NSW EDUCATION STANDARDS AUTHORITY

2017 HSC Engineering Studies Marking Guidelines

Section I

Multiple-choice Answer Key

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

Section II

Question 21 (a)

Criteria	Marks
• Explains why gears are used in vehicle design using examples	3
• Shows some understanding of why gears are used in vehicle design	2
• Provides some relevant information	1

Sample answer:

Gears are commonly used to change speed, torque and rotation direction in engineering mechanisms. Transport engineers use a combination of gear ratios and different types of gears to increase torque, speed or even change direction of effort in vehicles. For example, a sports car travels at fast speeds but cannot pull heavy loads. A truck can pull heavy loads but cannot travel as fast.

Answers could include:

Gear trains are also used to change direction of rotation (as in a car differential), change the direction of rotation in a gear train through an idler gear (eg reverse gear in a manual car) or to convert linear to rotary motion (rack and pinion gear).

Question 21 (b) (i)

Criteria	Marks
• Shows how properties of gears manufactured using sand casting and powder metallurgy are similar and/or different	4
• Outlines properties of gears manufactured using sand casting and/or powder metallurgy	2–3
• Shows a basic understanding of sand casting or powder metallurgy	1

Answers could include:

Sandcasting

- Poorer surface finish initiates fatigue cracking
- Due to casting, grains can be columnar if not poured correctly
- Poorer dimensional stability than powder metallurgy.

Powder metallurgy

- Can make gears in a range of alloys that are impossible to make using conventional alloy methods
- Near net shape forming
- Possible to make alloys that have pores – self lubrication
- Higher dimensional stability.

Question 21 (b) (ii)

Criteria	Marks
• Provides a description of the link between case hardening and the required structure–property relationships	3
• Provides some features of case hardening and/or the required structure–property relationships	2
• Shows a basic understanding of case hardening	1

Sample answer:

Case hardening involves heating the gear to red heat in an environment rich in carbon and/or nitrogen. At this high temperature the carbon and nitrogen diffuse into the surface of the steel, forming carbonitride if applicable, which increases the carbon content to a point where it can be hardened by quenching. When quenched, martensite is formed. The outer case becomes harder and wear-resistant while the inside remains soft and tough. The gear may be used with the outer case being either martensitic or tempered back to improve surface toughness.

Question 21 (c)

Criteria	Marks
• Calculates the correct number of teeth	3
• Calculates the number of teeth using an appropriate method with minor errors	2
• Applies an appropriate method	1

Sample answer:

$$n = \frac{MA}{VR}$$

$$\therefore VR = \frac{MA}{n} = \frac{1.6}{0.8} = 2$$

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

$$\therefore \text{Driven} = VR \times \text{Driver} = 2 \times 9 = 18 \text{ teeth}$$

Question 22 (a)

Criteria	Marks
• Outlines the advantages of using carbon fibre over steel	3
• Outlines an advantage of using carbon fibre OR • States advantages of using carbon fibre	2
• States a benefit of using carbon fibre	1

Sample answer:

Bike frames made from carbon fibre have an excellent strength to weight ratio, which is desirable and is higher than that of steel. The carbon fibre can be moulded to more intricate shapes than steel can. Carbon fibre bikes can be produced in a range of colours. Carbon fibre is corrosion-resistant and rigid.

Question 22 (b)

Criteria	Marks
• Explains how a carbon fibre bicycle frame is manufactured	3
• Outlines some aspects of a suitable manufacturing process	2
• Identifies a feature of the manufacturing process	1

Sample answer:

Bicycle frames can be manufactured by using pre-impregnated carbon fibres wrapped around a mould. The mould can be either a 'bladder' which is deflated once the frame has been cured or a smooth steel mould. Fibres can be wrapped as pre-manufactured sheets that are hand-laid over a mould or through roll-wrapping or filament-winding of carbon fibre directly onto the mould.

Once the frame is laid up, it is placed inside a vacuum-proof bag in a pressure chamber that may also be heated (autoclave) and the resin is activated by a catalyst, which can be sensitive to UV light or heat.

Question 22 (c)

Criteria	Marks
• Calculates the speed of the rider with correct units stated	2
• Applies an appropriate method	1

Sample answer:

$V = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = \sqrt{400} = 20 \text{ m/s}$

Question 22 (d)

Criteria	Marks
• Calculates the correct compressive stress	3
• Calculates compressive stress using an appropriate method with minor errors	2
• Applies an appropriate method	1

Sample answer:

$$\text{CSA} = \frac{\pi d_1^2}{4} - \frac{\pi d_2^2}{4}$$

$$= \frac{\pi}{4}\left(32^2 - 28^2\right)$$

$$= \frac{\pi}{4}(1024 - 784)$$

$$= 188.5 \text{ mm}^2$$

$$\sigma_c = \frac{F}{A} = \frac{3000}{188.5}$$

$$= 15.9 \text{ MPa}$$

Question 23 (a)

Criteria	Marks
• Completes the truth table	2
• Identifies some entries	1

Sample answer:

A	*B*	*Z*
0	0	1
0	1	0
1	0	0
1	1	0

Question 23 (b)

Criteria	Marks
• Provides similarities and/or differences of the operation of zener diodes and common diodes	3
• Identifies features of zener diodes and/or common diodes	2
• Identifies a feature of zener diodes or common diodes	1

Sample answer:

Both zener and common diodes allow current to flow when connected in a forward direction (forward biased) and are made by doping silicon, but the way in which they are doped is different.

A common diode will tend to ‘leak’ current if subjected to a reverse voltage.

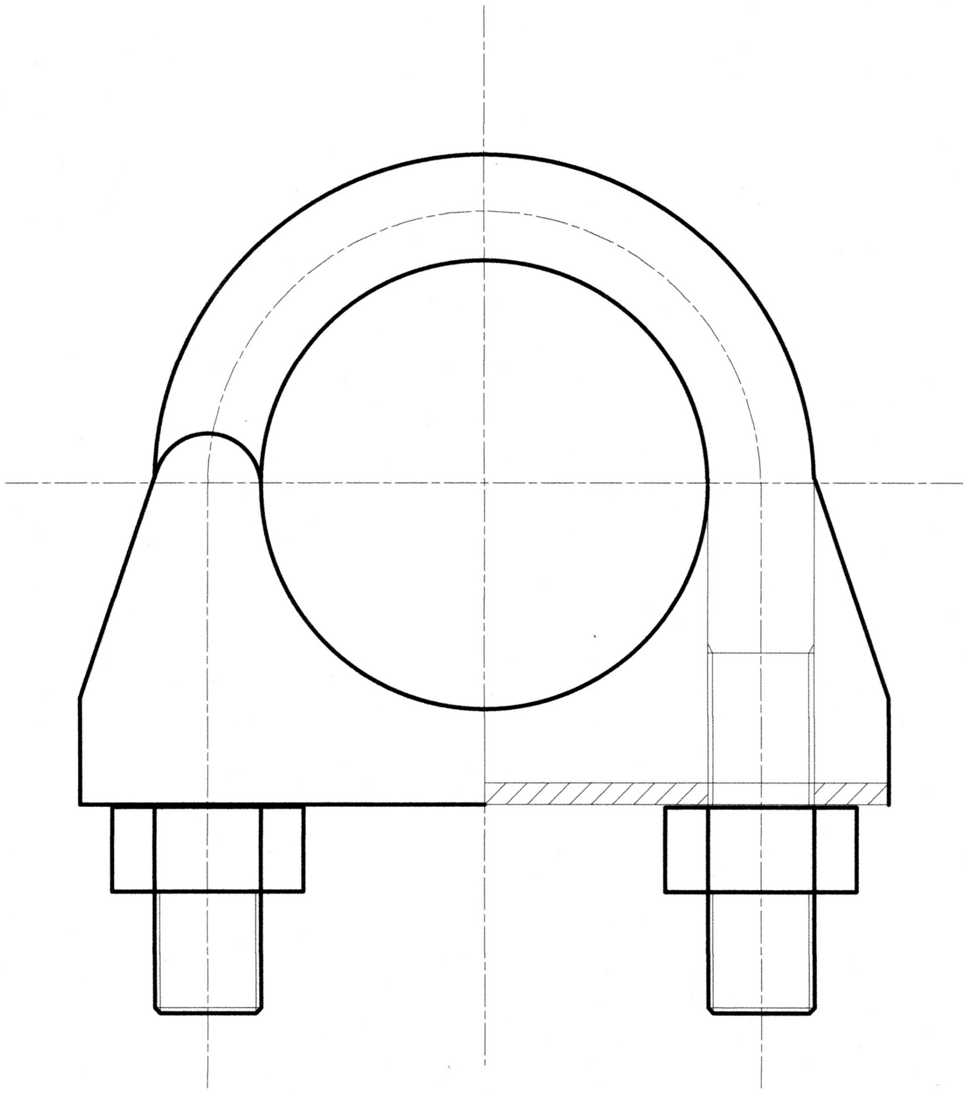
Common diodes are used for rectification whereas zener diodes are used for voltage regulation.

A common diode allows current to pass in one direction only, and break down if exposed to a sufficiently large reverse voltage, whereas zener diodes, when connected in reverse in a circuit (reverse biased), provide a stable reference voltage over a wide range of current flows when their breakdown voltage is exceeded. They are not damaged by large reverse currents.

Question 23 (c)

Criteria	Marks
• Provides an assembled half-sectional front view using AS 1100 conventions with no major errors or omissions	6
• Provides an assembled half-sectional front view using AS 1100 conventions with a major error or omission	4–5
• Provides some correct projection with a component drawn to standard	2–3
• Provides some aspects of a correct projection	1

Sample answer:



Question 24 (a) (i)

Criteria	Marks
• Provides an explanation of how the properties of polypropylene make it suitable for the application	3
• Outlines relevant properties of polypropylene	2
• Identifies a property of polypropylene	1

Sample answer:

Polypropylene is lightweight with a low coefficient of friction making it ideal for use in sleds, which require these properties.

Additionally, polypropylene is easy to mould in an injection moulding machine and provides high flexural strength and durability.

Answers could include:

Polypropylene is recognised as having outstanding flexural strength, which is why it is used to manufacture items which are subject to repeated bending, such as rope or hinged plastic lids.

Question 24 (a) (ii)

Criteria	Marks
• Describes a suitable manufacturing method	3
• Identifies some features of a suitable manufacturing method	2
• Identifies a feature of a suitable manufacturing method	1

Sample answer:

Polymer pellets are fed into an injection moulding machine. These are heated by friction internally and a heating unit wrapped around the outside of the machine, then forced under pressure into a steel mould of the desired shape. Once solidified, the mould halves are then separated and the item is removed from the mould (using ejector pins) and then subsequently cooled, surplus flash trimmed off and then polished.

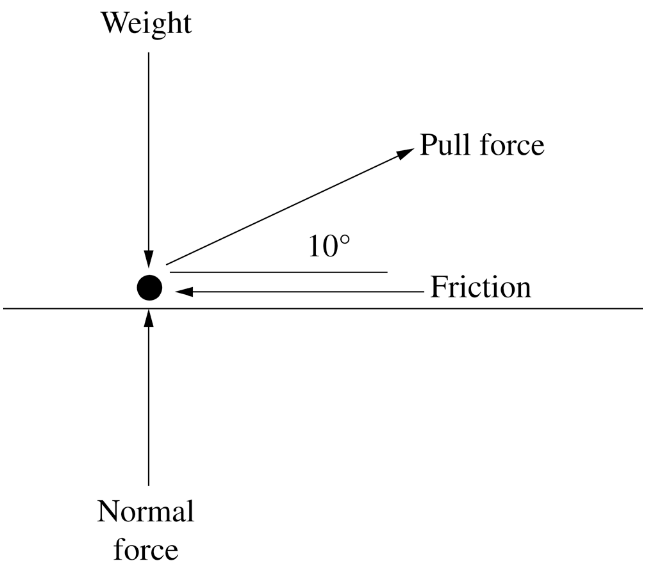
Answers could include:

Rotational moulding.

Question 24 (b) (i)

Criteria	Marks
• Provides a correctly labelled free-body diagram	2
• Identifies some forces correctly	1

Sample answer:



Question 24 (b) (ii)

Criteria	Marks
• Calculates the correct rope tension	3
• Calculates rope tension using an appropriate method with minor errors	2
• Applies an appropriate method	1

Sample answer:

Analytical

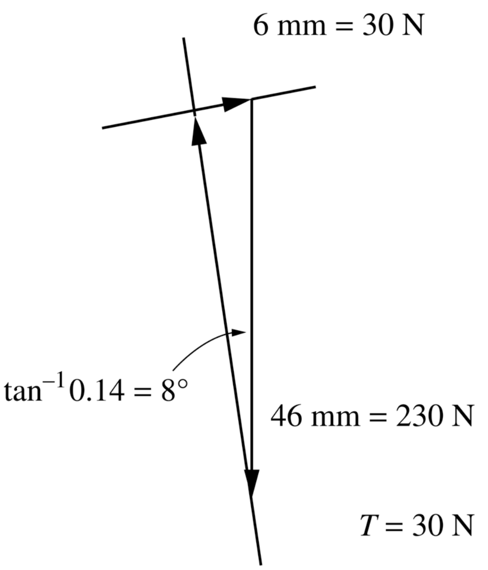
$\tan^{-1} 0.14 = 8°$

$= 8$

$$\frac{\sin 92}{230} = \frac{\sin 8}{p}$$

$$\therefore p = \frac{230 \sin 8}{\sin 92} = 32 \text{ N}$$

Graphical



Question 25 (a) (i)

Criteria	Marks
• Calculates the correct forces and directions	4
• Calculates forces and/or directions using an appropriate method with errors	2–3
• Applies an appropriate method	1

Sample answer:

$\overset{+}{\rightarrow}\sum M_A = 0$

$\therefore\ 3 \times 1.5 - 20 \times 3 + R_B \times 1.5 = 0$

$\therefore\ 4.5 - 60 + 1.5R_B = 0$

$\therefore\ 1.5R_B = 60 - 4.5$

$\therefore\quad R_B = 55.5$

$$R_B = \frac{55.5}{1.5}$$

$$= 37\text{ kN} \leftarrow$$

$\uparrow \sum F_V = 0$

$-20 + R_{AV} = 0$

$\therefore\ R_{AV} = 20\text{ kN } +\uparrow$

$\overset{+}{\rightarrow}\sum F_H = 0$

$-3 - 37 + R_{AH} = 0$

$\therefore\ R_{AH} = 40\text{ kN } \overset{+}{\rightarrow}$

$$R_A = \sqrt{20^2 + 40^2}$$

$$= \sqrt{400 + 1600}$$

$$= \sqrt{2000}$$

$$= 44.7\text{ kN}$$

$$\tan\theta = \frac{R_{AV}}{R_{AH}}$$

$$= \frac{20}{40}$$

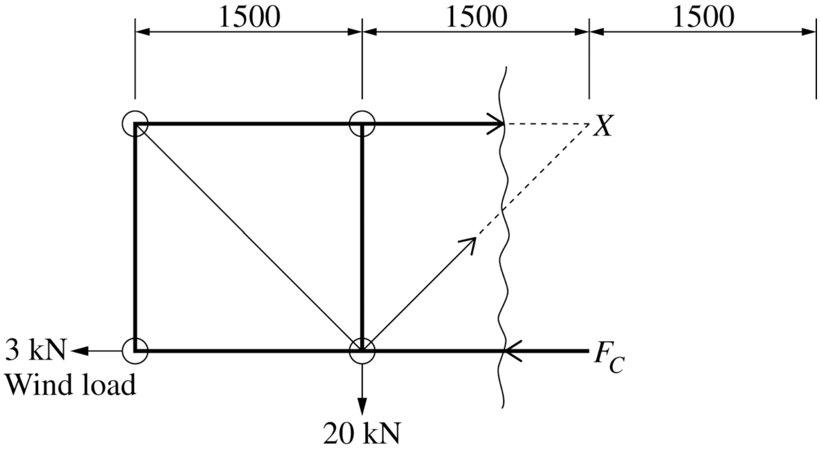
$$= 0.5$$

$\therefore\quad \theta = 26.6°$

Question 25 (a) (ii)

Criteria	Marks
• Calculates the correct force and identifies its nature	2
• Applies an appropriate method OR • Identifies the nature of the force	1

Sample answer:



Taking moments about point *X*.

$$+\circlearrowleft \sum M_X = 0 = -1.5 \times F_C + 1.5 \times 20 - 1.5 \times 3$$

$$0 = -F_C + 20 - 3$$

$$F_C = 17 \text{ kN (compression)}$$

Question 25 (a) (iii)

Criteria	Marks
• Explains why concrete would be a suitable material	2
• Provides some relevant information	1

Sample answer:

When correctly mixed, concrete is easy to place and form around the roadside sign column. It develops high strength and hardness during curing (setting and hardening).

Answers could include:

- It cures relatively quickly
- It resists weathering.

Question 25 (b) (i)

Criteria	Marks
• Shows a thorough understanding of the consequences of drilling and/or welding	3
• Shows some understanding of the consequences of drilling and/or welding	2
• Provides some relevant information	1

Sample answer:

The steel of the chassis rail is such that when welded it will become molten at a temperature well above the A1 temperature. On cooling, some areas of the weld will tend to form columnar grains. These are not desirable. Also, the steel (flanges plus weld metal) may cool at the rate at which martensite might form producing a hard and brittle microstructure having strength less than the 500 MPa steel of the chassis.

Flanges should not be drilled as this produces stress raisers. Surface roughness around the drill hole initiates fatigue failure.

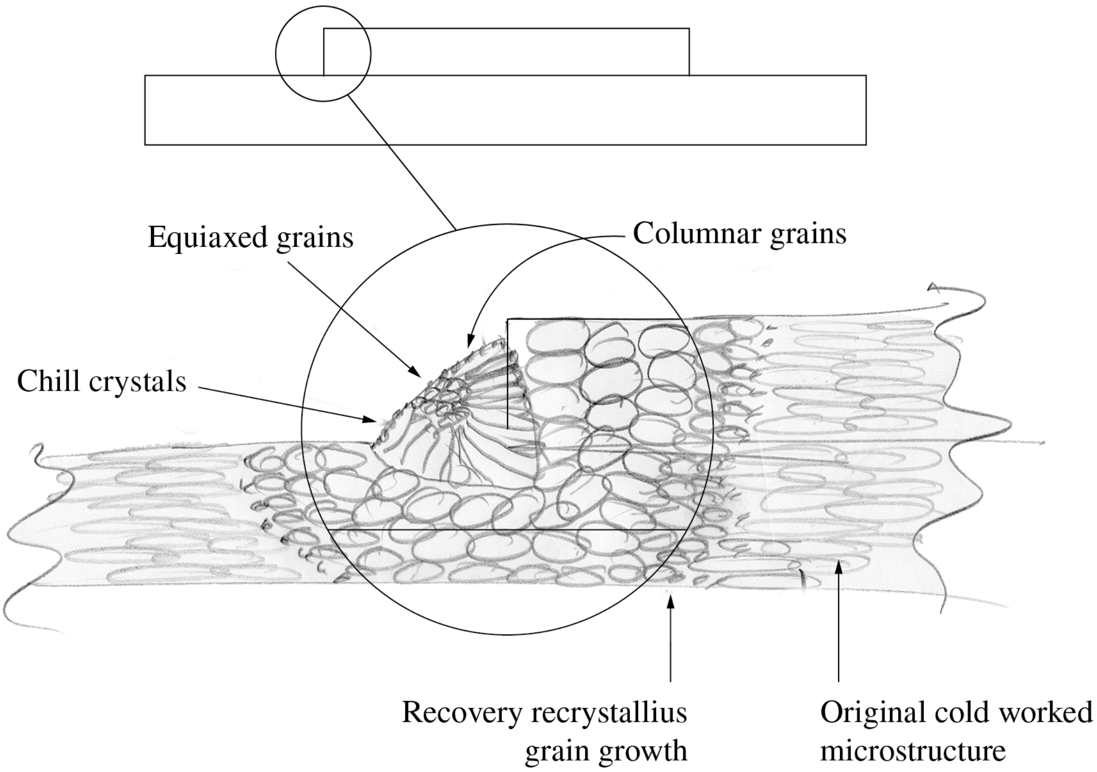
Answers could include:

The weld process may also cause cementite and ferrite to have the carbon burnt out reducing strength.

Question 25 (b) (ii)

Criteria	Marks
• Draws and labels the resulting weld macrostructure	2
• Identifies some features of the resulting weld macrostructure	1

Sample answer:



Answers could include:

A multi-pass weld

Question 26 (a)

Criteria	Marks
• Calculates the force correctly	3
• Calculates a force using an appropriate method with minor errors	2
• Applies an appropriate method	1

Sample answer:

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

$$= \frac{1000\ \text{N}}{5027\ \text{mm}^2} = \frac{F}{31\,416\ \text{mm}^2}$$

$$F = \frac{1000 \times 31\,416}{5027}$$

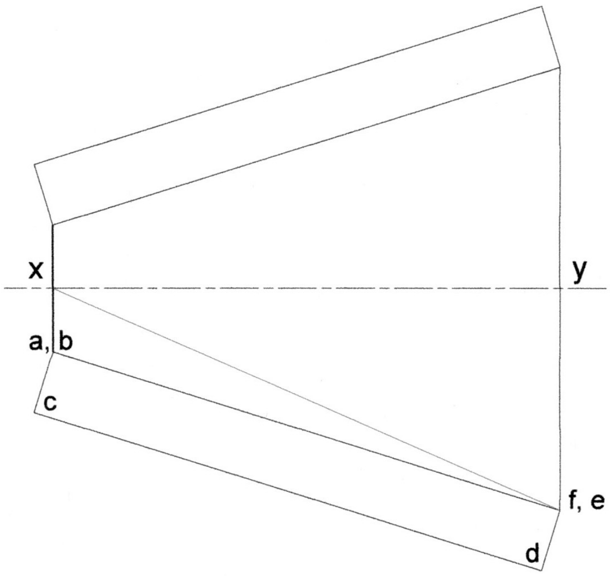
$$= 6249\ \text{N}$$

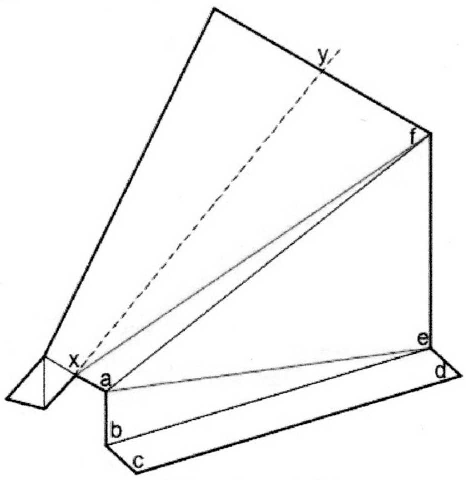
$$= 6.25\ \text{kN}$$

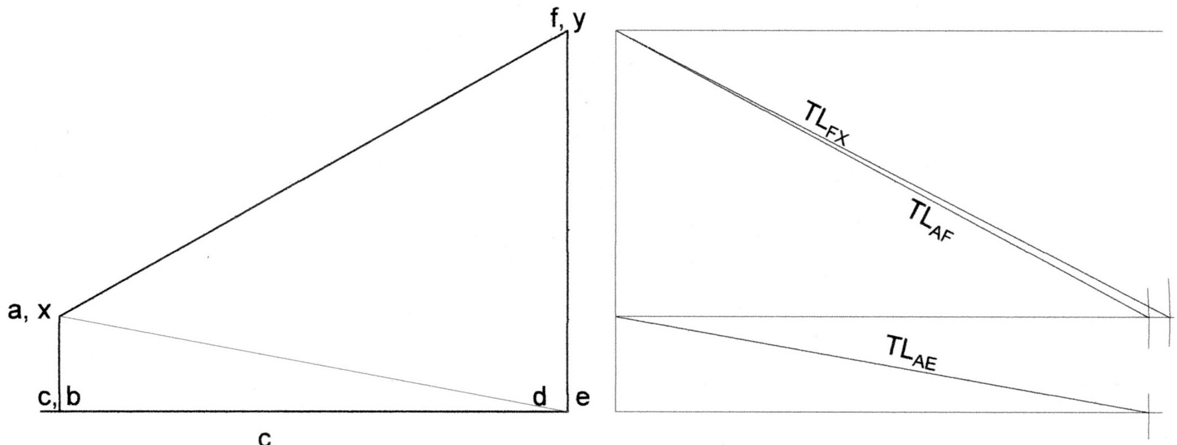
Question 26 (b) (i)

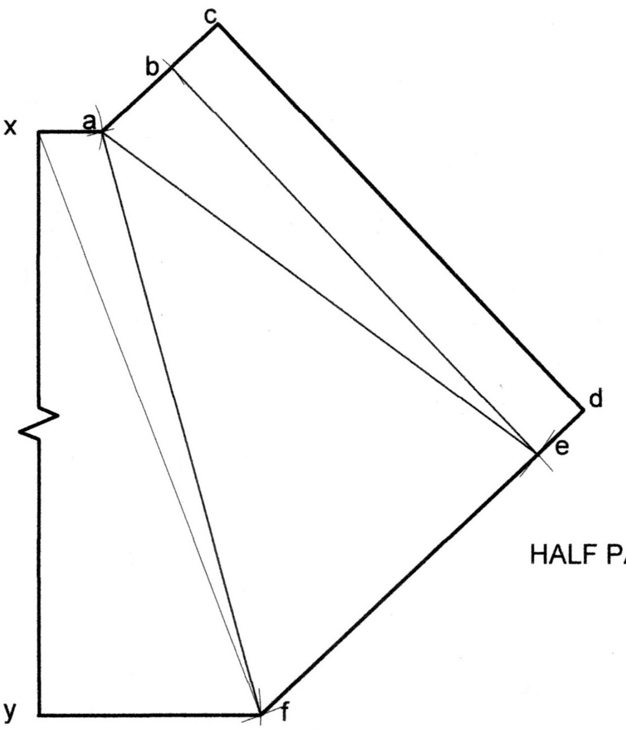
Criteria	Marks
• Provides a half-development with no major errors or omissions	4
• Provides a half-development with errors or omissions	3
• Provides a half-development with major errors or omissions	2
• Applies an appropriate projection method	1

Sample answer:









HALF PATTERN DEVELOPMENT

Question 26 (b) (ii)

Criteria	Marks
• Calculates the force required	3
• Calculates a force using an appropriate method with minor errors OR • Calculates the correct shear area	2
• Applies an appropriate method	1

Sample answer:

$$\delta_S = \frac{F_S}{A_S} \qquad A_S = \pi d \times t$$

$$= \pi \times 20 \times 0.5$$

$$= 31.4 \text{ mm}^2$$

$$\therefore \quad F_S = \delta_S \times A_S$$

$$= 110 \times 31.4$$

$$= 3455.7 \text{ N}$$

$$= 3.46 \text{ kN}$$

Question 26 (c)

Criteria	Marks
• Describes the changes that occur to the structure and properties	3
• Outlines some changes that occur to the structure and/or properties	2
• Identifies a change that occurs to the structure or properties	1

Sample answer:

After quenching, the rivet microstructure is an unstable solid solution of copper dissolved in aluminium. Once the rivet reaches room temperature, there is sufficient heat energy to allow the copper to precipitate out of solid solution as finely dispersed $CuAl_2$ precipitates that significantly strengthens the alloy. Refrigeration slows this process.

Additionally, the metal is cold worked when the rivet head is formed, producing work hardening.

As a result of installation the strength of the rivet increases substantially, as the hardness increases over time until precipitation hardening is fully completed. Ductility of the metal correspondingly decreases as well.

Answers could include:

- Reference to Guinier-Preston zones
- Overaging and optimum aging
- Strengthening through impeding dislocation motion
- Work hardening creates areas of high internal energy that preferentially corrode.

Question 27 (a)

Criteria	Marks
• Explains why routine testing is important	2
• Identifies a relevant reason	1

Sample answer:

Engineering components such as diesel trucks and aircraft jet engines, are subject to damaging conditions, including high duty cycles, heavy load, corrosive and dusty environments. Routine testing is important to ensure that there are no possible faults or dangerous conditions.

Question 27 (b)

Criteria	Marks
• Explains how the lifting device can be tested and evaluated to determine if all the criteria are met	6
• Explains how the lifting device can be tested and/or evaluated to determine if most of the criteria are met	4–5
• Explains how the lifting device can be tested and/or evaluated to determine if some of the criteria are met OR • Outlines how the lifting device can be tested and/or evaluated to determine if some of the criteria are met	2–3
• Provides some relevant information	1

Answers could include:

Mechanical efficiency	– Measuring power consumed vs power delivered under test loads – Calculating theoretical outcomes and comparing the current performance against benchmark
Working environment	– Wind tunnel testing of prototype – Computer simulations and/or finite element analysis of model
Materials	– Test specimens in similar coastal industrial areas – Past operational performance of materials in similar coastal industrial areas – Non-destructive testing of structure to monitor remaining thickness
Load	– Factor of safety used in service – Finite element analysis – Proof testing with container and measure deflection against specification

2017 HSC Engineering Studies Mapping Grid

Section I

Question	Marks	Content	Syllabus outcomes
1	1	Aero, Scope p31	H1.1
2	1	Telecommunications, Electronics p36	H3.3
3	1	PPT, Mechanics p28	H3.1
4	1	PPT, Aero Communication p29, 33	H3.3
5	1	Aero, Materials, PPT p33 and 28, 29	H1.2
6	1	Aero, Mechanics p32	H3.1
7	1	Telecommunications p36	H1.1
8	1	PPT, Materials p28	H1.2, H2.1
9	1	Civil Structures, Mechanics p25	H3.1
10	1	Civil Structures, Mechanics p25	H1.2, H2.1
11	1	Aero, Materials p33	H1.2
12	1	Civil Structures p26	H3.1, H3.3
13	1	Civil Structures, History p24	H4.1, H4.2
14	1	Civil Structures, Materials p25	H1.2, H2.1
15	1	PPT, Electricity p29	H1.2, H2.1
16	1	Telecommunications p37	H4.1, H1.1
17	1	Aero p33	H1.2, H3.1
18	1	Civil, Mechanics p25	H3.1
19	1	PPT, Communications p29	H3.3
20	1	PPT, Mechanics p28	H3.1

Section II

Question	Marks	Content	Syllabus outcomes
21 (a)	3	PPT, Simple Machines p28	H2.1, H4.2
21 (b) (i)	4	PPT, Materials p28	H1.2, H2.1
21 (b) (ii)	3	PPT, Materials p28	H1.2, H2.1,
21 (c)	3	PPT, Simple Machines p28	H2.1, H4.1
22 (a)	3	PPT, History p27, Aero p33	H1.2, H2.1
22 (b)	3	Aero p33	H1.2

Question	Marks	Content	Syllabus outcomes
22 (c)	2	PPT p28	H3.1
22 (d)	3	Civil Structures p25	H3.1
23 (a)	2	PPT, Control Technology p29, Telecommunications p37	H3.1
23 (b)	3	Telecommunications p36	H1.2
23 (c)	6	PPT p29, Aero p33	H3.1, H3.3
24 (a) (i)	3	PPT p29	H1.2, H2.1
24 (a) (ii)	3	PPT p29	H1.2, H2.1
24 (b) (i)	2	PPT p28	H3.1
24 (b) (ii)	3	PPT p28	H3.1
25 (a) (i)	4	Civil Structures p25	H3.1
25 (a) (ii)	2	Civil Structures p25	H3.1
25 (a) (iii)	2	Civil Structures p25	H1.2
25 (b) (i)	3	PPT p28	H1.2, H2.1
25 (b) (ii)	2	PPT p28	H1.2, H2.1
26 (a)	3	Aero, Fluid Mechanics p32	H3.1
26 (b) (i)	4	Aero, Communications p33	H3.3
26 (b) (ii)	3	Civil Structures p25	H3.1
26 (c)	3	Aero p33	H1.2
27 (a)	2	Civil Structures p25, PPT p29, Aero p32	H2.1
27 (b)	6	Civil Structures p25, PPT p29, Aero p32	H1.1, H2.1