Name _____

Sydney Technical High School

2022
Year 12 Trial Higher School Certificate Examination

Engineering Studies

General Instructions

- Reading Time – 5 minutes
- Working Time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Dimensions in millimetres unless otherwise stated
- Board-approved calculators may be used
- A formulae sheet is provided at the back of this paper
- Write your name at the top of this page.

Total Marks 100

Section I pages 2-10

20 marks
Attempt questions 1-10
Allow about 30 minutes for this section.

Section II pages 11-27

80 Marks
Attempt questions 21-27
Allow about 2 hours and 30 minutes for this section.

Section I
20 Marks
Attempt Questions 1–20
Allow about 30 minutes for this section

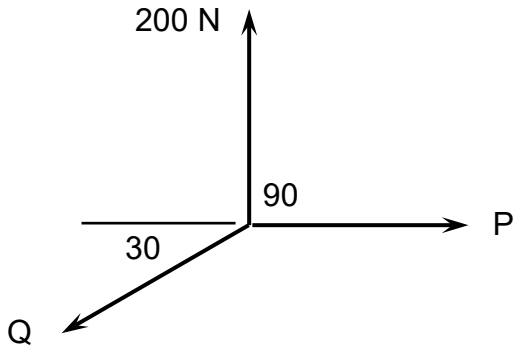
Answer the questions in the spaces provided.

Place a tick in the box to indicate your selection.

If you make a mistake cross it out then place the tick in your new selection.

Question	A	B	C	D
1				
2				
3				
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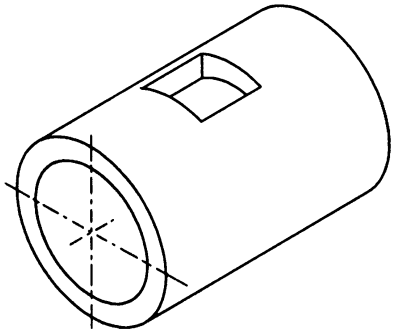
1. Three concurrent forces in a state of equilibrium are shown.



What will be the magnitude of *Q*?

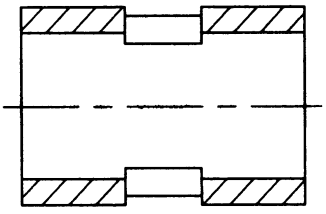
(A) 346 N
(B) 400 N
(C) 500 N
(D) 800 N

2. A component is shown in the pictorial drawing.

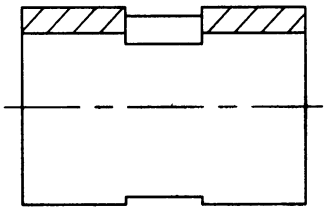


Which of the following drawings represents the half-section front view of the component?

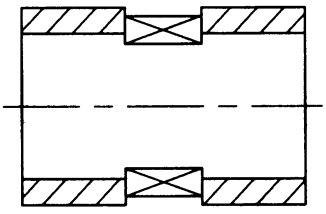
(A)



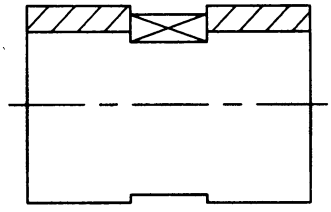
(B)



(C)



(D)



3. What value varies with the efficiency of a machine?

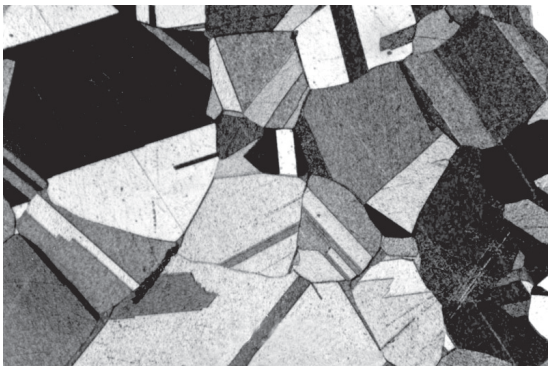
   (A) Velocity ratio
   (B) Kinetic energy
   (C) Potential energy
   (D) Mechanical advantage

4. Which best describes electromagnetic induction?
   (A) The induction of a magnetic field in a conductor.
   (B) Production of an electric current in a conductor that is subjected to a changing magnetic field.
   (C) Production of a magnetic field due to an alternating current.
   (D) Production of a magnetic current in a conductor that is subjected to changing current.

5. How is the toughness of a material indicated on a stress-strain curve?
   (A) The total area under the stress-strain curve.
   (B) The highest value of stress on the curve.
   (C) The area under the straight line section of the stress-strain curve.
   (D) The slope of the straight line portion of stress-strain curve.

6. Which best describes the process of galvanising?
   (A) Painting a structure with an anti-corrosion coating.
   (B) Electroplating metals with another metal to protect against corrosion.
   (C) Coating ferrous metals with zinc to protect against corrosion.
   (D) Alloying metals with particular anti-corrosion elements to permanently protect against corrosion.

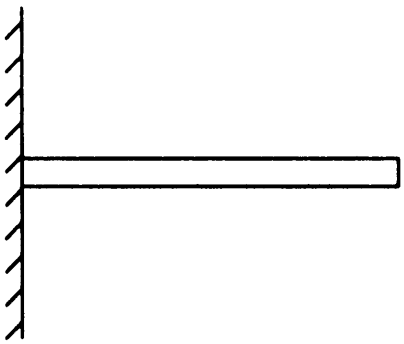
7. The image below shows a photomicrograph of brass.



What type of grain structure does the image represent?

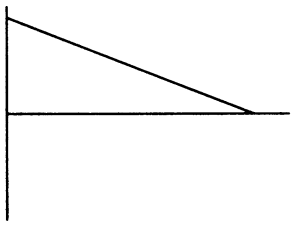
   (A) Deformed
   (B) Dendritic
   (C) Equiaxed
   (D) Stressed

8. A steel cantilever beam is shown?

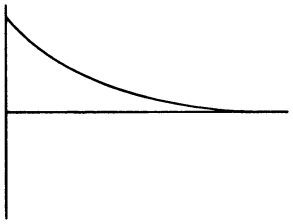


Which sketch best represents the shape of the bending diagram for the beam, if the mass of the beam is uniformly distributed?

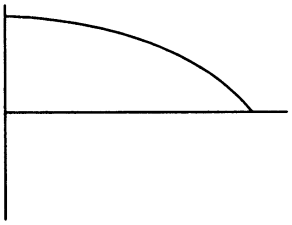
(A)



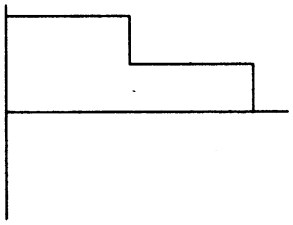
(B)



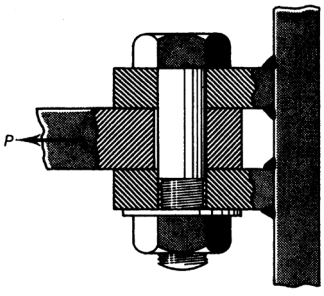
(C)



(D)



9. A force P, is applied to the plate as shown.



If the maximum allowable shear stress in the ∅20 mm bolt is 100 MPa, the maximum value of P will be:

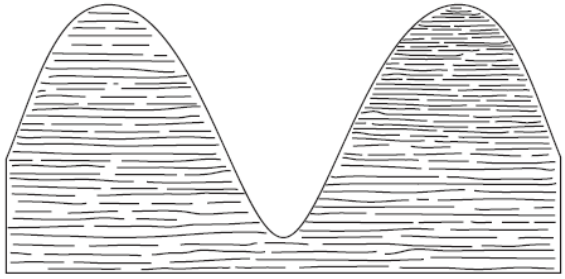
(A) 22.1 kN
(B) 31.4 kN
(C) 62.8 kN
(D) 125.6 kN

10. A high-carbon steel punch is to be used to make holes in mild-steel sheet.

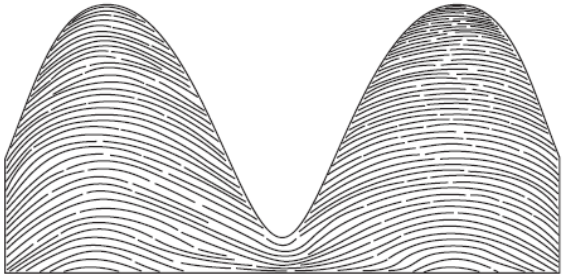
    What are the final heat-treatment processes required in the manufacture of the punch?

    (A) Normalising then hardening
    (B) Hardening then tempering
    (C) Normalising then tempering
    (D) Hardening then normalising

11. Deduce from the two macrostructures what manufacturing processes were used to form thread shape X and thread shape Y.



X



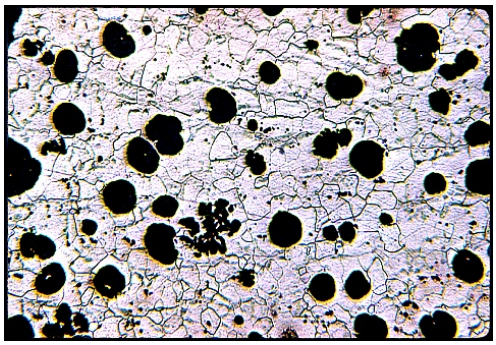
Y

    (A) X by cutting and Y by cutting
    (B) X by rolling and Y by rolling
    (C) X by cutting and Y by rolling
    (D) X by rolling and Y by cutting

12. Roll in an aircraft is primarily controlled by which control device?

    (A) Aileron
    (B) Elevator
    (C) Spoiler
    (D) Rudder

13. The photomicrograph of a spheroidal graphite cast iron is shown below. What are the names of the two phases present?

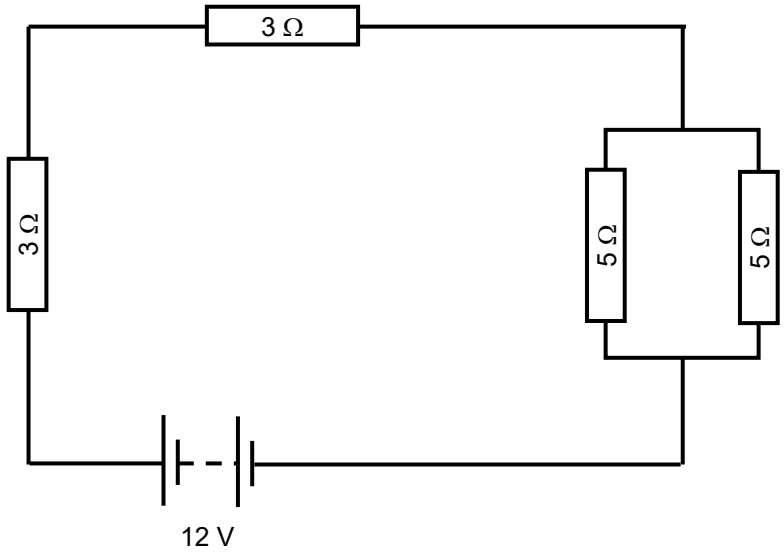


    (A) austenite and cementite
    (B) ferrite and austenite
    (C) ferrite and cementite
    (D) ferrite and graphite

14. What are the fundamental functions of transistors in an electronic circuit?

    (A) Switching and earthing
    (B) Invertor and resistance
    (C) Resistance and rectification
    (D) Amplification and switching

15. A simple electrical circuit with four resistors and is loaded with a 12 V 60 Ah (amp-hour) battery is shown.



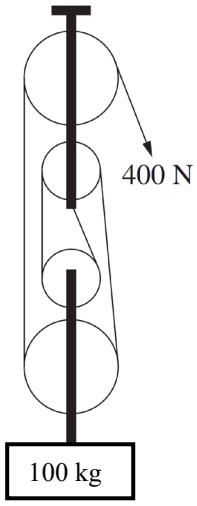
    How long will current flow in the circuit?

    (A) 12 hours
    (B) 16 hours
    (C) 43 hours
    (D) 60 hours

16. The structure of martensite may be described as:

    (A) Acicular,
    (B) Lamellar,
    (C) Twinned,
    (D) Peritectic?

17. The diagram shows a block and tackle pulley system.



NOT TO SCALE

A 400 N effort is needed to raise the 100 kg load.

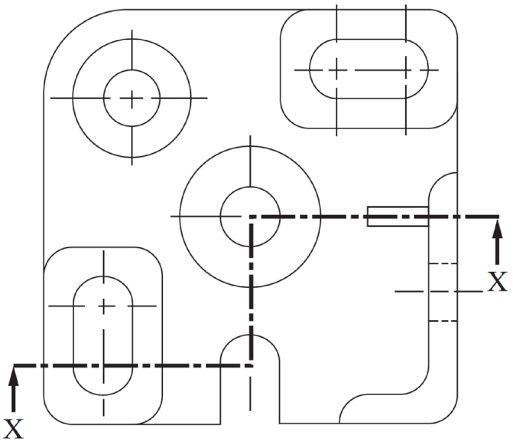
What is the efficiency of the pulley system?

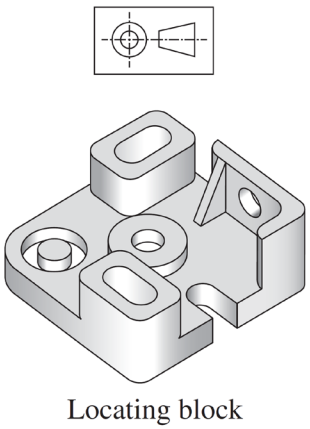
(A) 100%
(B) 75%
(C) 62.5%
(D) 50.5%

18. Control technology is used for electric motor control in the transport industry. What is the most efficient method used for motor speed control?

(A) Phase shift keying (PSK)
(B) Frequency Modulation (FM)
(C) Potentiometer or rheostat
(D) Pulse Width Modulation (PWM)

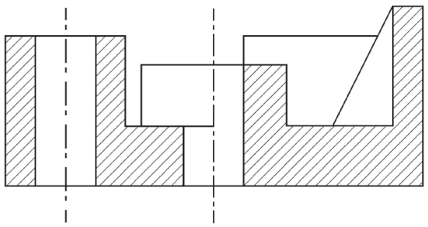
19. A locating block is sectioned by an offset cutting plane labelled X-X.



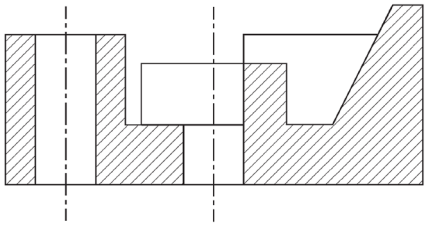

Locating block

Which front view is sectioned to AS1100 standards?

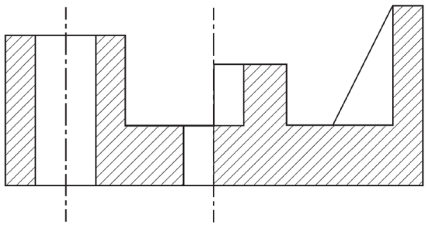
(A)



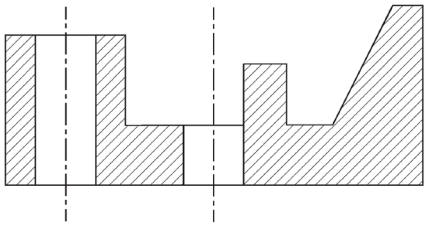
(B)



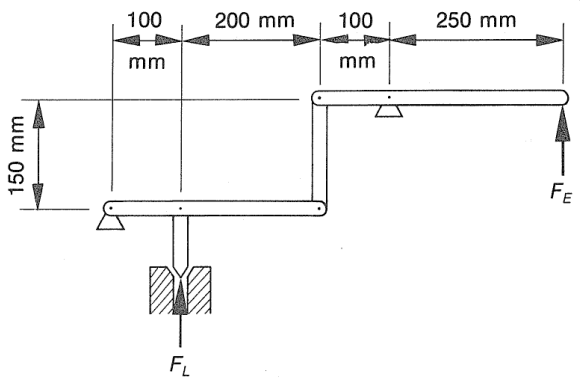
(C)



(D)



20. A compound lever system is shown?



What is the velocity ratio for the system?

(A) 1:1
(B) 2.5:1
(C) 5:1
(D) 7.5:1

Section II **Marks**
70 marks
Attempt Questions 21–27
Allow about 2 hours and 30 minutes for this section

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 21 (9 marks)

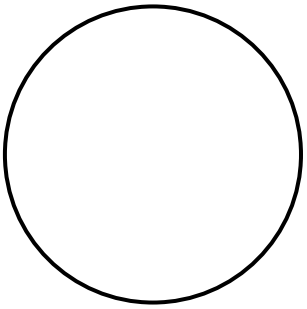
a) G clamps may be manufactured from spheroidal graphite cast iron by sand casting.



(i) Describe the sand casting process, and outline an advantage and disadvantage of sand casting. **3**

Question 21 continues the next page

(ii) Draw and label the microstructure for the spheroidal graphite cast iron used to make the G clamp. Explain why the spheroidal graphite cast iron is used in preference to grey cast iron for this specific application. **3**



b) Gears can be sand cast and machined or they may be formed using powder metallurgy. Compare the two forming methods for forming gears. **3**

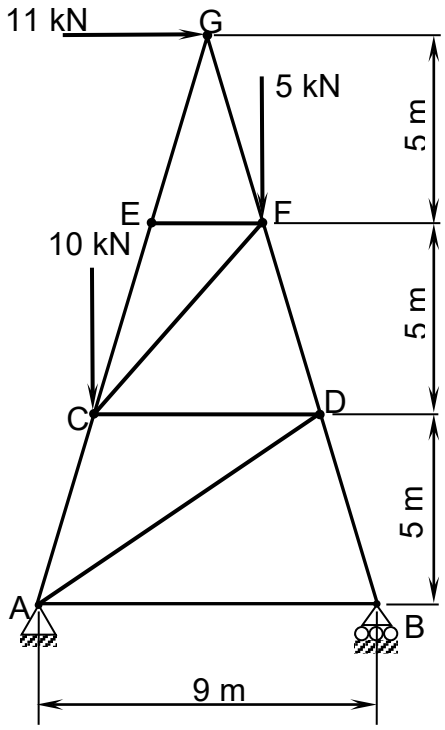
End of Question 21

Question 22 (12 marks) **Marks**

a) Modern personal transport devices use extensive control systems to achieve many different aspects. Identify two recent developments in control systems used in personal transport devices, outline what they do and then explain how those control systems have improved the performance or effectiveness of the transportation device. **6**

Question 22 continues on the next page

b) A pin-jointed symmetrical triangular tower is loaded by three forces as shown. **6**



Determine the magnitude and nature of the forces in members AC and AD.

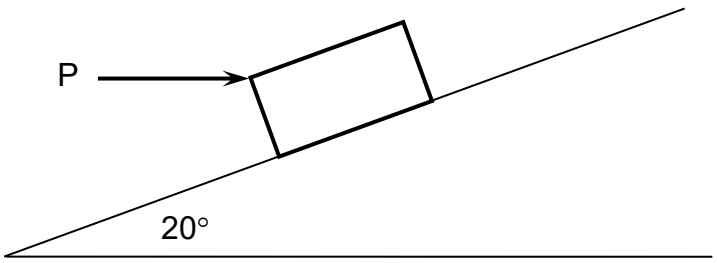
AC _____ kN _____

AD _____ kN _____

End of Question 22

Question 23 (12 marks) **Marks**

a) A box of mass 100 kg is held stationary an inclined ramp as shown. The coefficient of static friction between the suitcase and ramp is 0.1. Force *P* acts horizontally. **4**



Determine the minimum value of force *P* required to stop the box from sliding.

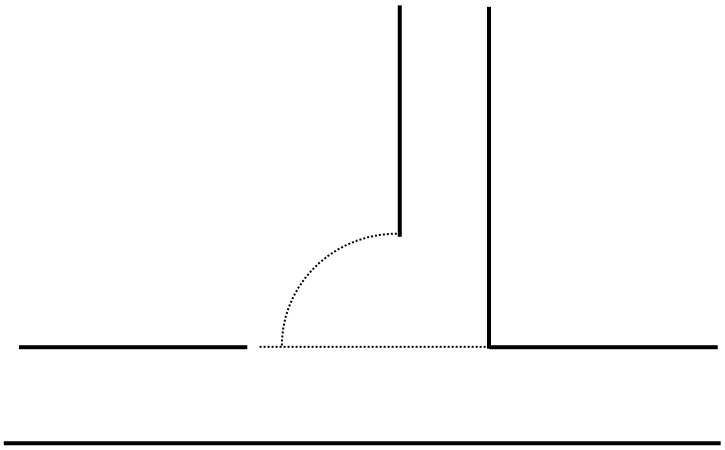
P = _____ N

Question 23 continues on the next page

Question 23 (continued) **Marks**

b) As part of the manufacture of a frame a weld is performed to join two pieces of cold rolled mild steel plate at an angle of 90°.

(i) Complete the diagram below by showing the weld and the resulting microstructural changes of both the weld metal and the original plates. Label the key features. **3**

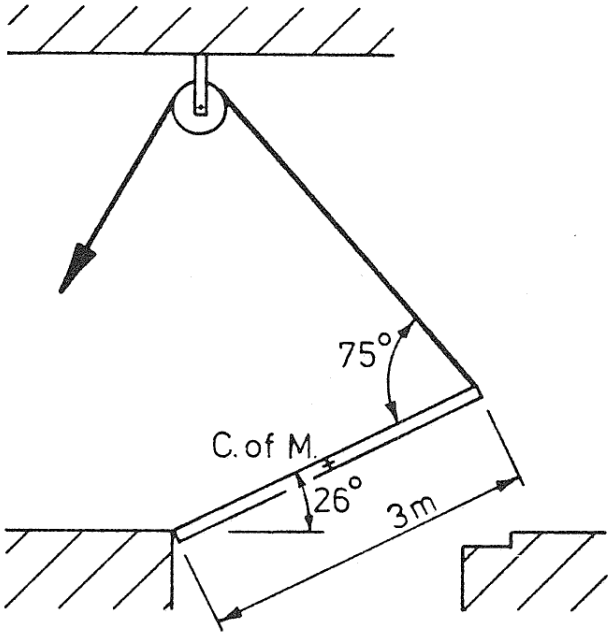


(ii) Explain why the strength around the weld varies, and how this affects the weld's performance in service. **3**

Question 23 continues on the next page

Question 23 (cont.) **Marks**

c) A trapdoor of mass 20 kg is raised by a rope passing around a fixed frictionless pulley as shown below. The centre of mass is in the middle of the trapdoor. **2**



Determine the tension in the rope when the trap door is held in the position shown.

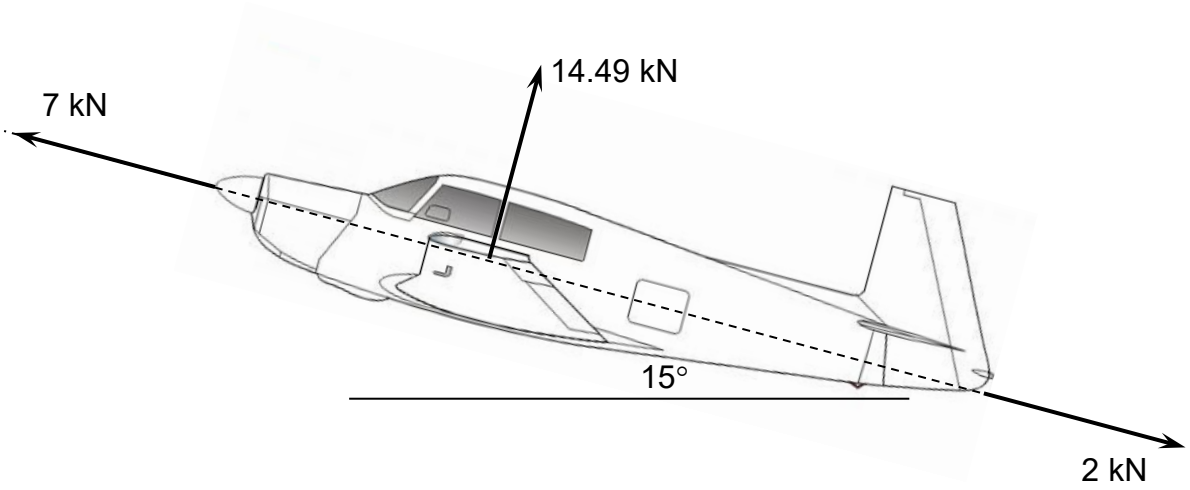
Tension = _____ kN

End of Question 23

Name:_____

Question 24 (12 marks) **Marks**

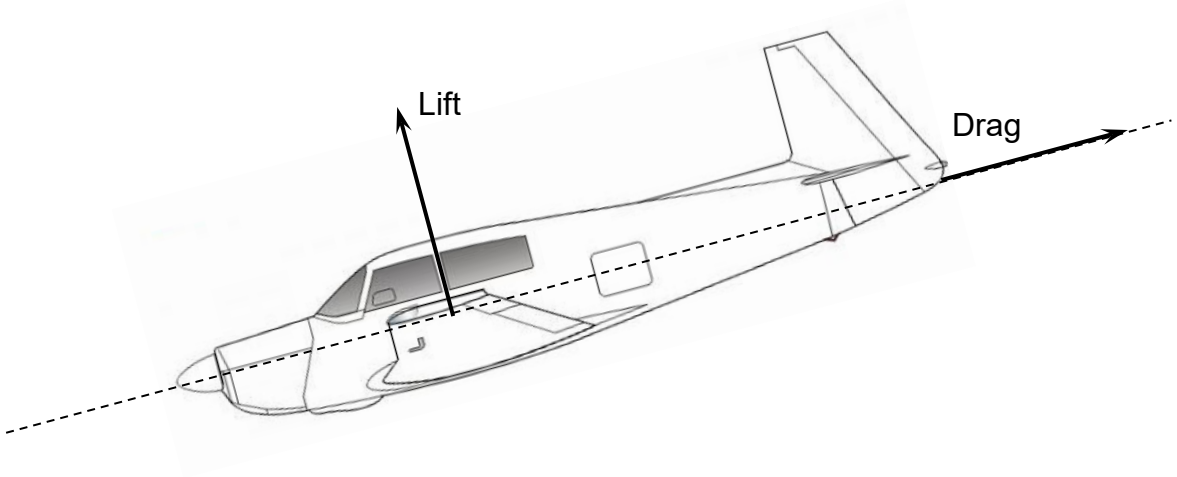
a) A small civil aircraft with a mass of 1.5 tonnes is climbing at an angle of 15°. Determine the acceleration of the plane along the flight path when the 7 kN thrust force and the 2 kN drag force acts along the line of flight. Lift force is 14.49 kN. **4**



Acceleration =_____ ms^{-2}

Question 24 continues on the next page

b) For another set of conditions the 1.5 tonne aircraft is descending with the engine off at a glide angle of 15°, determine the lift force acting along the line of flight and the Lift to Drag ratio. **3**



Lift force = _____ kN

Lift to Drag Ratio = _____

Question 24 continues on the next page

Question 24 (cont.) **Marks**

c) In this aircraft, the external skin is riveted to the frame using solution treated and quenched aluminium 4% copper alloy rivets. These rivets are used immediately to attach the external skin of the aircraft to the frame. Describe the changes that occur to the structure and properties of these after installation. **3**

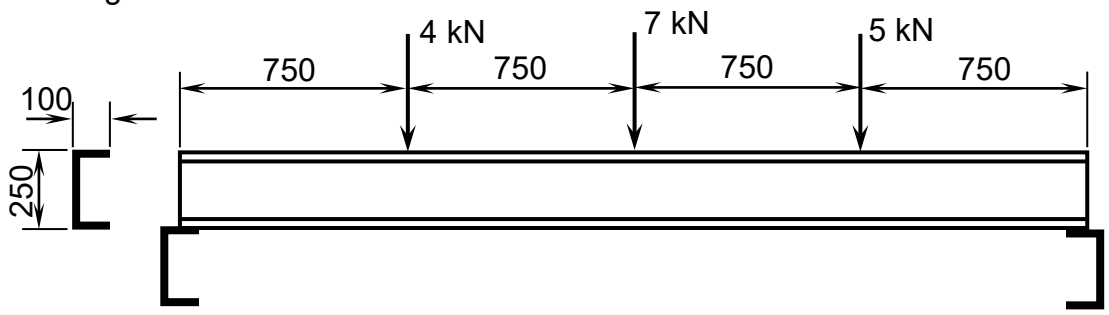
d) Explain why a precipitation hardened aluminium alloy cannot be used where hot jet exhaust will elevate its temperature above 175°C. **2**

End of Question 24

Question 25 (15 marks) **Marks**

a) An aluminium alloy C-beam is used as a support structure in an aircraft wing. The beam is supported by two similar beams to provide reactions to the external loads shown. The C-beam's cross section is symmetrical about the neutral axis. **4**

(i) Using an appropriate scale construct a shear force and bending moment diagram for the loaded beam.



Shear Force Diagram

Bending Moment Diagram

Question 25 continues on the next page

Question 25 (cont.) **Marks**

(ii) Determine the maximum bending stress in the C-beam. Assume the second moment of area for them beam to be 50×10^6 mm^4. **2**

Bending stress _____ MPa

b) A small polyethylene component for an aircraft is to be mass produced. Identify and then describe an appropriate forming process. **3**

_____

_____

_____

_____

_____

_____

_____

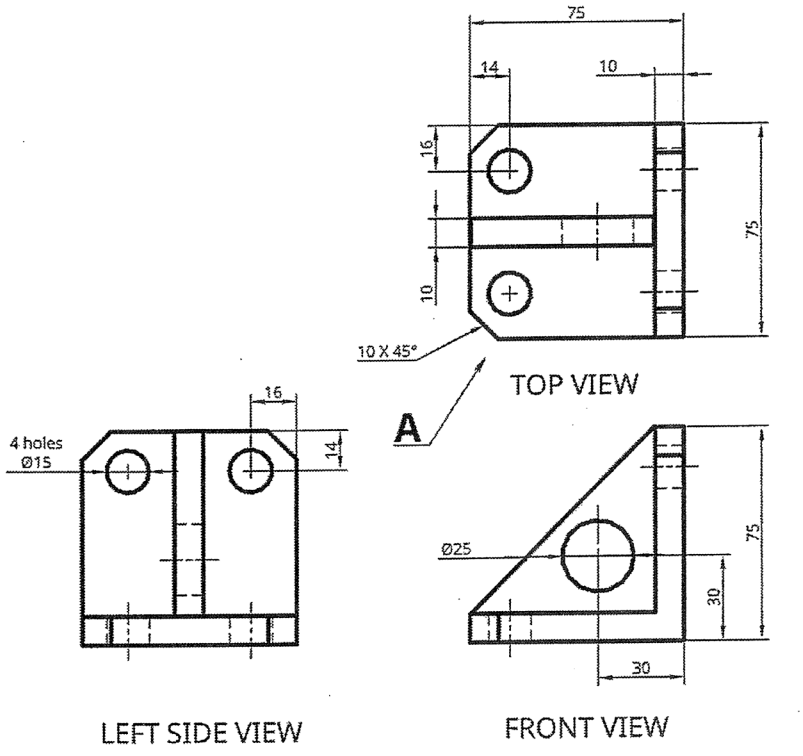
_____

_____

Question 25 continues on the next page

Question 25 (cont.) **Marks**

c) A dimensioned orthogonal drawing of a webbed bracket is shown below. The web is positioned in the centre of the bracket. **6**



Draw a pictorial drawing of the bracket when viewed from the direction of A.
Use a scale of 1:1 and do not dimension the drawing.

End of Question 25

Question 26 (12 marks) **Marks**

a) A bicycle and rider of combined mass 80 kg are travelling at 30 km/h on a flat road and expending power at a rate of 200 W. The rider starts ascending a hill that is 500 m long with a grade of 1:20. Presuming friction and air resistance forces remain constant; determine the force the rider needs to provide so the velocity at the top of the hill is 25 km/h. Then determine the average power needed for that force. **6**

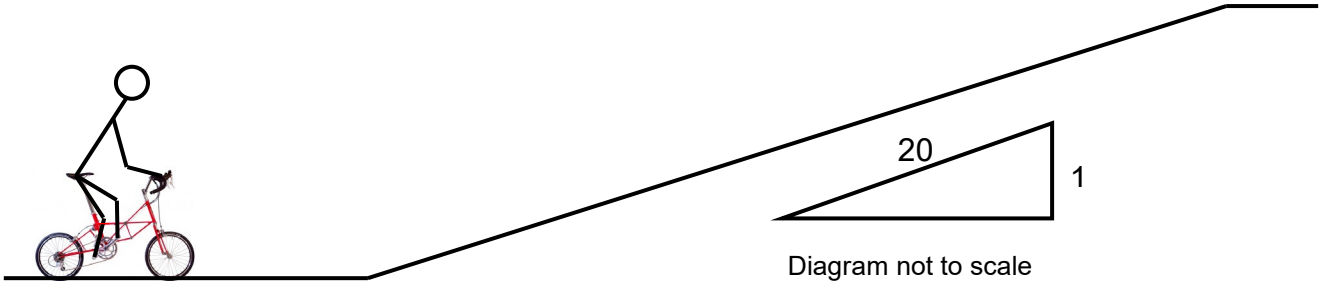


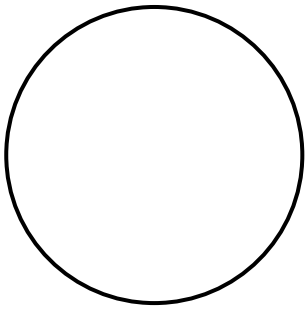
Diagram not to scale

Force _____ N

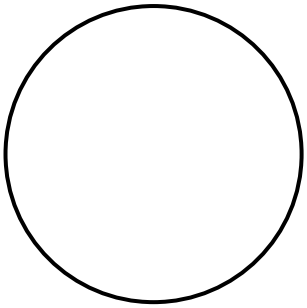
Power _____ W

Question 26 continues on the next page

b) The bicycle could be made from cold rolled alloy steel tubing. The alloy steel has a similar microstructure to mild steel. Draw and label the microstructure of a cold rolled mild steel, and a process annealed mild steel. Explain why the cold rolled steel will have greater tensile strength. **4**



Cold rolled



Process annealed

c) The bicycle uses stainless steel in certain areas to avoid corrosion. Explain why stainless steels are resistant to corrosion despite being an iron alloy. **2**

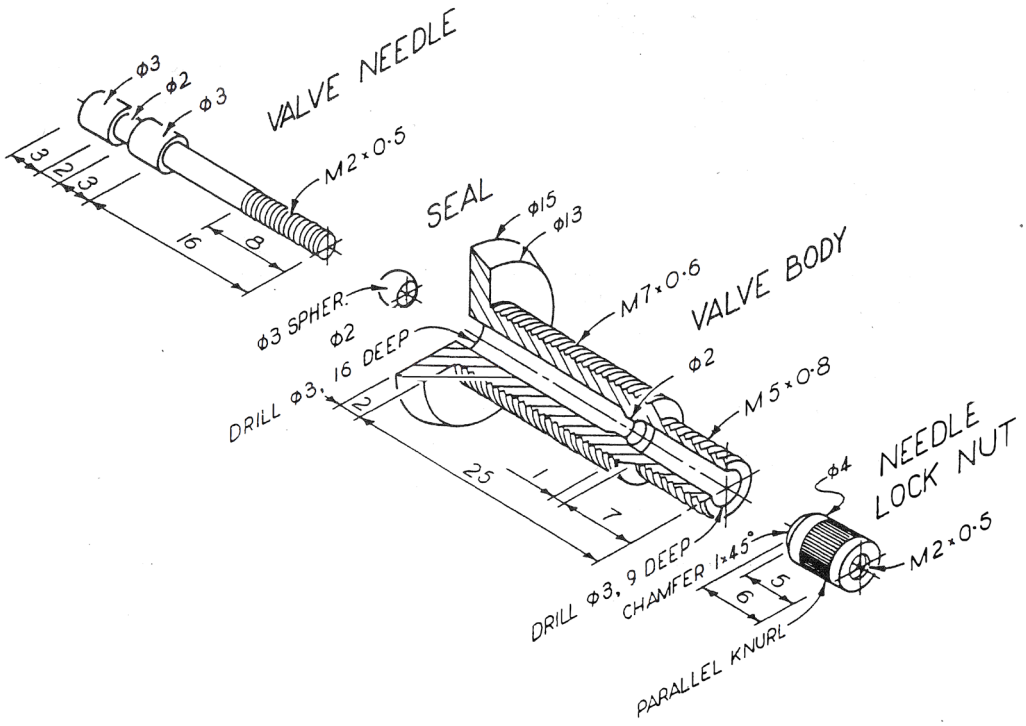
End of Question 26

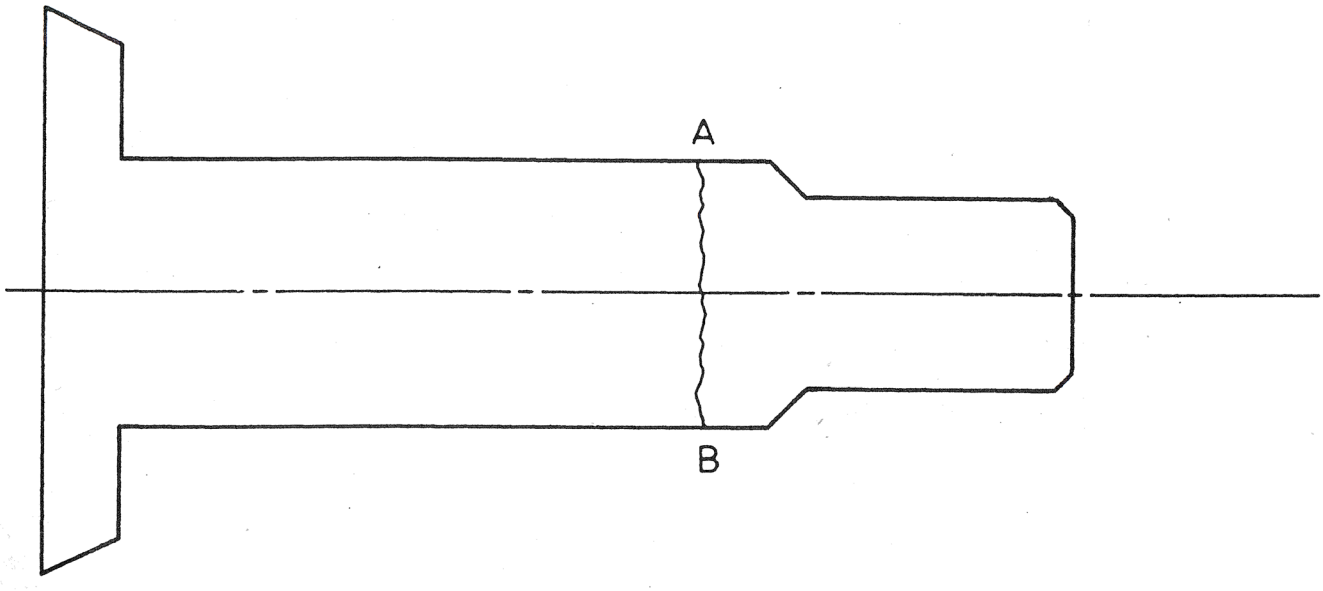
Question 27 (8 marks) **Marks**

An exploded pictorial drawing of a high pressure “Presta style” valve from a bicycle tube is shown. Shape and size details of the valve body are given. **8**

A part sectional front view of the assembled components is commenced below, using a scale of 5:1.

Complete the part sectional front view. The seal must be drawn in the closed position. The part section is to the left of line AB. Follow AS1100 standards, additionally do not section the seal.





SCALE – 5:1

End of paper

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Formulae Sheet

Force, Moments

$F = ma; \quad M = Fd$

If a body is in equilibrium, then $\sum F_x = 0; \quad \sum F_y = 0; \quad \sum M = 0$

Friction

$F = \mu N; \quad \mu = \tan\phi$

Energy, Work, Power

$KE = \frac{1}{2}mv^2; \quad PE = mgh; \quad W = Fs = \Delta PE + \Delta KE; \quad P = \frac{W}{t}; \quad P = \frac{Fs}{t}$

Pressure

$P = \frac{F}{A}; \quad P = P_o + \rho gh$

Stress and Strain

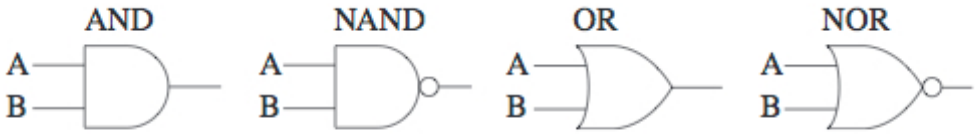
$\sigma = \frac{F}{A}; \quad \varepsilon = \frac{e}{L}; \quad E = \frac{\sigma}{\varepsilon}; \quad \sigma = \frac{My}{I}$

$\sigma_{\text{allowable}} = \frac{\sigma_{yield}}{F \text{ of } S}$ (Ductile); $\quad \sigma_{\text{allowable}} = \frac{\sigma_{UTS}}{F \text{ of } S}$ (Brittle)

Machines

$MA = \frac{L}{E}; \quad VR = \frac{d_E}{d_L}; \quad \eta = \frac{MA}{VR}$

Digital electronics



Electricity, Electronics

$E = IR \qquad P = I^2R$

Series $R_t = R_1 + R_2 + R_3 + R_4 + \ldots + R_n$

Parallel $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \ldots + \frac{1}{R_n}$

Name _____

Sydney Technical High School

2022
Year 12 Trial Higher School Certificate Examination

Engineering Studies

Solutions

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Dimensions in millimetres unless otherwise stated
- Board-approved calculators may be used
- A formulae sheet is provided at the back of this paper
- Write your name at the top of this page.

Total Marks 100

Section I pages 2-10

20 marks
Attempt questions 1-10
Allow about 30 minutes for this section.

Section II pages 11-27

80 Marks
Attempt questions 21-27
Allow about 2 hours and 30 minutes for this section.

Section I
20 Marks
Attempt Questions 1–20
Allow about 30 minutes for this section

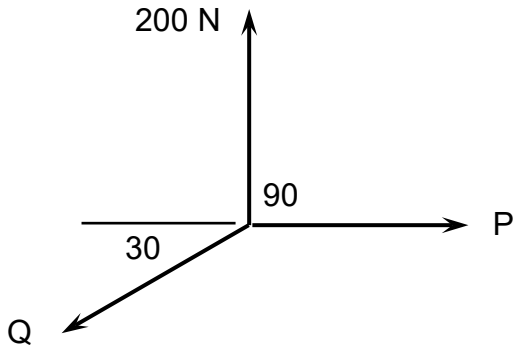
Answer the questions in the spaces provided.

Place a tick in the box to indicate your selection.

If you make a mistake cross it out then place the tick in your new selection.

Question	A	B	C	D
1		■		
2				■
3				■
4		■		
5	■			
6			■	
7			■	
8		■		
9			■	
10		■		
11			■	
12	■			
13				■
14				■
15			■	
16	■			
17			■	
18				■
19	■			
20				■

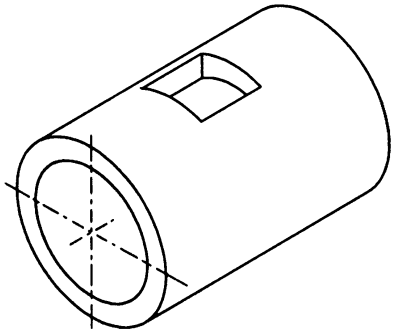
1. Three concurrent forces in a state of equilibrium are shown.



What will be the magnitude of Q?

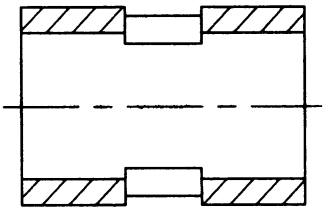
(A) 346 N
(B) 400 N
(C) 500 N
(D) 800 N

2. A component is shown in the pictorial drawing.

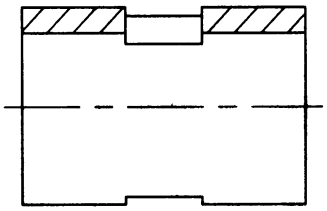


Which of the following drawings represents the half-section front view of the component?

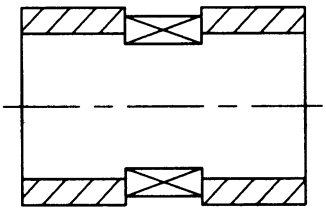
(A)



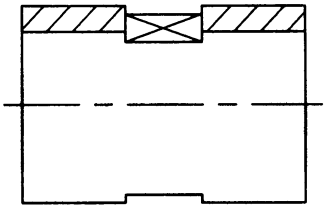
(B)



(C)



(D)



3. What value varies with the efficiency of a machine?

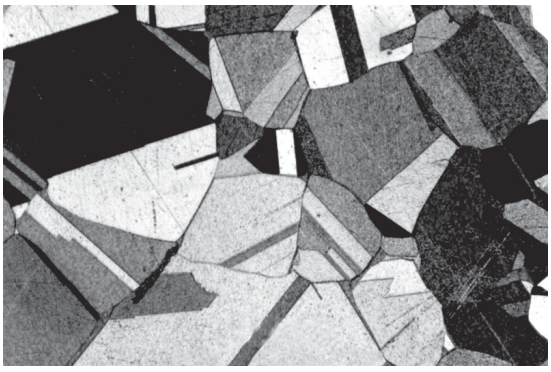
   (A) Velocity ratio
   (B) Kinetic energy
   (C) Potential energy
   (D) Mechanical advantage

4. Which best describes electromagnetic induction?
   (A) The induction of a magnetic field in a conductor.
   (B) Production of an electric current in a conductor that is subjected to a changing magnetic field.
   (C) Production of a magnetic field due to an alternating current.
   (D) Production of a magnetic current in a conductor that is subjected to changing current.

5. How is the toughness of a material indicated on a stress-strain curve?
   (A) The total area under the stress-strain curve.
   (B) The highest value of stress on the curve.
   (C) The area under the straight line section of the stress-strain curve.
   (D) The slope of the straight line portion of stress-strain curve.

6. Which best describes the process of galvanising?
   (A) Painting a structure with an anti-corrosion coating.
   (B) Electroplating metals with another metal to protect against corrosion.
   (C) Coating ferrous metals with zinc to protect against corrosion.
   (D) Alloying metals with particular anti-corrosion elements to permanently protect against corrosion.

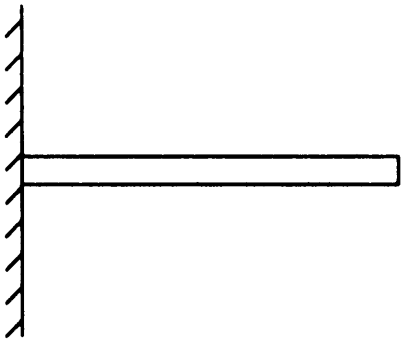
7. The image below shows a photomicrograph of brass.



What type of grain structure does the image represent?

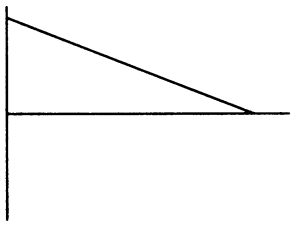
   (A) Deformed
   (B) Dendritic
   (C) Equiaxed
   (D) Stressed

8. A steel cantilever beam is shown?

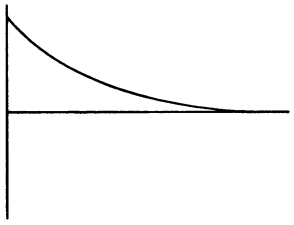


Which sketch best represents the shape of the bending diagram for the beam, if the mass of the beam is uniformly distributed?

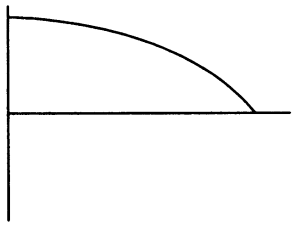
(A)



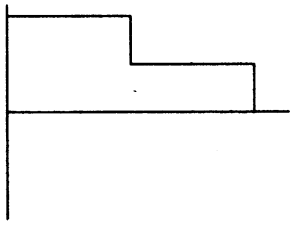
(B)



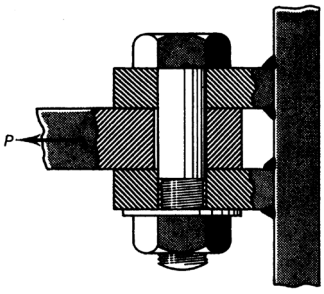
(C)



(D)



9. A force P, is applied to the plate as shown.



If the maximum allowable shear stress in the ∅20 mm bolt is 100 MPa, the maximum value of P will be:

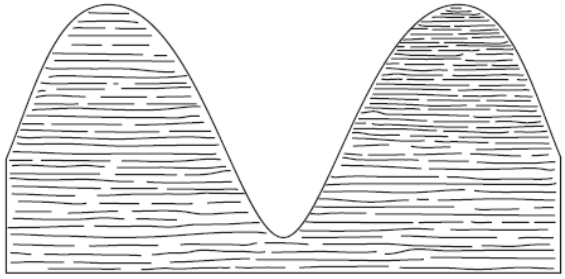
(A) 22.1 kN
(B) 31.4 kN
(C) 62.8 kN
(D) 125.6 kN

10. A high-carbon steel punch is to be used to make holes in mild-steel sheet.

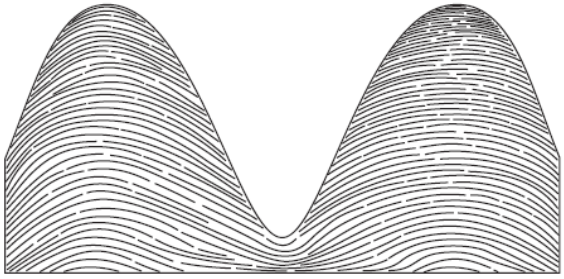
    What are the final heat-treatment processes required in the manufacture of the punch?

    (A) Normalising then hardening
    (B) Hardening then tempering
    (C) Normalising then tempering
    (D) Hardening then normalising

11. Deduce from the two macrostructures what manufacturing processes were used to form thread shape X and thread shape Y.



X



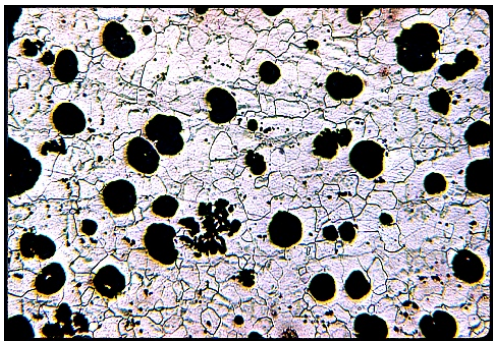
Y

    (A) X by cutting and Y by cutting
    (B) X by rolling and Y by rolling
    (C) X by cutting and Y by rolling
    (D) X by rolling and Y by cutting

12. Roll in an aircraft is primarily controlled by which control device?

    (A) Aileron
    (B) Elevator
    (C) Spoiler
    (D) Rudder

13. The photomicrograph of a spheroidal graphite cast iron is shown below. What are the names of the two phases present?

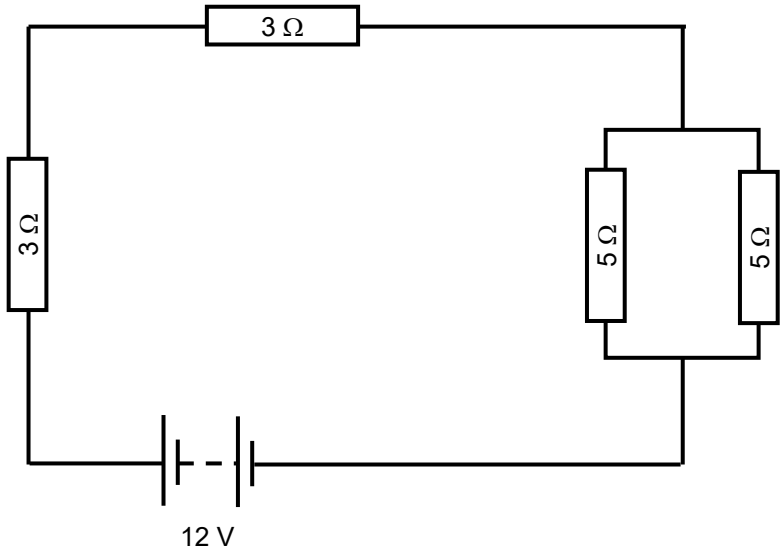


    (A) austenite and cementite
    (B) ferrite and austenite
    (C) ferrite and cementite
    (D) ferrite and graphite

14. What are the fundamental functions of transistors in an electronic circuit?

(A) Switching and earthing
(B) Invertor and resistance
(C) Resistance and rectification
(D) Amplification and switching

15. A simple electrical circuit with four resistors and is loaded with a 12 V 60 Ah (amp-hour) battery is shown.



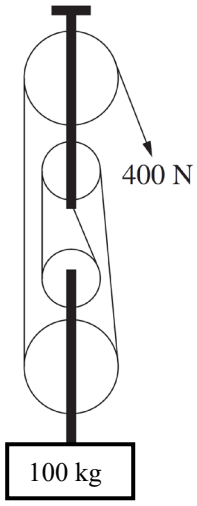
How long will current flow in the circuit?

(A) 12 hours
(B) 16 hours
(C) 43 hours
(D) 60 hours

16. The structure of martensite may be described as:

(A) Acicular,
(B) Lamellar,
(C) Twinned,
(D) Peritectic?

17. The diagram shows a block and tackle pulley system.



NOT TO SCALE

A 400 N effort is needed to raise the 100 kg load.

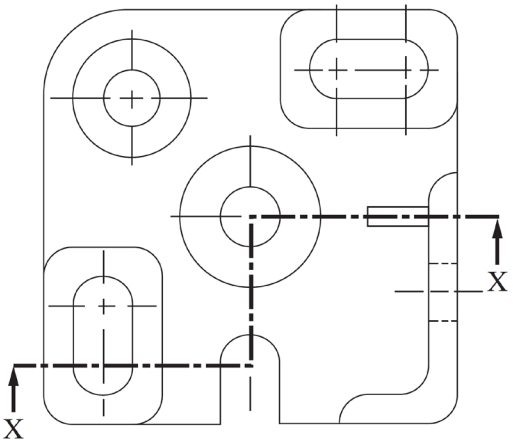
What is the efficiency of the pulley system?

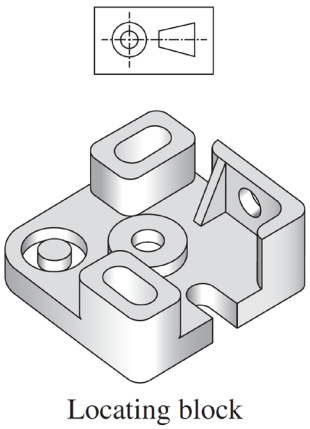
(A) 100%
(B) 75%
(C) 62.5%
(D) 50.5%

18. Control technology is used for electric motor control in the transport industry. What is the most efficient method used for motor speed control?

(A) Phase shift keying (PSK)
(B) Frequency Modulation (FM)
(C) Potentiometer or rheostat
(D) Pulse Width Modulation (PWM)

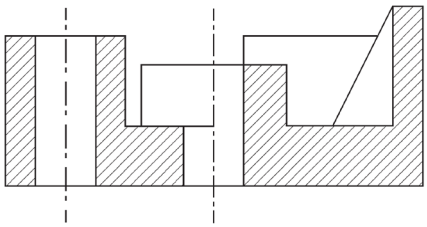
19. A locating block is sectioned by an offset cutting plane labelled X-X.



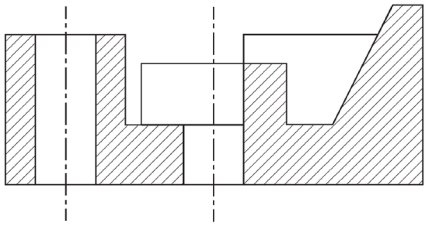

Locating block

Which front view is sectioned to AS1100 standards?

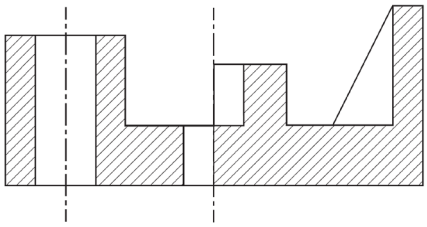
(A)



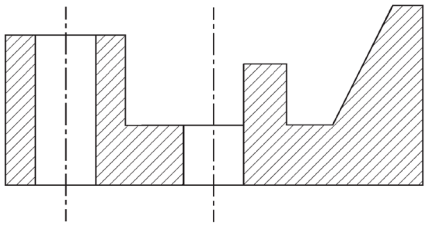
(B)



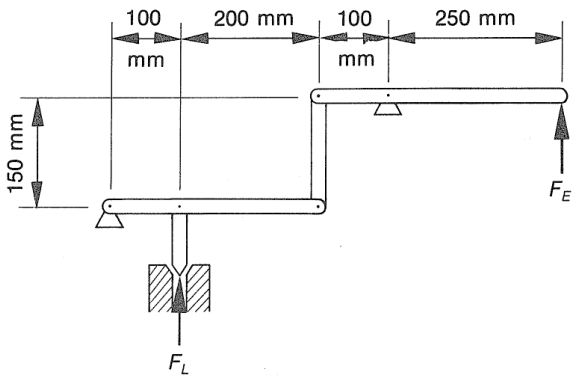
(C)



(D)



20. A compound lever system is shown?



What is the velocity ratio for the system?

(A) 1:1
(B) 2.5:1
(C) 5:1
(D) 7.5:1

Section II **Marks**
70 marks
Attempt Questions 21–27
Allow about 2 hours and 30 minutes for this section

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 21 (9 marks)

a) G clamps may be manufactured from spheroidal graphite cast iron by sand casting.

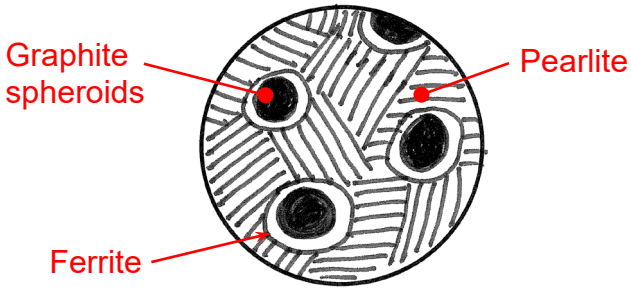


(i) Describe the sand casting process, and outline an advantage and disadvantage of sand casting. **3**

Sand containing a binder is compacted around a pattern of the object to be cast. The mould comprises of two halves: the cope and the drag. Once the mould is formed the two halves are separated and the pattern removed to leave a cavity. The molten metal is poured into the mould, riser and runner pins. Once solidified the sand is broken away to reveal the completed casting.
Advantages: Can cast high temp. alloys, good cooling rate, easy to form complex shapes with cores. Can be automated.
Disadvantages: Poor surface finish, mould must be separated which leaves a parting line. Mould must be made for each casting.

Question 21 continues the next page

(ii) Draw and label the microstructure for the spheroidal graphite cast iron used to make the G clamp. Explain why the spheroidal graphite cast iron is used in preference to grey cast iron for this specific application. **3**



The G clamp will experience compression and tensile forces when clamping. The tensile forces would promote cracking in a grey cast iron due to the sharp edges on the graphite flakes. Whereas SG cast iron has rounded graphite spheroids which are better able to handle tensile forces.

3

b) Gears can be sand cast and machined or they may be formed using powder metallurgy. Compare the two forming methods for forming gears.

Cast and Machined

- good for lower volume production,
- poor surface finish,
- casting may result in columnar grains or inclusions,
- poorer dimensional stability than powder metallurgy.
- machining adds to manufacturing time and cost

Powder Metallurgy

- Good for lower volume
- allows alloys that cannot normally be made,
- can be made self-lubricating,
- has a higher dimensional stability,
- less machining required post forming

End of Question 21

Question 22 (12 marks) **Marks**

a) Modern personal transport devices use extensive control systems to achieve many different aspects. Identify two recent developments in control systems used in personal transport devices, outline what they do and then explain how those control systems have improved the performance or effectiveness of the transportation device. **6**

Driverless cars: Three control systems come together to allow driverless cars to be a viable option.

(a) GPS systems allow the car to *know* where it is going.

(b) Proximity sensors and cameras allow the car to *see* where it is going and detect obstacles in the immediate vicinity.

(c) Actuators and control systems allow the car to *get* where it is going, these control the propulsion systems and brakes and steering.

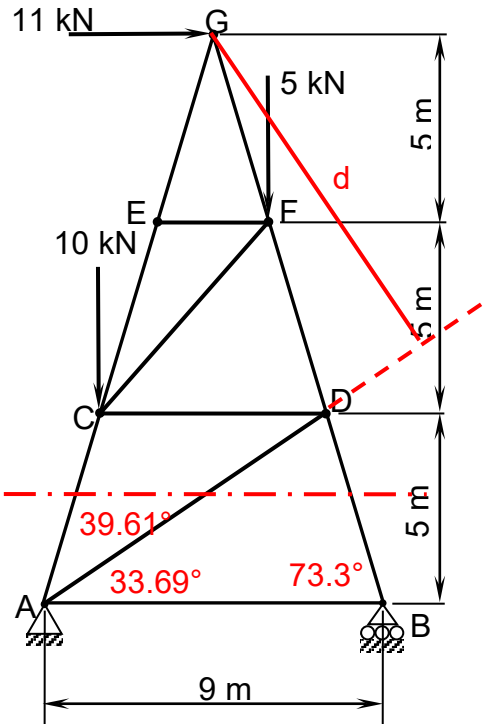
These systems will allow cars to be driverless and potentially safer without human error. However challenges remain with decsions about avoiding live obstacles.

Dynamic Stability Controls: These use a mixture of the ABS technology and augment it with sensors that detect a car's intended motion with what is actually happening. The CPU then operates the brakes to make the vehicle move as intended when situations of poor adhesion are preventing that. This leads to safer vehicles that are less like to have an accident in adverse conditions.

Question 22 continues on the next page

Question 22 (continued) **Marks**

A pin-jointed symmetrical triangular tower is loaded by three forces as shown. **6**



$$AG = \sqrt{15^2 + 4.5^2}$$
$$AG = 15.66 \text{ m}$$
$$\sin 39.61 = \frac{d}{15.66}$$
$$d = 9.9846 \text{ m}$$

a) Determine the force in members AD and AC.

Consider truss section above the section plane:

$$\circlearrowleft \Sigma M_G = 0$$
$$0 = +(5 \times 1.5) - (10 \times 3) + (F_{AD} \times 9.9846)$$
$$0 = 7.5 - 30 + 9.9846 F_{AD}$$
$$F_{AD} = \frac{22.5}{9.9846}$$
$$F_{AD} = 2.253 \text{ kN (tens)}$$

$$\circlearrowleft \Sigma M_D = 0$$
$$0 = +(11 \times 10) - (5 \times 1.5) - (10 \times 6) + (F_{AC} \sin 73.3° \times 6)$$
$$0 = 110 - 7.5 - 60 + 5.747 F_{AC}$$
$$F_{AC} = \frac{42.5}{5.747}$$
$$F_{AC} = 7.395 \text{ kN (tens)}$$

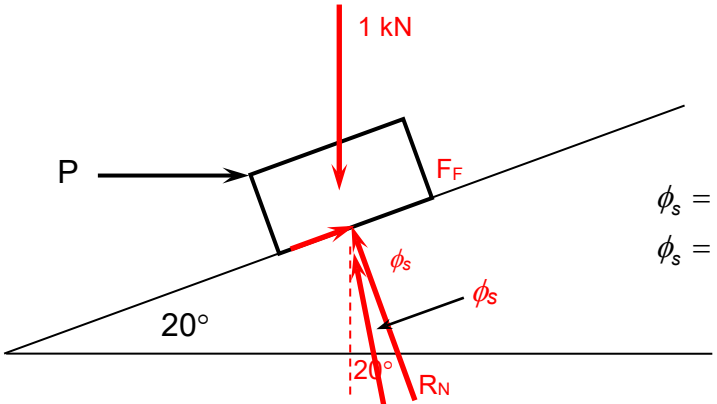
AD **2.253** kN **tens**

AC **7.395** kN **tens**

End of Question 22

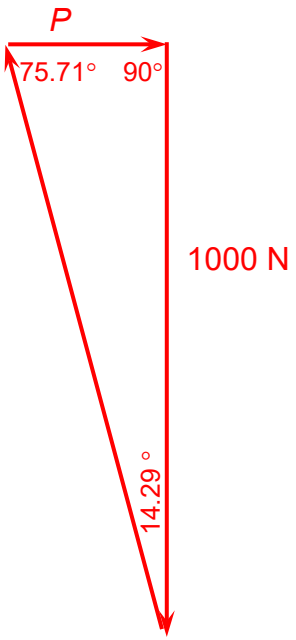
Question 23 (12 marks) **Marks**

a) A box of mass 100 kg is held stationary an inclined ramp as shown. The coefficient of static friction between the suitcase and ramp is 0.1. Force *P* acts horizontally. **4**



$$\phi_s = \tan^{-1} 0.1$$
$$\phi_s = 5.71°$$

Determine the minimum value of force *P* required to stop the box from sliding.



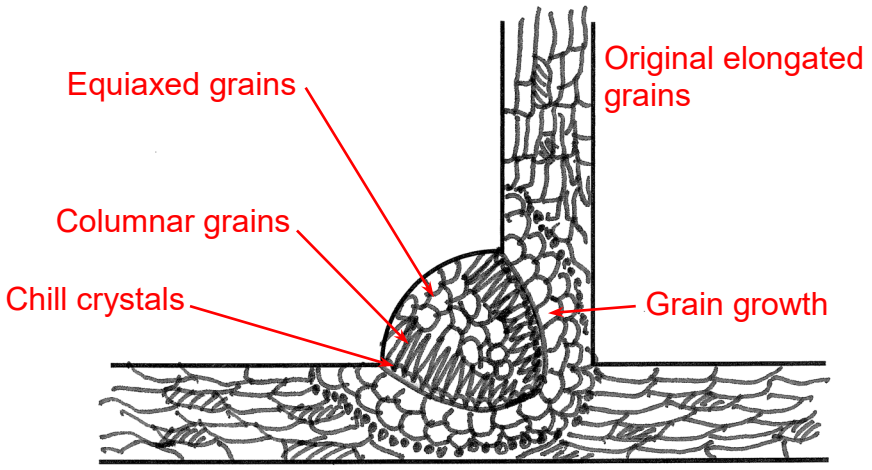
$$\tan 14.29° = \frac{P}{1000}$$
$$P = 1000 \times \tan 14.29°$$
$$P = 254.7 \text{ N}$$

P = **254.7** N

Question 23 continues on the next page

b) As part of the manufacture of a frame a weld is performed to join two pieces of cold rolled mild steel plate at an angle of 90°.

(i) Complete the diagram below by showing the weld and the resulting microstructural changes of both the weld metal and the original plates. Label the key features. **3**

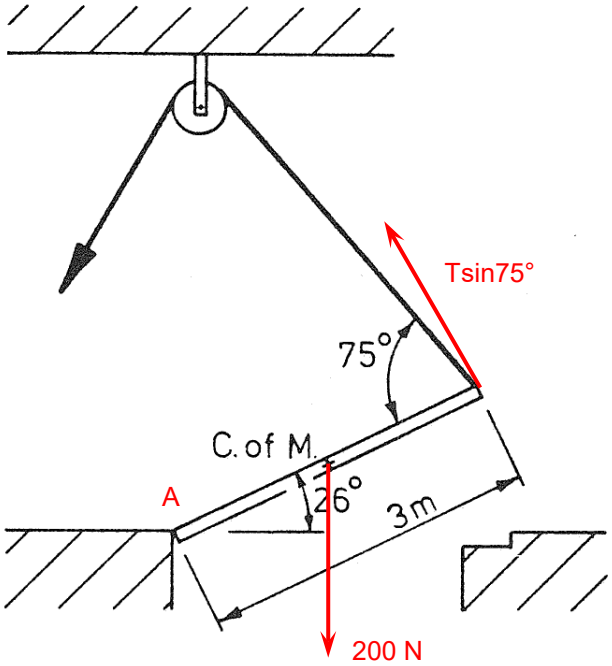


(ii) Explain why the strength around the weld varies, and how this affects the weld's performance in service. **3**

The cold rolled plate near the weld will have recrystallised grains because of the elevated weld temperature. This creates a heat affected zone (HAZ) that has lower strength than the original strength of the cold rolled plate. The unstressed grains in the HAZ have not work hardened and this have less strength.

Question 23 continues on the next page

c) A trapdoor of mass 20 kg is raised by a rope passing around a fixed frictionless pulley as shown below. The centre of mass is in the middle of the trapdoor. **2**



Determine the tension in the rope when the trap door is held in the position shown.

$$\circlearrowleft^{+} \quad \Sigma M_A = 0$$

$$0 = (200 \times 1.5\cos 26^\circ) - (T \sin 75^\circ \times 3)$$

$$T = \frac{269.64}{3\sin 75^\circ}$$

$$T = 93.05 \text{ N}$$

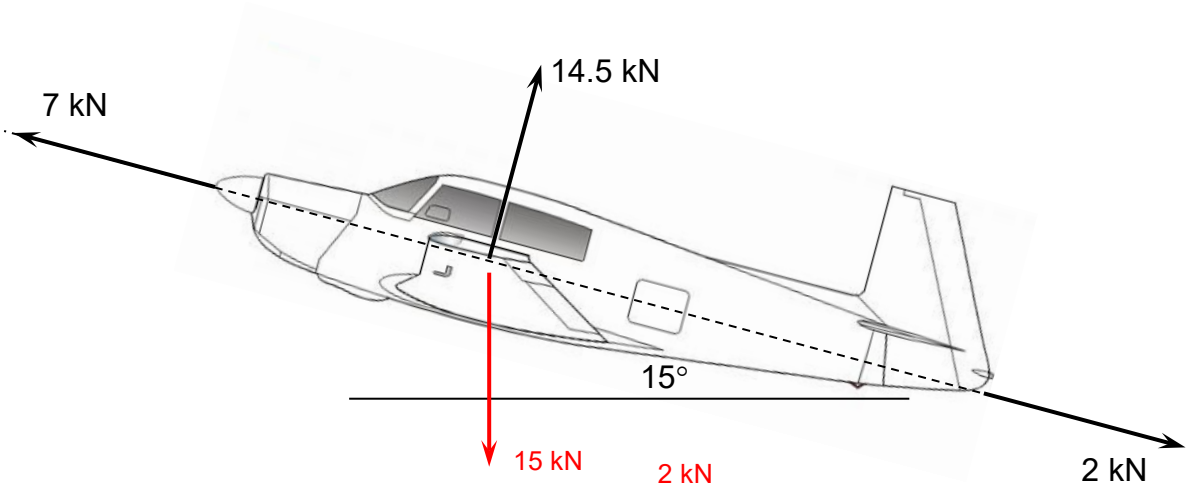
Tension = **93.05** N

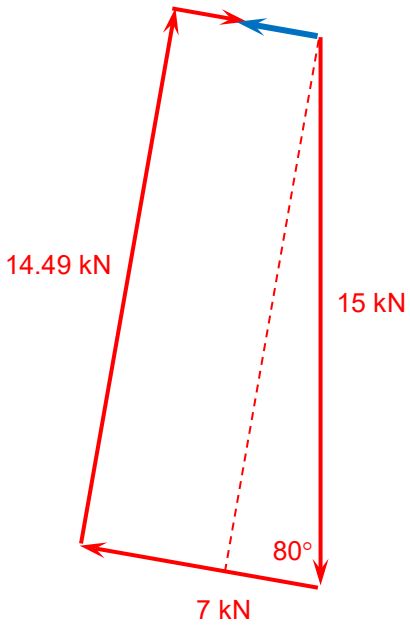
End of Question 23

Question 24 (12 marks)

Marks

a) A small civil aircraft with a mass of 1.5 tonnes is climbing at an angle of 15°. Determine the acceleration of the plane along the flight path when the 7 kN thrust force and the 2 kN drag force acts along the line of flight. Lift force is 14.49 kN. **4**



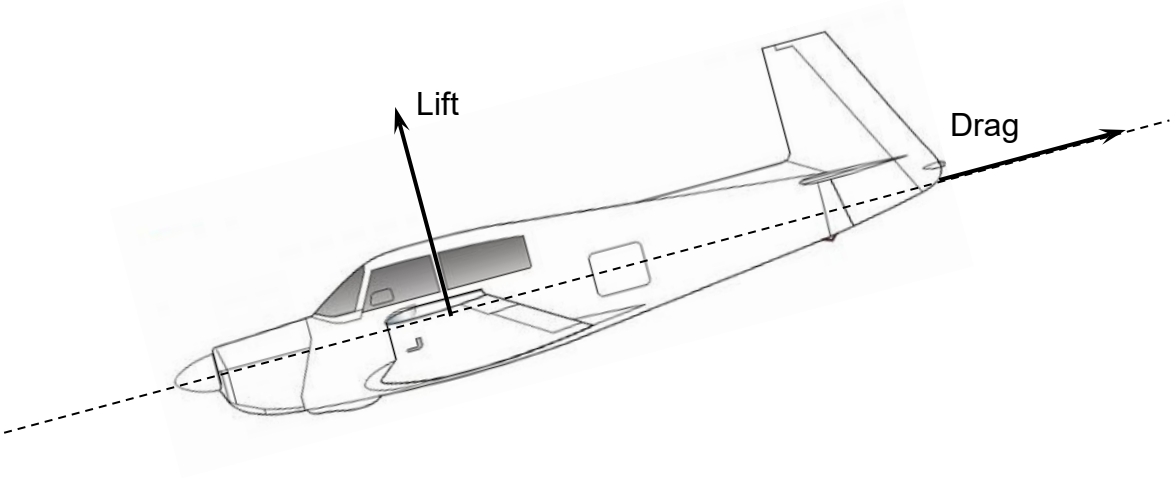


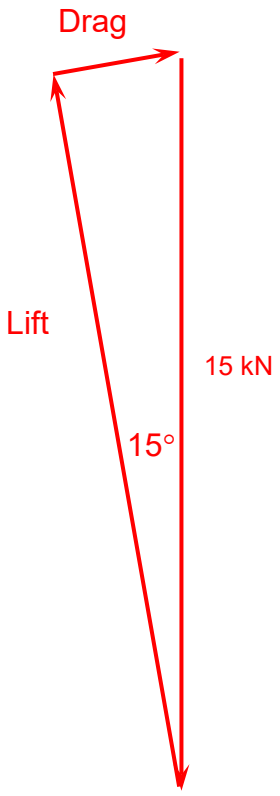
$$R + 2 = 7 - 15\cos 75°$$
$$R = 5 - 15\cos 75°$$
$$R = 1.1177 \text{ kN}$$
$$R = ma$$
$$a = \frac{R}{m}$$
$$a = \frac{1117.7}{1500}$$
$$a = 0.745 \text{ ms}^{-2}$$

Acceleration = **0.745** ms^{-2}

Question 24 continues on the next page

b) For another set of conditions the 1.5 tonne aircraft is descending with the engine off at a glide angle of 15°, determine the lift force acting along the line of flight and the Lift to Drag ratio. **3**





Lift =15cos15°=14.49 kN

$$L:D=\frac{1}{\tan 15°}$$

$$L:D=3.732$$

Lift force = **14.49** kN

Lift to Drag Ratio = **3.732**

Question 24 continues on the next page

Question 24 (cont.) **Marks**

c) In this aircraft, the external skin is riveted to the frame using solution treated and quenched aluminium 4% copper alloy rivets. These rivets are used immediately to attach the external skin of the aircraft to the frame. Describe the changes that occur to the structure and properties of these after installation. **3**

The quenched structure is a single phase α solid solution, which is super saturated. This is not stable and the θ phase will slowly precipitate out as a coherent precipitate within the existing atomic structure. The precipitate slightly distorts the atomic structure which impedes the movement of dislocations, which in turn makes the alloy more resistant to deformation, hence stronger in application.

d) Explain why a precipitation hardened aluminium alloy cannot be used where hot jet exhaust will elevate its temperature above 175°C. **2**

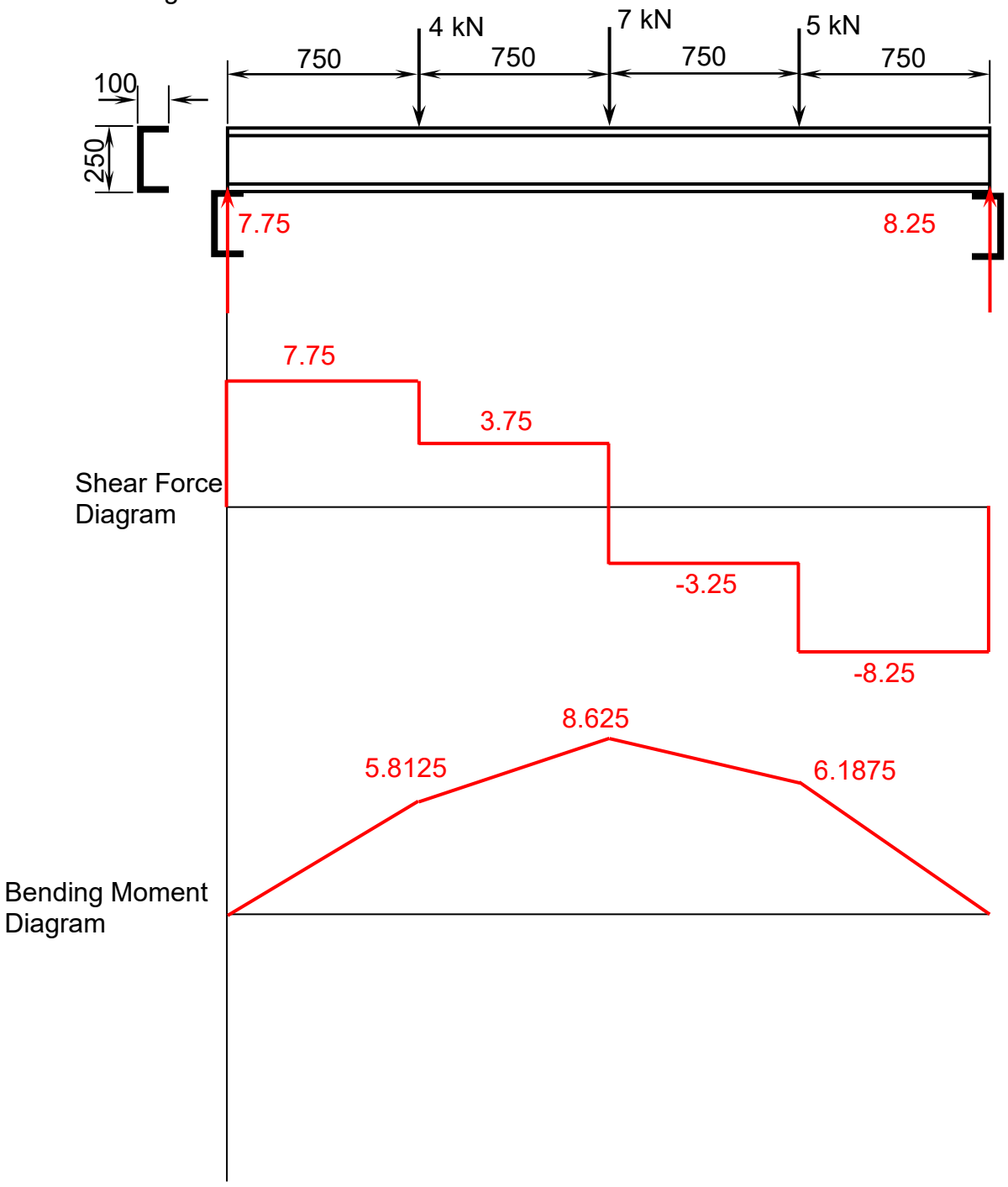
By heating the part to above 175°C the aluminium alloy will become overaged. This causes the precipitate to become coarse and incoherent – this results in a weaker material than would occur from optimal precipitation hardening. Hence the material will no longer to be able to provide the strength properties that were required for the application.

End of Question 24

Question 25 (15 marks) **Marks**

a) An aluminium alloy C-beam is used as a support structure in an aircraft wing. The beam is supported by two similar beams to provide reactions to the external loads shown. The C-beam's cross section is symmetrical about the neutral axis. **4**

(i) Using an appropriate scale construct a shear force and bending moment diagram for the loaded beam.



Question 25 continues on the next page

(ii) Determine the maximum bending stress in the C-beam. Assume the second moment of area for them beam to be 50×10^6 mm^4. **2**

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

$$\sigma_b = \frac{(8.625\times10^3)(125\times10^3)}{50\times10^{-6}}$$

$$\sigma_b = 21.56\times10^6 \text{ Pa}$$

$$\sigma_b = 21.56 \text{ MPa}$$

Bending stress _____ MPa

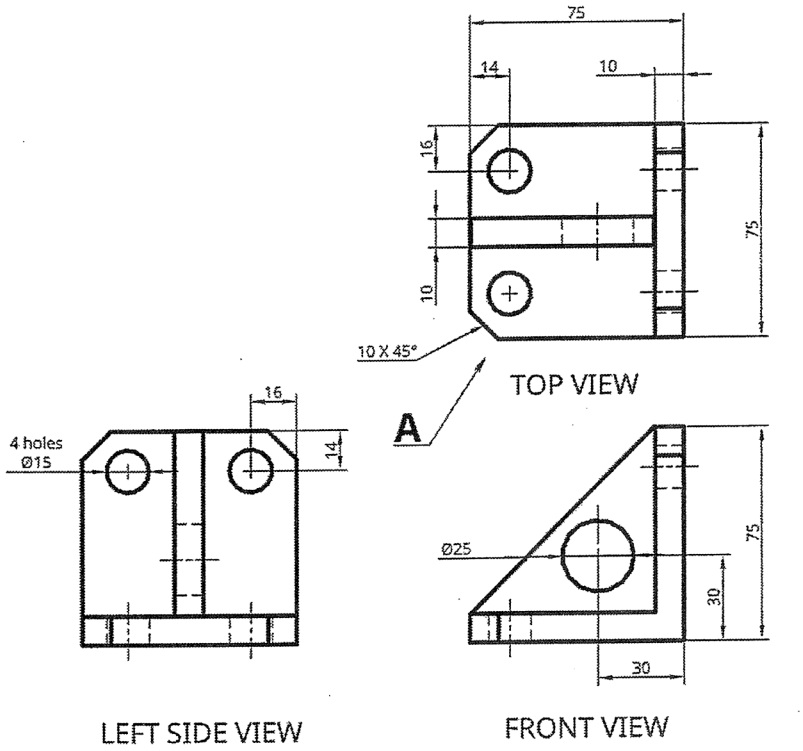
b) A small polyethylene component for an aircraft is to be mass produced. Identify and then describe an appropriate forming process. **3**

Injection moulding.

Polyethylene granules are placed into a hopper, they are then moved to a heating chamber where they are melted. The molten polymer is then injected into a permanent metal mould of the finished object. Upon solidification the mould opens, the finished article is ejected from the mould, and the mould closes and the process is repeated.

Question 25 continues on the next page

c) A dimensioned orthogonal drawing of a webbed bracket is shown below. The web is positioned in the centre of the bracket. **6**



Draw a pictorial drawing of the bracket when viewed from the direction of A.
Use a scale of 1:1 and do not dimension the drawing.

Solution to come

End of Question 25

Question 26 (12 marks) **Marks**

a) A bicycle and rider of combined mass 75 kg are travelling at 30 km/h on a flat road and expending power at a rate of 200 W. The rider starts ascending a hill that is 500 m long with a grade of 1:20. Presuming friction and air resistance forces remain constant; determine the force the rider needs to provide so the velocity at the top of the hill is 25 km/h. Then determine the power needed for that force. **6**

v_i=36 km/h=8.33 ms^{-1}
v_f=28 km/h=6.944 ms^{-1}

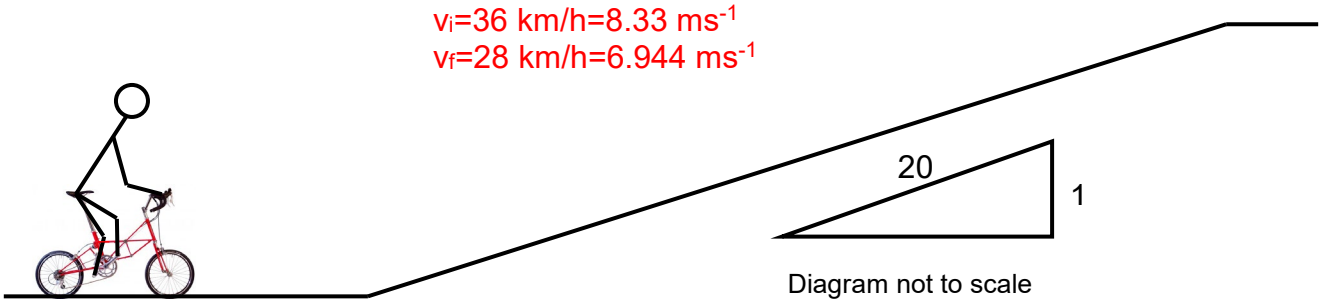


Diagram not to scale

First calculate the resistance force the rider experiences riding on the flat.

$$P = F_R v$$

$$F_R = \frac{P}{v} = \frac{200}{8.33}$$

$$F_R = 24 \text{ N}$$

Now that you have the resistance force (F_R) you use the work-energy principle to determine the force the rider needs to provide.

$$PE_i + KE_i + W - W_R = PE_f + KE_f$$

$$KE_i + W - W_R = PE_f + KE_f \text{ (since } PE_i = 0)$$

$$\tfrac{1}{2}mv_i^2 + Fs - F_R s = mgh + \tfrac{1}{2}mv_f^2$$

$$(\tfrac{1}{2}\times 85\times 8.33^2) + F(500) - (24\times 500) = (80\times 10\times 25) + (\tfrac{1}{2}\times 85\times 6.944^2)$$

$$2777.78 + 500F - 12000 = 20000 + 1929.012$$

$$F = \frac{31151.235}{500}$$

$$F = 62.302 \text{ N}$$

Now determine the average power using that force, and the average velocity for the ascent.

$$v_{av} = \frac{8.33 + 6.944}{2}$$

$$v_{av} = 7.639 \text{ ms}^{-1}$$

$$P = Fv_{av}$$

$$P = 62.302\times 7.639$$

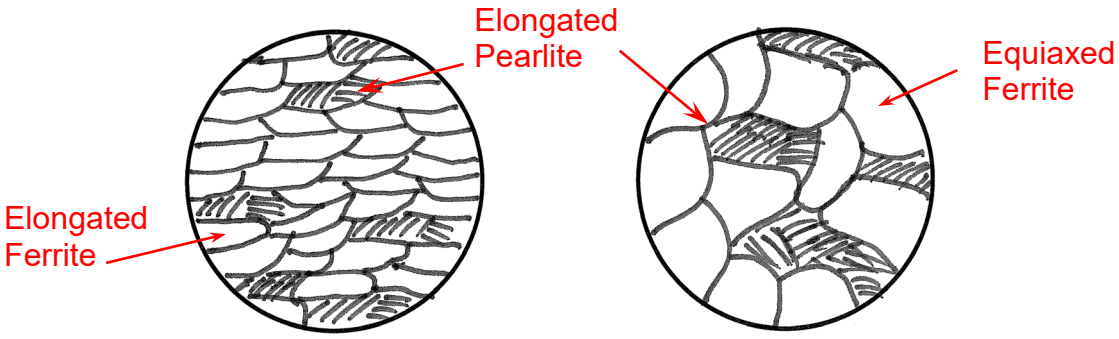
$$P = 475.92 \text{ W}$$

Force _____**62.302**_____ N

Power _____**475.92**_____ W

Question 26 continues on the next page

b) The bicycle could be made from cold rolled alloy steel tubing. The alloy steel has a similar microstructure to mild steel. Draw and label the microstructure of a cold rolled mild steel, and a process annealed mild steel. Explain why the cold rolled steel will have greater tensile strength. **4**



Cold rolled Process annealed

Cold rolled steel has greater strength because the deformed grain have already undergone work hardening. This means the dislocations cannot move as much hence the material will be stronger and harder. The process annealed steel has equiaxed ferrite grains which will allow more dislocation movement which makes the material weaker by comparison.

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c) The bicycle uses stainless steel in certain areas to avoid corrosion. Explain why stainless steels are resistant to corrosion despite being an iron alloy. **2**

Stainless steels have at least 10% chromium added. The chromium reacts with the oxygen to form a passive chromium oxide layer that protects the stainless steel from any further corrosion.

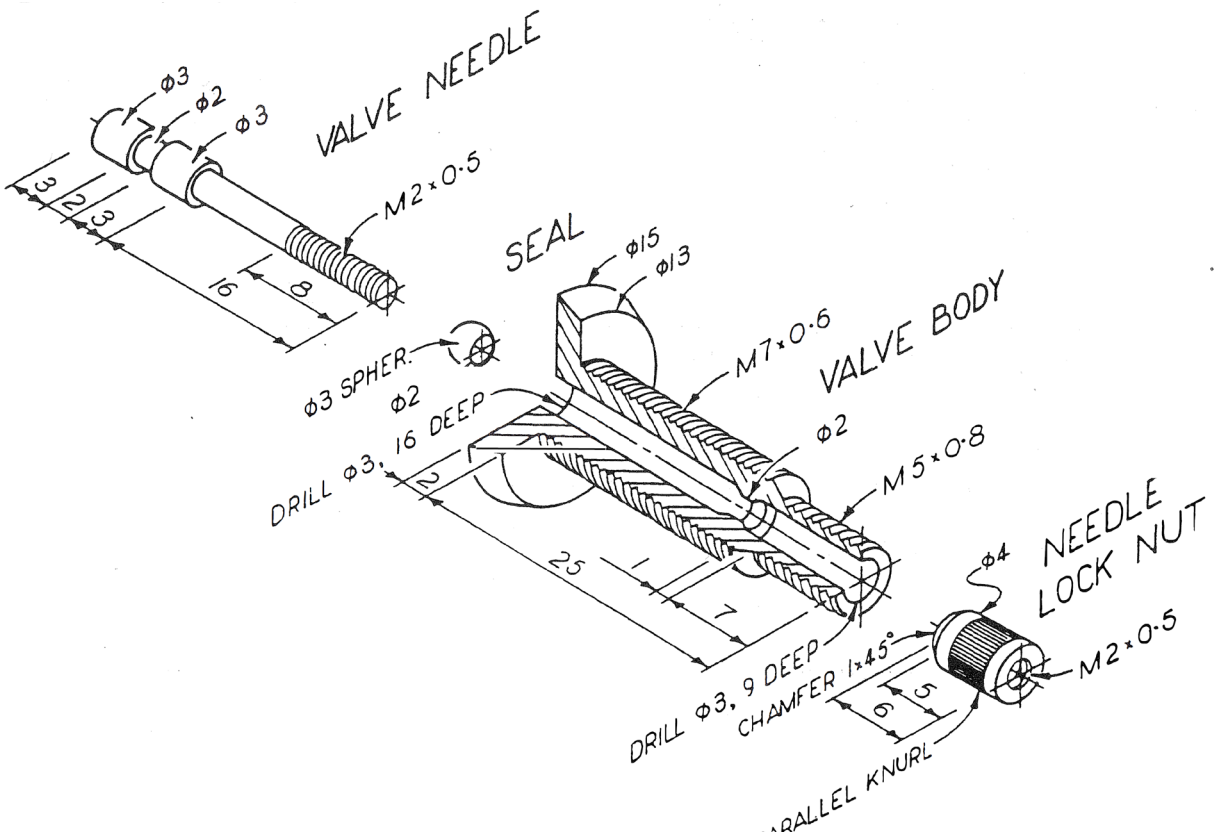
End of Question 26

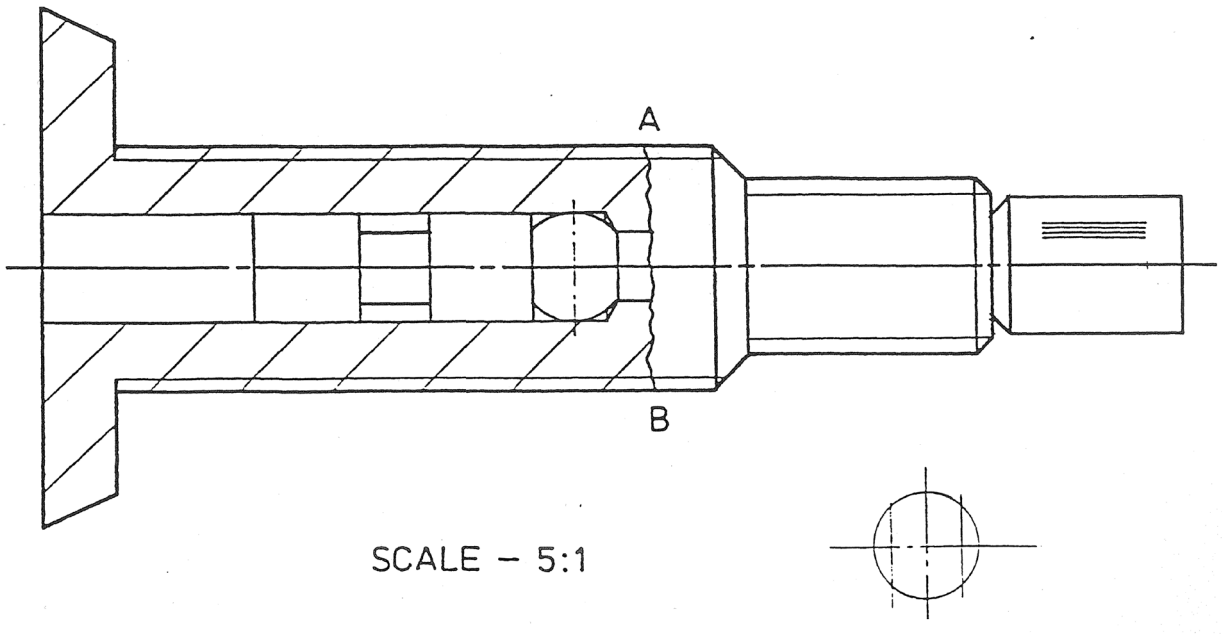
Question 27 (8 marks) **Marks**

An exploded pictorial drawing of a high pressure “Presta style” valve from a bicycle tube is shown. Shape and size details of the valve body are given. **8**

A part sectional front view of the assembled components is commenced below, using a scale of 5:1.

Complete the part sectional front view. The seal must be drawn in the closed position. The part section is to the left of line AB. Follow AS1100 standards, additionally do not section the seal.





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Formulae Sheet

Force, Moments

$F = ma; \quad M = Fd$

If a body is in equilibrium, then $\sum F_x = 0; \quad \sum F_y = 0; \quad \sum M = 0$

Friction

$F = \mu N; \quad \mu = \tan\phi$

Energy, Work, Power

$KE = \frac{1}{2}mv^2; \quad PE = mgh; \quad W = Fs = \Delta PE + \Delta KE; \quad P = \frac{W}{t}; \quad P = \frac{Fs}{t}$

Pressure

$P = \frac{F}{A}; \quad P = P_o + \rho gh$

Stress and Strain

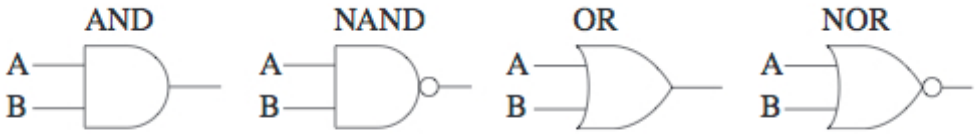
$\sigma = \frac{F}{A}; \quad \varepsilon = \frac{e}{L}; \quad E = \frac{\sigma}{\varepsilon}; \quad \sigma = \frac{My}{I}$

$\sigma_{\text{allowable}} = \frac{\sigma_{yield}}{F \text{ of } S}$ (Ductile); $\quad \sigma_{\text{allowable}} = \frac{\sigma_{UTS}}{F \text{ of } S}$ (Brittle)

Machines

$MA = \frac{L}{E}; \quad VR = \frac{d_E}{d_L}; \quad \eta = \frac{MA}{VR}$

Digital electronics



Electricity, Electronics

$E = IR \qquad P = I^2R$

Series $R_t = R_1 + R_2 + R_3 + R_4 + \ldots + R_n$

Parallel $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \ldots + \frac{1}{R_n}$