AQA Level 3 Technical Level Engineering
Materials Technology and Science

Unit Number: F/506/5952

Specimen Question Paper

Time allowed: **1 hour 45 minutes**

Materials
For this paper you must have:
- Pens
- Pencils
- Calculator

Instructions
- Answer **all** questions on the paper
- Answer the questions in the spaces provided – there may be more space than you need.
- Show all of your working

Information
- There are two sections to this paper
- Both sections should be attempted
- Learners should spend approximately 65 minutes on Section A and 40 minutes on Section B
- The total mark for this paper is 80. The marks for each question are shown in brackets

Advice
- Please read each question carefully before starting

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Please write clearly, in block capitals, to allow character computer recognition.

Centre number ☐☐☐☐☐ Learner number ☐☐☐☐

Surname ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

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Learner signature _____

Electricity and Electronics Formulae

Flux Density: $B = \frac{\Phi}{A}$	**Magnetising Force:** $H = \frac{N I}{l}$ and $H = \frac{m.m.f.}{l}$
Magneto Motive Force (m. m. f.) $m.m.f. = IT$	**Electrical Power:** $P = VI$, $P = I^2R$ and $P = \frac{V^2}{R}$
Electrical Charge for Capacitors: $Q = C_{\text{Total}} V$	**Absolute Permeability:** $\mu = \mu_0\mu_r$ and $\mu = \frac{B}{H}$.
Energy Storage in an Inductor: $W = \frac{1}{2}LI^2$	**Lenz' Law:** $E = -N\frac{d\Phi}{dt}$
AC Instantaneous Current and Voltage: $i = \frac{V_{Max}\sin(\omega t \pm \phi)}{R}$ $v = V_{Max}\sin(\omega t \pm \phi)$	**Voltage Division:** $V_{\text{Out}} = V_{\text{In}}\left(\frac{R_2}{R_1 + R_2}\right)$ **Kirchhoff's Current Law:** $I_1 + I_2 + I_3 + I_4 + I_5 ... = 0$
Current Division: $I_{\text{Out}} = I_{\text{In}}\left(\frac{R_1}{R_1 + R_2}\right)$	**Angular Velocity:** $\omega = 2\pi f$
Forces in Current Carrying Conductors: $F = Bil\sin(\theta)$	**Transformer – Turns Ratio:** $\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$

Statics and Dynamics and other Engineering Formulae

Linear Equations of Motion: $s = \left(\frac{v+u}{2}\right)\times t$ $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$	**Centripetal Force:** $F_{\text{Cent}} = ma_{\text{Cent}}$ $F_{\text{Cent}} = \frac{mv^2}{r}$

Force Ratio: $\text{Force Ratio} = \frac{F_2}{F_1} = \frac{A_2}{A_1} = \frac{D_2^2}{D_1^2}$	**Angular Equations of Motion:** $\theta = \left(\frac{\omega_1 + \omega_2}{2}\right) \times t$ $\omega_2 = \omega_1 + \alpha t$ $\theta = \omega_1 t + \frac{1}{2}\alpha t^2$ $\omega_2^2 = \omega_1^2 + 2\alpha\theta$
Poisson's Ratio: $\nu = -\frac{\varepsilon_{lateral}}{\varepsilon_{longitudinal}}$	**Movement Ratio:** $A_1 x_1 = A_2 x_2$
Mechanical Power: $\text{Power} = Fv$ $\text{Power} = T\omega$	**Characteristic Gas Equation:** $pV = mRT$
Combined Gas Law: $\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$	**Charles' Law: (constant pressure)** $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Boyle's Law: (constant temperature) $P_1 V_1 = P_2 V_2$	**Friction:** $F = \mu N$
Potential Energy: $E_{potential} = mgh$	**Kinetic Energy:** $E_{kinetic} = \frac{mv^2}{2}$
Coefficient of Linear Expansion: $L_2 = L_1\left[1 + \alpha\left(t_2 - t_1\right)\right]$	**Conservation of Energy:** $mgh = \frac{mv^2}{2}$

Areas, Volume and other Mathematical Formulae

Linear Velocity: $V = \omega R$	**Volume of a Solid Sphere:** $V = \frac{4}{3}\pi r^3$
Linear Acceleration: $a = \omega^2 R$	**Surface Area of a Solid Sphere:** $S = 4\pi r^2$

Section A

Answer **ALL** question(s) in this section

Some of the questions in this paper relate to a car such as the one shown in Figure 1.

Figure 1

0 1 The table below lists five parts used in the manufacturing of the car.

Complete the table by giving:

- One material suitable for the part named.
- A suitable class of that material.

Each answer must be a different material.

Part	Suitable Material	Class of material
Car road wheel		
Car tyre		
Car door panel		
Windscreen		
Windscreen washer fluid bottle		

[10 marks]

0 2 Materials used to manufacture the saloon car can be selected by their mechanical properties.

Complete the table by stating:

- One specific mechanical property.
- The units of the properties' measurement.

Mechanical Property	Units of Measure

[6 marks]

0 3 Some of the fasteners (screws, nuts, bolts, etc.) used to assemble the saloon car are manufactured from stainless steel.

(a) Explain why stainless steel is an appropriate material.

Physical property 1:

Physical property 2:

[2 marks]

(b) Give two reasons why the use of stainless steel is appropriate in car manufacturing.

Reason 1:

Reason 2:

[2 marks]

0 4 Some of the components of the saloon car are manufactured using high carbon steel.

(a) State a property change that happens to high carbon steel when it is heated in a furnace and rapidly cooled in water.

[1 mark]

(b) What is this process called?

[1 mark]

0 5 Some of the components used in the manufacture of the saloon car are manufactured from aluminium alloys, as shown in Figure 2.

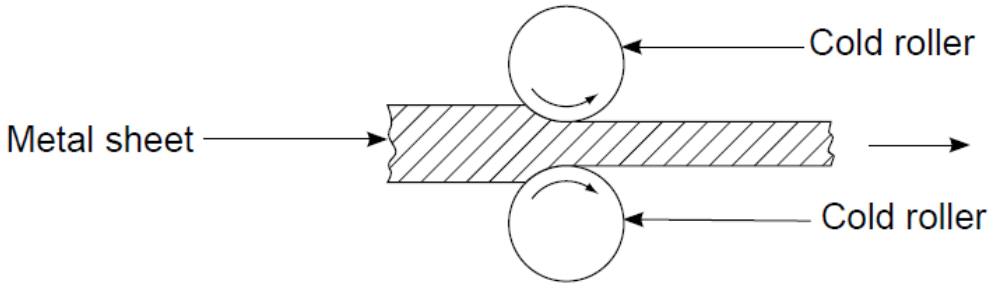


Figure 2

(a) Describe the impact that cold working has on the structure of the aluminium alloys.

[3 marks]

(b) Describe how the process is reversed.

[5 marks]

0 6 Figure 3 shows the electrical circuit from the headlights on the saloon car.

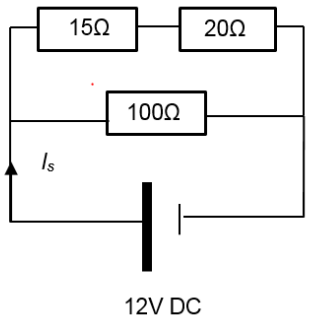


Figure 3

(a) Describe the type of electrical circuit shown in Figure 3.

[2 marks]

(b) Calculate the value of the supply current (I_s) present in the circuit.

[6 marks]

0 7 Analogue and digital signals are often found in modern electronics circuits and equipment. Describe the difference between an analogue and digital signal.

[2 marks]

0 8 Energy is found in the saloon car.

(a) Describe kinetic energy.

[2 marks]

(b) What are the SI units of kinetic energy?

[1 mark]

(c) Give an engineering application where kinetic energy is found.

[1 mark]

(d) Describe potential or gravitation energy.

[2 marks]

(e) Give an example of an engineering application where this type of energy can be found.

[1 mark]

0 9 A process pipe on an off-shore oil platform contains very hot fluid that needs transporting back on-shore.

(a) Name two forms of heat energy loss that will be present through the pipe walls.

[2 marks]

(b) Name the SI unit of temperature.

[1 mark]

Section B

Answer **ALL** questions in this section

Figure 4 represents the current found in the electrical circuit of a power supply in a machine tool workshop.

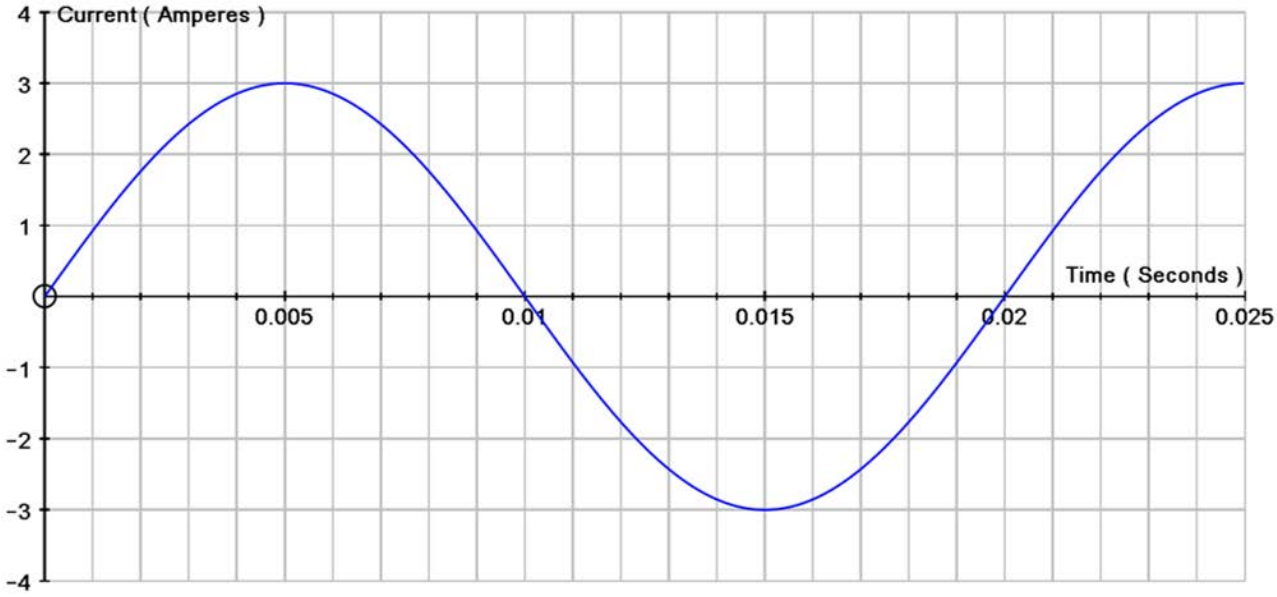


Figure 4

1 0 This question relates to Figure 4 above.

(a) What is the name of this waveform?

_____

_____

[1 mark]

(b) What is the value of the amplitude of the waveform?

_____

_____

[1 mark]

(c) What is the value of the periodic time of the waveform?

_____

_____

[1 mark]

(d) Calculate the value of the frequency of the waveform using a suitable equation.

[3 marks]

(e) A copper conductor of 25 m length and 1.95 mm diameter is required to supply electrical power to a machine tool.

The copper resistivity of $\rho = 1.68\ x\ 10^{-6}\Omega m$.

Determine the electrical resistance of the conductor.

[4 marks]

The crane shown below, in Figure 5, is widely used in engineering/industry and is used to lift heavy loads.

Figure 5

1 1 This question relates to Figure 5 above.

(a) Name the control system used to move the arms of the crane shown above.

_____

_____

[1 mark]

(b) Give one reason why this type control system is used.

_____

_____

[1 mark]

(c) Calculate how much energy will be required to lift an object through a distance of 15 metres.

Take the mass of the object to be $2500\ kg$ and show your answer in kJ.

[3 marks]

(d) Having reached a height of 15 m, the load was allowed to fall straight back to Earth.

What would be its velocity at the point of contact with the ground?

Ignore the effects of wind/air resistance. Your answer must contain the correct units.

[5 marks]

Figure 6 represents the results of a tensile test as applied to a sample of low carbon steel.

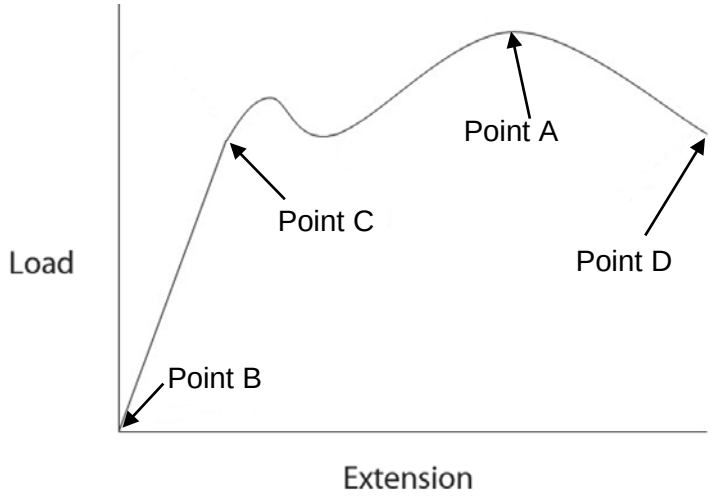


Figure 6

1 2 This question relates to Figure 6 above.

(a) What is the name of the critical quantity at Point A?

_____

_____

[1 mark]

(b) Name the region between Points B and C.

_____

_____

[1 mark]

(c) Name the region between Points C and D.

_____

_____

[1 mark]

(d) Name the critical point at D.

_____

_____

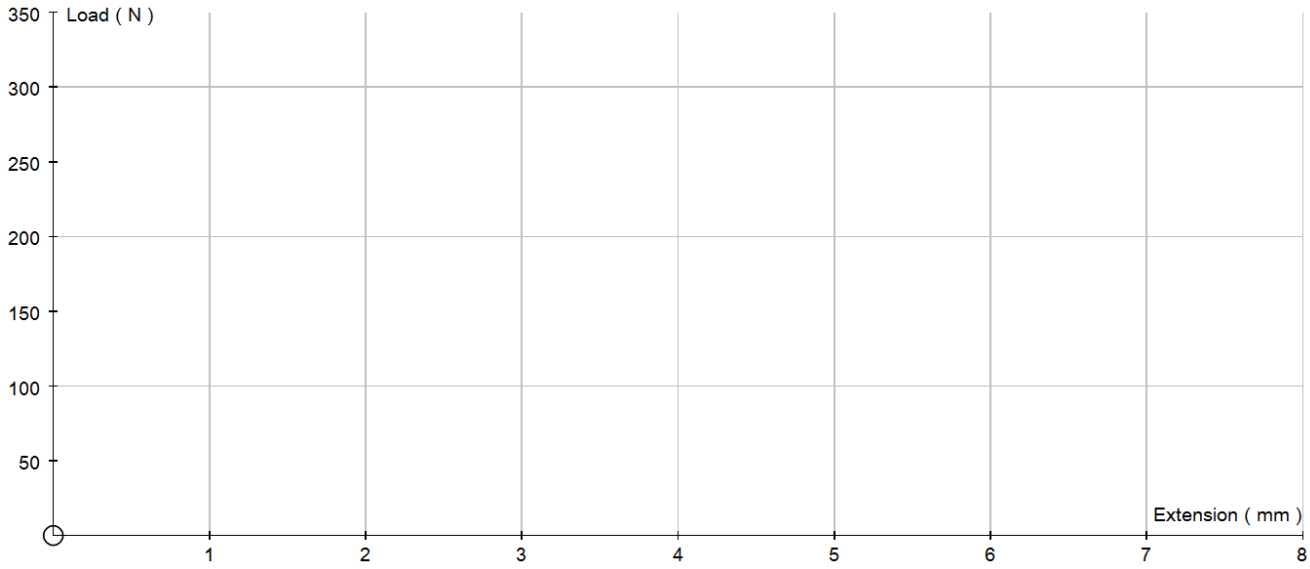
[1 mark]

The following results were obtained in a tensile test on a specimen of steel wire:

Load (N)	0	50	100	150	200	250	300
Extension (mm)	0	1.1	2.2	3.3	4.4	5.7	7.1

(e) Plot a suitable load/extension graph and find the value of Young's Modulus for the steel as used in the specimen.

The initial length of the wire was 2.3 m and its diameter 0.94 mm.



The following equation will be useful.

$$E = \frac{\text{Gradient} \times \text{Original Length}}{\text{Area}}$$

Show your working here:

[6 marks]

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Figure 1 © iStock
Figure 5 © iStock

AQA Level 3 Technical Level Engineering
Materials Technology and Science

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Mark scheme

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the learners' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation, each associate analyses a number of learners' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of learners' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from: aqa.org.uk/tech-levels

01 Complete the table by giving:

- One material suitable for the part named.
- A suitable class of that material.

Each answer must be a different material.

[10 marks]

Part	Suitable Material	Class of the Material
Car road wheel	• Aluminium alloy • Magnesium alloy	• Non-ferrous metal
Car tyre	• Rubber • Elastomer	• Composite • Allow polymer
Car door panel	• Aluminium alloy (if not used above) • Low carbon steel	• Non-ferrous metal • Ferrous metal
Windscreen	• Toughened glass	• Ceramic
Windscreen washer fluid bottle	• HDPE • PP • Any suitable polymer	• Thermoplastic polymer • Allow polymer

1 mark for each correct cell in the table. Please note each material must be different.

02 Materials used to manufacture the saloon car can be selected by their mechanical properties.

Complete the table by stating:
- One specific mechanical property.
- The units of the properties measurement.

[6 marks]

Mechanical Property	Units of Measure
Tensile strength Compressive strength	Pa or $N\ m^{-2}$ Accept multiples of either
Hardness	Rockwell, Vickers, Brinell, Shore etc.
Toughness	Allow Charpy, Izod or $J\ m^{-3}$.
Elasticity	Pa or $N\ m^{-2}$ Accept multiples of either
Plasticity Ductility Malleability	% elongation

1 mark for each correct cell in the table. Maximum of **6 marks**.

03 Some of the fasteners (screws, nuts, bolts, etc.) used to assemble the saloon car are manufactured from stainless steel.

(a) Explain why stainless steel is an appropriate material.

[2 marks]

Any physical property from the following:

- High melting point.
- Good thermal conductivity.
- Good electrical conductivity.
- Good corrosion resistance.

1 mark for each to a maximum of **2 marks**

(b) Give two reasons why the use of stainless steel is appropriate in car manufacturing.

[2 marks]

The answers could be:

- Can be used in the engine compartment.
- Can remove heat quickly from brakes etc.
- Can be used in electrical equipment to conduct signals etc.
- Can be used on exposed parts of the car.

1 mark for each to a maximum of **2 marks**

04 Some of the components of the saloon car are manufactured using high carbon steel.

(a) State a property change that happens to high carbon steel when it is heated in a furnace and rapidly cooled in water.

[1 mark]

1 mark for hardness

(b) What is this process called?

[1 mark]

1 mark for quenching

05 Some of the components used in the manufacture of the saloon car are manufactured from aluminium alloys, as shown in Figure 2.

(a) Describe the impact that cold working has on the structure of the aluminium alloys.

[3 marks]

Work hardening, also known as strain hardening or cold working, is the strengthening of a metal by plastic deformation. This strengthening occurs because of dislocation movements and dislocation generation within the crystal structure of the material.
1 mark for strengthen or harden.
1 mark for plastic deformation.
1 mark for dislocation.

(b) Describe how the process is reversed

[5 marks]

Annealing, in materials science, is a heat treatment that alters the physical properties of a material to increase its ductility and to make it more workable. It involves heating a material to a suitable temperature and then cooling in air. Annealing can induce ductility, soften material and relieve internal stresses.

1 mark for heat treatment (annealing).
1 mark for increase ductility.
1 mark for making it more workable or less prone to cracking (maximum 1 mark).
1 mark for cooling in air.
1 mark for soften or relieve internal stresses.

06 Figure 3 shows the electrical circuit from the headlights on the saloon car.

(a) Describe the type of electrical circuit shown in Figure 3.

[2 marks]

The answer is a series/parallel resistance circuit.

1 mark for series/parallel.
1 mark for resistance circuit.

(b) Calculate the value of the supply current (I_s) present in the circuit

[6 marks]

The answer is:

$$R_{Series} = 15\Omega + 20\Omega = 35\Omega$$

$$R_{Parallel} = \frac{35\Omega \times 100\Omega}{35\Omega + 100\Omega} = 25.9\Omega$$

$$V = I_s R \therefore I_s = \frac{12V}{25.9\Omega} = 463mA$$

1 mark for correct calculation for series branch of circuit.
1 mark for correct parallel formula.
1 mark for correct answer.
1 mark for Ohm's Law.
1 mark for correct transposition.
1 mark for correct answer.

07 Analogue and digital signals are often found in modern electronics circuits and equipment.

Describe the difference between an analogue and digital signal.

[2 marks]

In analogue technology**,** a wave is recorded or used in its original form. In digital technology**,** the analogue wave is sampled at some interval, and then turned into numbers that are stored in the digital device.

1 mark for some reference to original form.
1 mark sampled then tuned into numbers, or similar description.

08 Energy is found in the saloon car.

(a) Describe kinetic energy.

[2 marks]

A description such as: the energy contained in the mass of the saloon car whilst it is in motion.

2 marks for a full description similar to that above.
1 mark for velocity, motion or speed.
1 mark for mass.

(b) What are the SI units of kinetic energy?

[1 mark]

The units of kinetic energy are Joules or $N\ m$.

1 mark for either form of the unit.

(c) Give an engineering application where kinetic energy is found.

[1 mark]

An application such as: a pile driver, a nail gun, a hydraulic/pneumatic ram, etc.

1 mark for any of the above or other suitable application.

(d) Describe potential or gravitation energy.

[2 marks]

A description such as: the energy contained within mass of a body or object relating to some distance above a datum.

2 marks for this or similar description.
1 mark for 1 word answer like: position, height etc.
1 mark for mass.

(e) Give an example of an engineering application where this type of energy can be found.

[1 mark]

An application such as: water in a dam, a hoist on a crane, a compressed spring etc.

09 A process pipe on an off-shore oil platform contains very hot fluid that needs transporting back on-shore.

(a) Write down two forms of heat energy loss that will be present through the pipe walls.

[2 marks]

Any two from: conduction, convection or radiation.

1 mark each, for a total of 2 marks.
Don't allow flow energy or momentum energy or pressure energy.

(b) Name the SI unit of temperature.

[1 mark]

The answer should be Kelvin "K".
1 mark for Kelvin or K.

10 Figure 4 represents the current found in the electrical circuit of a power supply in a machine tool workshop.

(a) What is the name of this waveform?

[1 mark]

The answer should be a sine wave or sinusoidal waveform
1 mark for either answer

(b) What is the value of the amplitude of the waveform?

[1 mark]

The amplitude of the waveform is 3 Amps.
1 mark for the above answer.

(c) Write down the value of the periodic time of the waveform.

[1 mark]

The periodic time of the waveform is 0.02 seconds or $20\ ms$.
1 mark for either answer.

(d) Calculate the value of the frequency of the waveform using a suitable equation.

[3 marks]

The calculation will be:

$$f = \frac{1}{T} \Rightarrow f = \frac{1}{20 \times 10^{-3}} \therefore$$
$$f = 50Hz$$

1 mark for correct use of formula.
1 mark for correct value.
1 mark for correct units.

(e) A copper conductor of 25 *m* length and 1.95 *mm* diameter is required to supply electrical power to a machine tool. The copper resistivity of $\rho = 1.68\ x\ 10^{-6}\Omega m$.

Determine the electrical resistance of the conductor.

[4 marks]

The Calculation will be:

$$L = 25m$$
$$D = 1.95mm \equiv 1.95 \times 10^{-3} m$$
$$\rho = 1.68 \times 10^{-6}\Omega\, m$$

The Area:

$$A = \frac{\pi D^2}{4} = \frac{\pi \times 1.95 \times 10^{-3^2}}{4} = 2.97 \times 10^{-6} m^2$$

The Resistance:

$$R = \frac{\rho L}{A} = \frac{1.68 \times 10^{-6} \times 25}{2.97 \times 10^{-6}} = 14.06\Omega.$$

1 mark for correct area formula; allow $\pi\, r^2$ also.
1 mark for correct value.
1 mark for correct resistivity formula.
1 mark for correct value.

11 The crane shown below, in figure 5, is widely used in engineering / industry and is used to lift heavy loads.

(a) Name the control system used to move the arms of the crane shown above.

[1 mark]

The control system in operation is a hydraulic one.
1 mark for hydraulic. Don't allow pneumatic.

(b) Give one reason why this type control system is used.

[1 mark]

The reason could be lubrication, incompressible fluid, non-explosive or similar suitable response.
1 mark for either:

- Lubrication.
- Non-compressible.
- Non-explosive.

(c) Calculate how much energy will be required to lift the object shown through a distance of 15 metres. Take the mass of the object to be $2500\ kg$ and show your answer in kJ

[3 marks]

The energy calculation will be:

$$m = 2500\,kg$$
$$g = 9.81 ms^{-2}$$
$$h = 15m$$
$$E = mgh \Rightarrow$$
$$E = 2500 \times 9.81 \times 15 = 368kJ.$$

1 mark for correct formula.
1 mark for correct value.
1 mark for correct value in kJ.

(d) Having reached a height of 15 m, the load was allowed to fall straight back to Earth. What would be its velocity at the point of contact with the ground? Ignore the effects of wind / air resistance. Your answer must contain the correct units.

[5 marks]

The velocity calculation will be:

$$E = 368\,kJ$$
$$m = 2500\,kJ.$$
$$E = \frac{mV^2}{2} \therefore V = \sqrt{\frac{2E}{m}}$$
$$V = \sqrt{\frac{2 \times 368 \times 10^3}{2500}} = 17.2\,ms^{-1}$$

1 mark for correct formula.
2 marks for correct transposition.
1 mark for correct value.
1 mark for correct units.

12 Figure 6 represents the results of a tensile test as applied to a sample of low carbon steel.

(a) What is the name of the critical quantity at Point A?

[1 mark]

The name of the critical quantity at Point A is the UTS or Ultimate Tensile Strength.
1 mark for either answer.

(b) Name the region between Points B and C.

[1 mark]

The name of the region between Points B and C is the elastic range.
1 mark for this answer or similar.
Don't accept Young's Modulus.

(c) Name the region between Points C and D.

[1 mark]

The name of the region between Points C and D is the plastic range.
1 mark for this answer or similar.

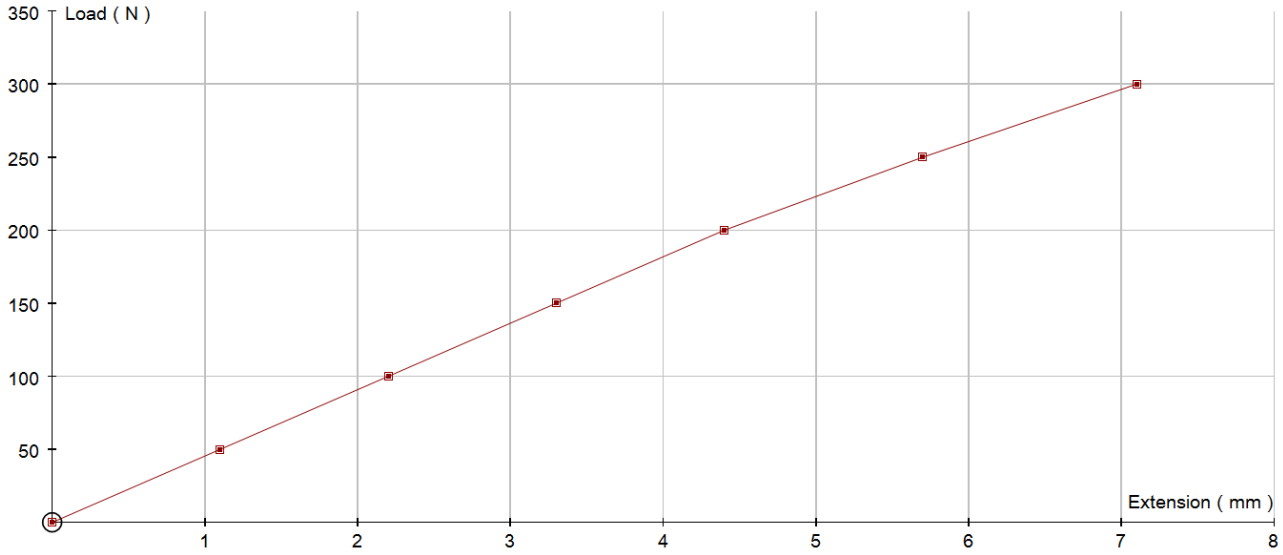
(d) Name the critical point at D.

[1 mark]

The answer is breaking point or catastrophic failure.
1 mark for either answer.

(e)	Plot a suitable load/extension graph and find the value of Young's Modulus for the steel as used in the specimen. The initial length of the wire was 2.3 m and its diameter 0.94 mm	**[6 marks]**

The graph will look like that below.



The calculation will be:

$D = 0.94\,mm$

$L = 2.3m$

Gradient of line (stiffness):

$$k = \frac{\delta y}{\delta x} = \frac{200}{4.4 \times 10^{-3}} = 45.5\,kN\,m^{-1}$$

Area of wire:

$$A = \frac{\pi D^2}{4} = \frac{\pi \times \left(0.94 \times 10^{-3}\right)^2}{4} = 694 \times 10^{-9} m^2$$

Young's Modulus:

$$E = \frac{k}{A} L = \frac{45.5 \times 10^3}{694 \times 10^{-9}} \times 2.3 = 151 GPa \text{ or } 151 G\,Nm^{-2}.$$

1 mark for points on graph.
1 mark for line.
1 mark for gradient – stiffness.
1 mark for area calculation.
1 mark for correct Young's Modulus calculation.
1 mark for correct units.

Assessment outcomes coverage

Assessment Outcomes	Marks and % of marks available in section A	Marks and % of marks available in section B	Total Marks
AO1: Understand the properties of materials	10 marks 12.5 %	14 marks 17.5 %	24 Marks
AO2: Understand engineering materials	10 Marks 12.5 %	0 marks 0 %	10 Marks
AO3: Understand engineering chemistry	10 Marks 12.5 %	0 marks 0 %	10 Marks
AO4: Understand electricity and electronics	10 Marks 12.5 %	06 marks 7.5 %	16 Marks
AO5: Understand the transfer of energy	10 Marks 12.5 %	10 marks 12.5 %	20 Marks
Total Marks	50 Marks 62.5 %	30 Marks 37.5 %	80 Marks

Question	Assessment Outcome 1	Assessment Outcome 2	Assessment Outcome 3	Assessment Outcome 4	Assessment Outcome 5
1	N/A	10	N/A	N/A	N/A
2	6	N/A	N/A	N/A	N/A
3	4	N/A	N/A	N/A	N/A
4	N/A	N/A	2	N/A	N/A
5	N/A	N/A	8	N/A	N/A
6	N/A	N/A	N/A	8	N/A
7	N/A	N/A	N/A	2	N/A
8	N/A	N/A	N/A	N/A	7
9	N/A	N/A	N/A	N/A	3
10	4	N/A	N/A	6	N/A
11	N/A	N/A	N/A	N/A	10
12	10	N/A	N/A	N/A	N/A
Totals	**24**	**10**	**10**	**16**	**20**