.

(ii) White cast iron is generally very hard and brittle. Briefly describe the change in mechanical properties that results from the heat treatment described above.

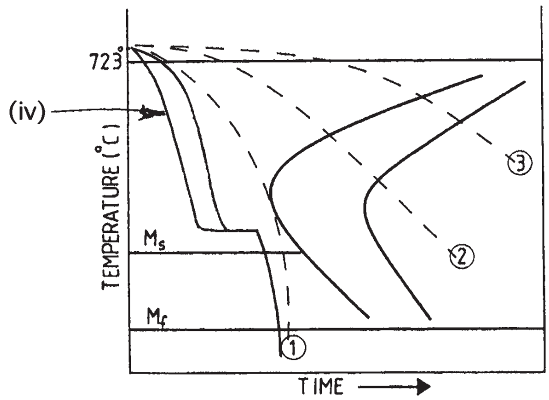
It becomes softer and less brittle
Toughness increases

In studying Cast Irons, candidates need to understand the distribution of carbon in the combined form as Fe_3C in White Cast Iron or in free graphite form as:

- Flakes in Grey Cast Iron
- Nodules (spheroids) in Nodular Cast Iron
- Rosettes (temper carbon) in Malleable Cast Iron

Candidates must understand the heat treatment and manufacturing processes that produce each of these cast irons and recognise the effect that the form and distribution of the carbon has on each cast iron.

(b) A time-temperature transformation diagram for a eutectoid steel is shown below, indicating three cooling rates.



(i) Explain the significance of cooling rate ↲ to the resultant microstructure.

represents the slowest cooling rate for a full martensite transformation.

(ii) Each of the cooling rates is started from a temperature above the eutectoid isotherm.
Explain why this is necessary in the formation of martensite.

Steel has to be fully austenitic (γ) BCC before transformation to martensite, body centred tetragonal structure, can occur.

(iii) Name the cooling processes indicated by cooling ratesϒ and ←.

Cooling rate ϒ Normalising (air cooled)

Cooling rate ← Annealing (furnace cooled)

(iv) On the time–temperature transformation diagram, clearly sketch the martempering cooling rate.

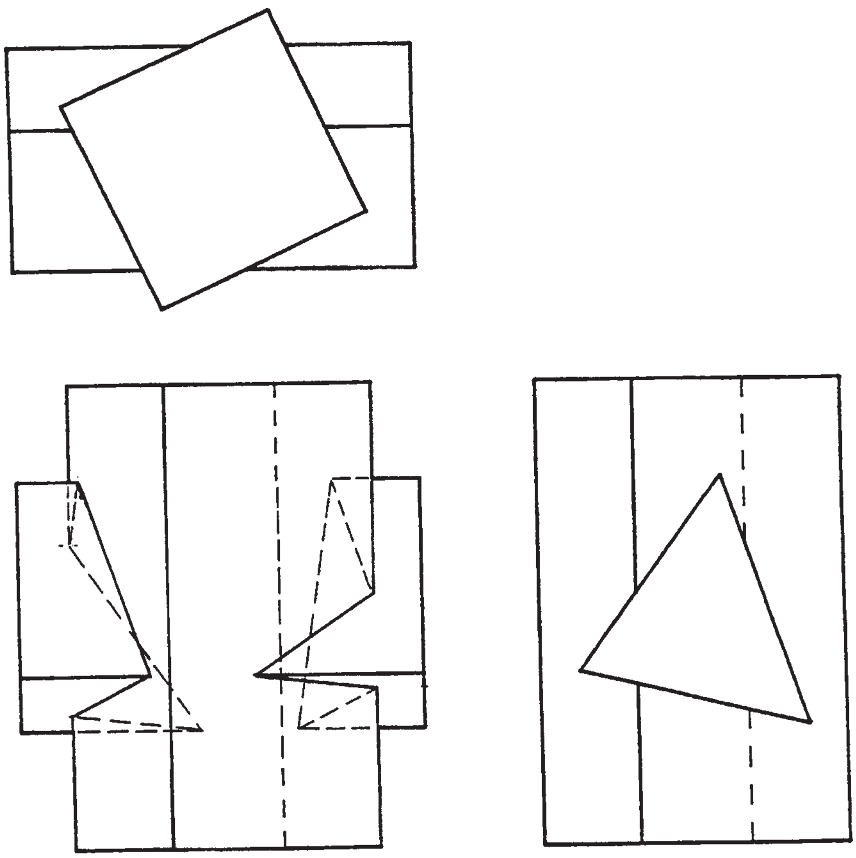
In studying the Temperature/Time/Transformation curve, candidates need to understand the significant cooling rates along with the relevant microstructures and associated properties.

eg. The critical cooling rate for a fully martensitic structure (the slowest cooling rate to form full martensite) falls before the ënoseí and produces an acicular, hard and brittle structure. Students need to know the cooling rates for Annealing, Normalising and Hardening as well as Austempering (to form Bainite) and Martempering.

QUESTION 7

The top view, right-side view and partly completed front view of a square prism intersecting with an irregular triangle prism are shown below in third-angle projection.

Complete the front view.



The solution to this problem fell into two parts:

- The correct location of the ten points of intersection;
- The visualisation of both visible and hidden outline.

Most candidates attempted this question with the majority able to locate some visible lines. Many students had difficulty locating the four points on the edges of the square prism while the points of intersection along the edges of the triangular prism were found easily by most students. Most difficulty was encountered in using appropriate visible and hidden detail lines to complete the drawing.

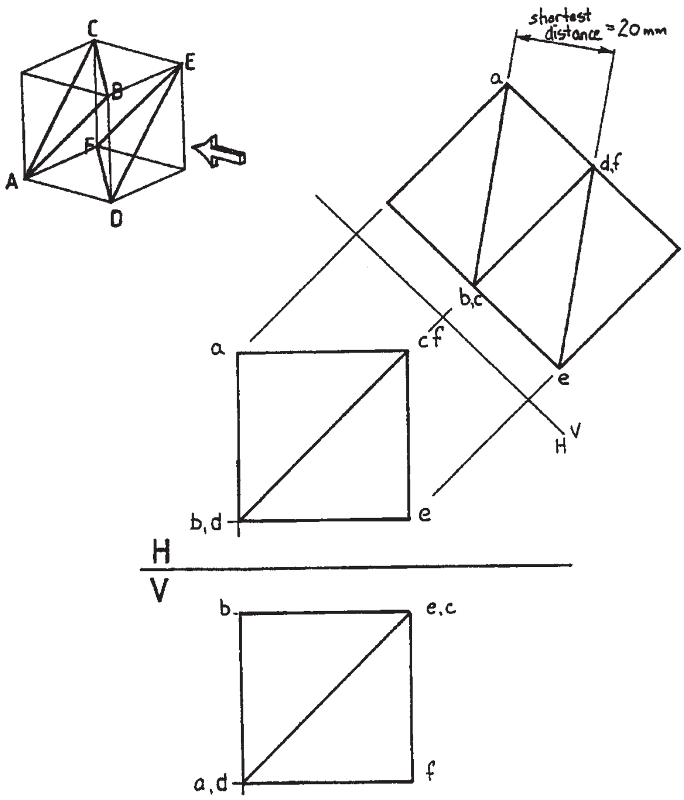
Suggested steps to assist in the completion of a solution:

1. Letter all lines in both views;
2. Identify, and number in cyclic order, all intersection points in the top view;
3. Project these points to the front view either directly or via the right side view;
4. Identify the visibility of the solution by looking through the vertical plane at the top view. Join the points accordingly using the appropriate lines.

QUESTION 8

A pictorial drawing of a cube is shown below. Planes ABC and DEF are given. The cube has edges of length 35 mm. The top view and front view of point, d, are drawn below in third-angle projection. Complete the top view and front view of the cube, and the planes, when viewed in the direction of the arrow.

Graphically determine the shortest distance between the planes ABC and DEF.



Most students who attempted this question scored well. Drawing the front and top views of the cube presented few difficulties and most students were able to draw the representation of the planes within the cube. Once again, labelling of points, while not essential, aids understanding particularly when projecting new views.

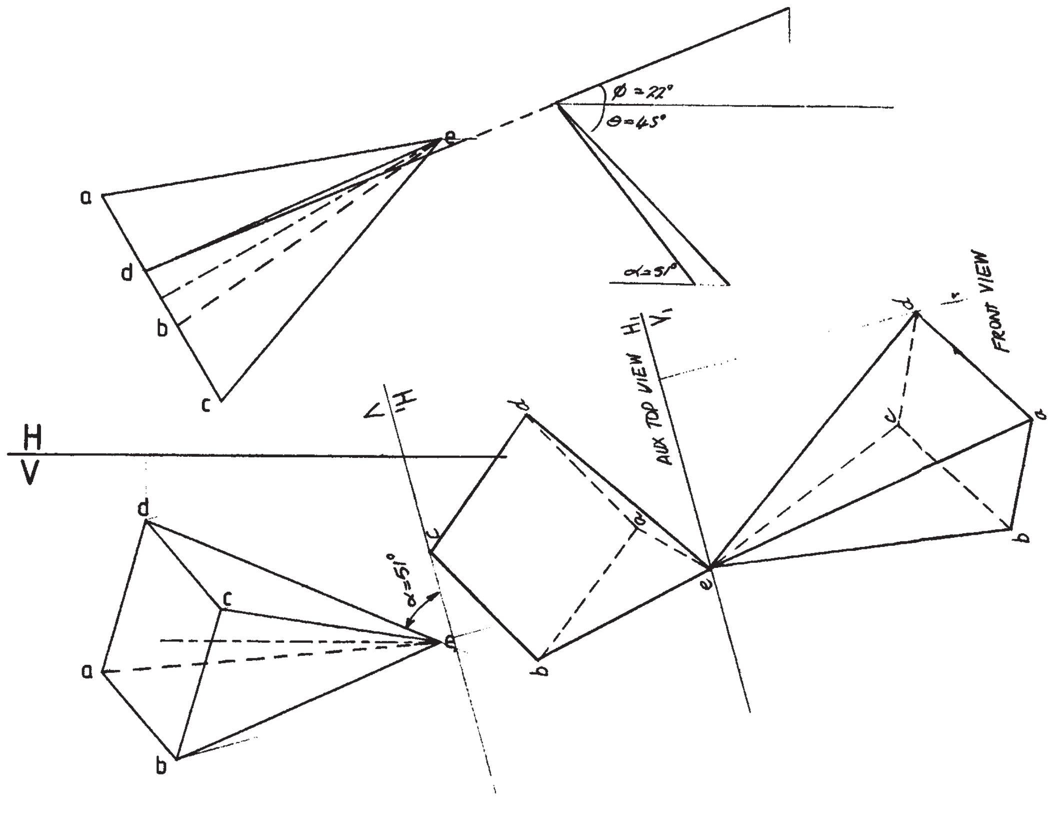
There were a number of correct methods but the easiest and most common involved using an auxiliary plane perpendicular to the top view (true length) of the edge of plane cb. The new auxiliary view, when projected through this plane, shows the edges of the two parallel planes (they appear as lines). On this auxiliary view, a line perpendicular to these two planes indicates the distance between the planes.

Many students did not understand the need to project an auxiliary view along the line of the true length of cb. In doing this, cb was viewed as a point and therefore the plane ‘cbdf’ as a line. Only then is the true distance between the planes apparent.

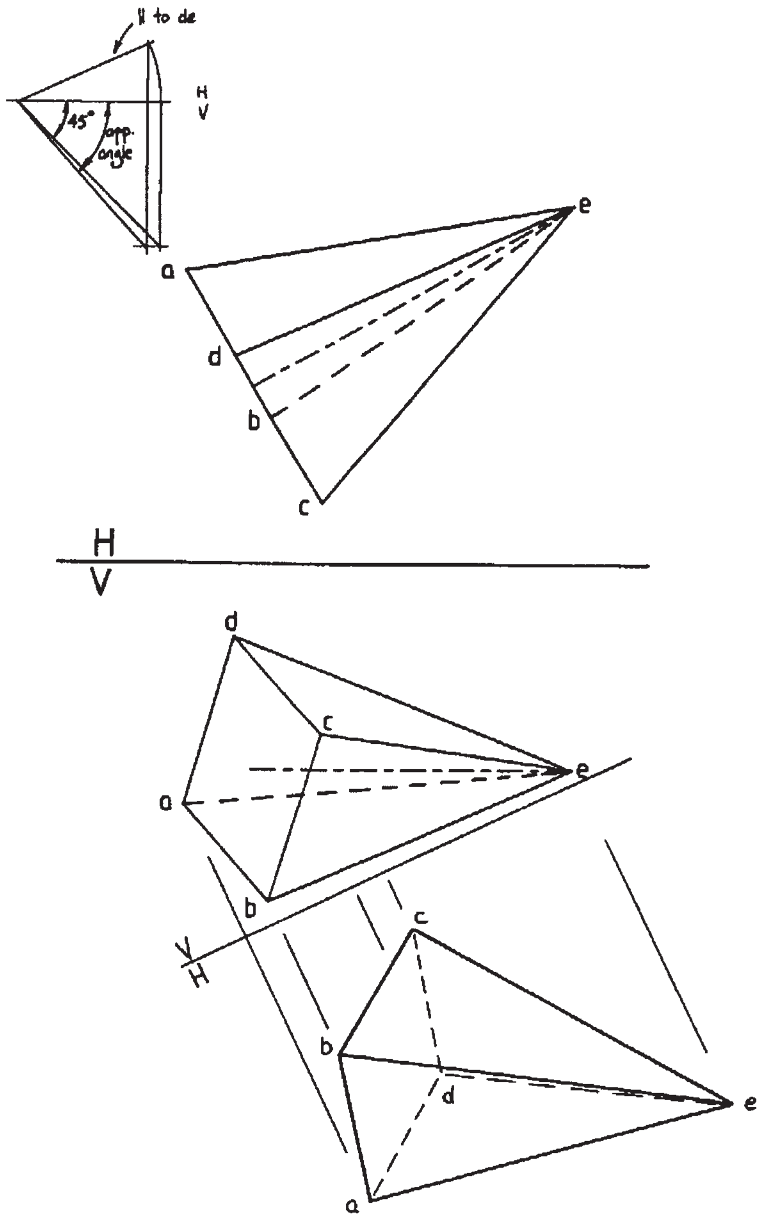
QUESTION 9

The top view and front view of a square pyramid are drawn below in third-angle projection. Project from the front view an auxiliary view of the pyramid if slant edge, de, is to remain at the same angle to the principal vertical plane and is inclined at 45° to the horizontal.

The apex, e, is to be to the left and in front of the centre of the base.



This question was attempted by the least number of students. This was probably due to the great difficulty in interpreting the question. A fully correct solution required the projection of two new views. The solution below, visualised in third angle projection, with the apex to the left but behind the centre of the base, was a common response.



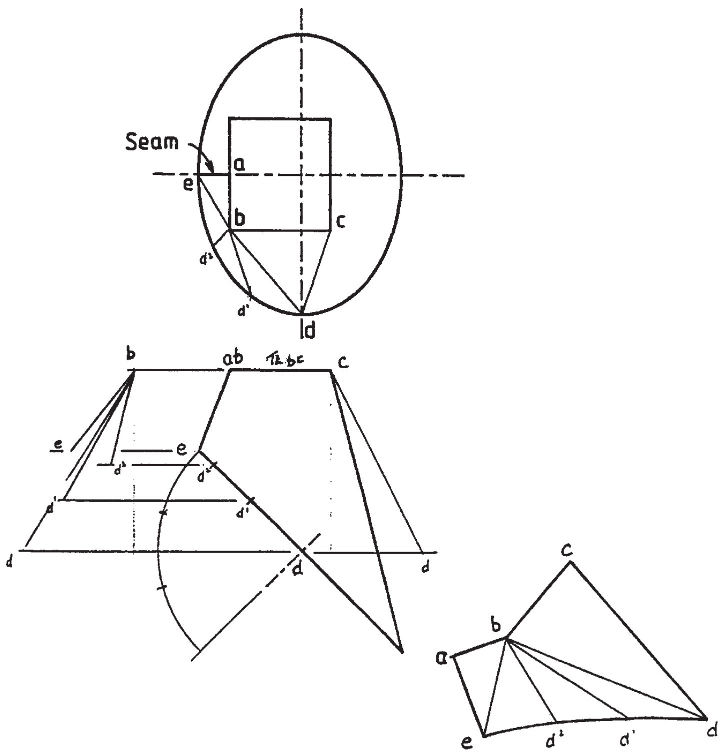
Good candidates were able to calculate the correct apparent angle to the Principal Horizontal Plane and then project a new top view. Most students were able to show correct visibility.

QUESTION 10

The top view and front view of a transition piece, used to join rectangular ducting to circular ducting, are shown below in third-angle projection.

Draw a pattern for the surface, abcde.

The starting position for the seam, ae, is indicated below.



This question yielded mixed responses. Most problems occurred with the varying heights used in the true length calculations which was linked to a failure to calculate the true lengths around the curved edge.

Suggested steps to assist in the completion of a solution:

1. Triangulate surface abcde using abc along the top edge and dividing the curved edge into at least three parts. Labelling these points is not essential but will assist in completing the problem.
2. Calculate the required true lengths and clearly label each to avoid confusion when completing the development.
3. Projecting these lengths, with pair of dividers or compass, will assist accuracy.
4. Use only true lengths to draw the development, commencing with triangle abe.
5. Accurately complete the development including the curved line ed.
6. Thick, black outlines are required with thin, black fold lines. A symmetry line must not be used as the development is not a half pattern.

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