National
Qualifications
2024

2024 Engineering Science

Advanced Higher

Question Paper Finalised Marking Instructions

General marking principles for Advanced Higher Engineering Science

Always apply these general principles. Use them in conjunction with the detailed marking instructions, which identify the key features required in candidates' responses.

(a) Always use positive marking. This means candidates accumulate marks for the demonstration of relevant skills, knowledge and understanding; marks are not deducted for errors or omissions.

(b) If a candidate response does not seem to be covered by either the principles or detailed marking instructions, and you are uncertain how to assess it, you must seek guidance from your team leader.

(c) Where a candidate makes an error at an early stage in a multi-stage calculation, award marks for correct follow-on working in subsequent stages. Do not award marks if the error significantly reduces the complexity of the remaining stages. Apply the same principle in questions which require several stages of non-mathematical reasoning.

(d) SQA presents all units of measurement in a consistent way, using negative indices where required (for example ms^{-1}). Candidates can respond using this format, or solidus format (m/s), or words (metres per second), or any combination of these (for example metres/second).

(e) For numerical questions, candidates should round their answers to an appropriate number of significant figures. However, award marks if their answer has up to two figures more or one figure less than the expected answer.

(f) Unless a numerical question specifically requires candidates to show evidence of their working, award full marks for a correct final answer (including unit) on its own.

(g) Award marks where a labelled diagram or sketch conveys clearly and correctly the response required by the question.

(h) Award marks regardless of spelling if the meaning is unambiguous.

(i) Candidates can answer programming questions in any appropriate programming language. Award marks where the intention of the coding is clear, even where there are minor syntax errors.

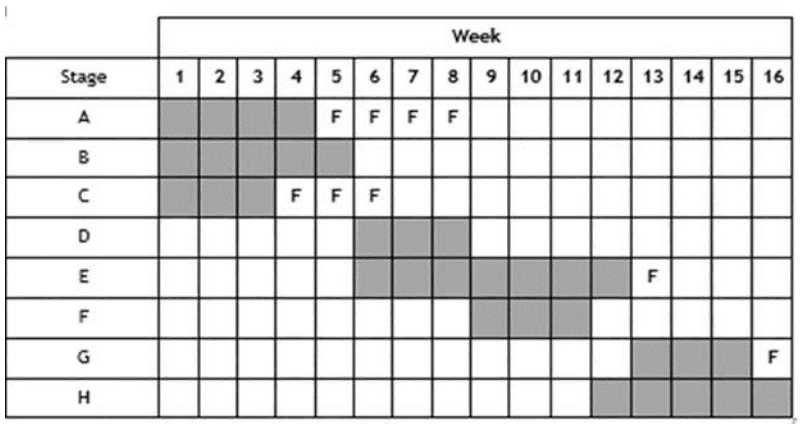
(j) For 'Explain' questions, only award marks where the candidate goes beyond a description, for example by giving a reason, or relating cause to effect, or providing a relationship between two aspects.

(k) Where separate space is provided for rough working and a final answer, only award marks for the final answer. Ignore all rough working.

Marking instructions for each question

Section 1

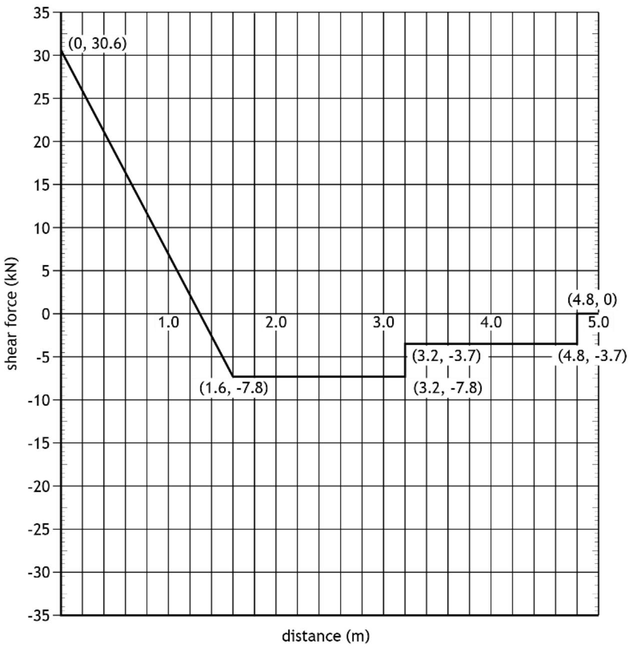
Question			Expected response	Max mark	Additional guidance
1.	(a)	(i)		**3**	1 mark - any two out of E, F, G and H added correctly without float. 1 mark - remaining two out of E,F,G and H added correctly without float. 1 mark - Float added correctly for E and G.

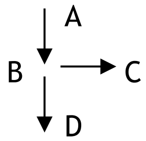
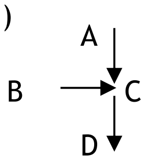
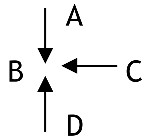
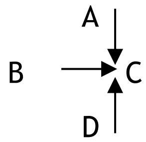


Question			Expected response	Max mark	Additional guidance
1.	(a)	(ii)	B, D, F, H	**1**	1 mark - critical path correct (potential for FTE from a(i)). If float is applied to stage F (incorrectly) on the Gantt chart, but the correct critical path is given, award this mark.
	(b)	(i)	A direct cost is a cost that can be controlled by the project manager and assigned entirely to the project alone and not to other parts of the organisation's costs. An on-cost is a cost that arises because of legislation, and that cannot be controlled by the project manager.	**2**	1 mark for each description.
		(ii)	Direct costs: • Construction materials • Travel expenses of engineers and technicians. On-costs: • Preliminary site work (to ensure compliance with Health & Safety legislation) • Employer National Insurance contributions • Engineering, technical and construction worker salaries.	**1**	1 mark for correct identification.

Question			Expected response	Max mark	Additional guidance
2.			$\eta_{overall} = \eta_{C-H_2} \times \eta_{H_2-C}$ Fuel cell A $\eta_{overall} = 0.84 \times 0.56$ $\eta_{overall} = 0.47\ (2\ \text{s.f.})(47\%)$ Fuel cell B $\eta_{overall} = 0.75 \times 0.65$ $\eta_{overall} = 0.49\ (2\ \text{s.f.})(49\%)$ Fuel cell B has the higher overall efficiency.	**3**	1 mark - extract efficiencies from diagram and convert to decimal. 1 mark - correct value of efficiency for both fuel cells. 1 mark - correct answer.

Question			Expected response	Max mark	Additional guidance
3.	(a)		Base demand is the minimum level of demand on the national grid over a period, for example, a week or a month, whereas peak demand is the maximum power required during the same interval.	**1**	Clear difference between the two types of demand is given, related to a period.
	(b)		Nuclear power, coal power	**1**	Accept gas.
	(c)		The function of the step-up transformer is to increase the voltage and reduce the current produced at the power station to transmit power along the powerlines. To allow this power to be usable at the end of the powerline, this power is stepped down to the required voltage, for example 230V for home consumers. Without step-up and step-down transformers, the current would produce high heat loss in the transmission powerlines reducing the distance the electricity can be distributed efficiently (this would mean an increase in the number of power stations required in the UK).	**2**	1 mark - description of what each transformer does. 1 mark - reason given for requiring low transmission current, so high transmission voltage.
	(d)		$P = \frac{3 \times 1000 \times 40^2 \times 1.68 \times 10^{-8} \times 550}{45}$ $P = 985.6 \times 10^{-3}$ kW $\eta = \frac{P_{out}}{P_{in}} = \frac{17}{17 + 985.6 \times 10^{-3}} = 0.9452...$ $\eta = 0.95$, 95% (2 s.f.)	**2**	1 mark - calculate power loss. 1 mark - calculate efficiency.

Question			Expected response	Max mark	Additional guidance
4.	(a)		$\sum M_A = 0$ $(24 \times 1.6 \times 0.8) - 4.1 \times 3.2 - R_B \times 4.8 = 0$ $R_B = 3.6666......\ = 3.67\ \text{kN(3 s.f.)}$ $\sum F_V = 0$ $R_A + 4.1 + R_B - (24 \times 1.6) = 0$ $R_A = 30.633.....\ = 30.6\ \text{kN(3 s.f.)}$	**4**	1 mark - calculate reactions (units not required). 1 mark - reactions on shear force diagram correct and point load on shear force diagram correct. 1 mark - slope in region of UDL $(0 \le x \le 1.6)$. 1 mark - constant shear force for $(1.6 \le x < 3.2)$ and $(3.2 \le x < 4.8)$.
			 		
	(b)		The point would mean the shear force is zero and this equates to a maximum or minimum magnitude of bending moment. From the bending moment a maximum stress level in the beam can be determined and this will tell the engineer whether the beam will fail under loading. **OR** The engineer will determine the maximum bending moment using these positions. Knowing the safe working stress for the beam material, the engineer will be able to determine a safe cross-section for the beam.	**2**	1 mark - identify that it gives the potential position of maximum magnitude of bending moment. 1 mark - link bending moment to the determination of stress levels, and whether the beam is a safe design.

Question			Expected response	Max mark	Additional guidance
5.			 $I_{AB} - I_{BC} - I_{BD} = 0$ $\frac{V_A - V_B}{R_{AB}} - \frac{V_B - V_C}{R_{BC}} - \frac{V_B - V_D}{R_{BD}} = 0$ $\frac{9.0 - V_B}{30} - \frac{V_B - V_C}{50} - \frac{V_B - 0}{150} = 0$ (*) $\frac{45 - 5V_B}{150} - \frac{3V_B - 3V_C}{150} - \frac{V_B}{150} = 0$ $9V_B - 3V_C = 45$ $3V_B - V_C = 15 \quad \ldots(1)$  $I_{AC} + I_{BC} - I_{CD} = 0$ $\frac{V_A - V_C}{R_{AC}} + \frac{V_B - V_C}{R_{BC}} - \frac{V_C - V_D}{R_{CD}} = 0$ $\frac{9.0 - V_C}{100} + \frac{V_B - V_C}{50} - \frac{V_C - 0}{60} = 0$ (**) $\frac{27 - 3V_C}{300} + \frac{6V_B - 6V_C}{300} - \frac{5V_C}{300} = 0$ $-6V_B + 14V_C = 27 \quad \ldots(2)$ *Add* $2\times(1)$ to (2) $(6V_B - 2V_C) + (-6V_B + 14V_C)$ $=(30)+(27)$ $12V_C = 57$ $V_C = 4.75$ *substitute* for V_C in (1) $3V_B - 4.75 = 15$ $V_B = 6.58\dot{3}$ $V_B = 6.6\ \text{V},\ V_C = 4.8\ \text{V}$ (2 s.f.)	5	1 mark(*) - correct application of KCL and Ohm's law to node B. **Alternative**  $I_{AB} + I_{CB} + I_{DB} = 0$ $\frac{V_A - V_B}{R_{AB}} + \frac{V_C - V_B}{R_{BC}} + \frac{V_D - V_B}{R_{BD}} = 0$ $\frac{9.0 - V_B}{30} + \frac{V_C - V_B}{50} + \frac{0 - V_B}{150} = 0$ (*) $\frac{45 - 5V_B}{150} + \frac{3V_C - 3V_B}{150} - \frac{V_B}{150} = 0$ $9V_B - 3V_C = 45$ $3V_B - V_C = 15 \quad \ldots(1)$ 1 mark(**) - correct application of KCL and Ohm's law to node C. **Alternative**  $I_{AC} + I_{BC} + I_{DC} = 0$ $\frac{V_A - V_C}{R_{AC}} + \frac{V_B - V_C}{R_{BC}} + \frac{V_D - V_C}{R_{CD}} = 0$ $\frac{9.0 - V_C}{100} + \frac{V_B - V_C}{50} + \frac{0 - V_C}{60} = 0$ (**) $\frac{27 - 3V_C}{300} + \frac{6V_B - 6V_C}{300} - \frac{5V_C}{300} = 0$ $-6V_B + 14V_C = 27 \quad \ldots(2)$ 1 mark - begin to solve simultaneous equations correctly (equations do not need to be correct but both must include terms for V_B and V_C). 1 mark - correct value for V_C. 1 mark - correct value for V_B (FTE from fourth mark possible).

Question			Expected response	Max mark	Additional guidance
6.			$100\ kN\ m^{-2} =$ $100\times10^{3}\ N\ \times\left[\frac{1\text{ m}}{10^{3}\text{mm}}\right]^{2}\times\frac{1}{1\text{ m}^{2}}$ $=100\times10^{-3}\ N\ mm^{-2}$ $r=1\times10^{3}\ mm$ $p=100\times10^{-3}\ N\ mm^{-2}$ $E=196\times10^{3}\ N\ mm^{-2}$ $\delta=15$ mm $Z=\frac{100\times10^{-3}\times(1\times10^{3})^{4}}{64\times15}=104.1\dot{6}\times10^{6}$ $Z=\frac{196\times10^{3}\times t^{3}}{12\times(1-0.3^{2})}=104.1\dot{6}\times10^{6}$ $t=\sqrt[3]{\frac{104.1\dot{6}\times10^{6}\times12\times(1-0.3^{2})}{196\times10^{3}}}$ $t=17.97...$ $t=18mm$ (2 s.f.) **OR** $196\ kN\ \text{mm}^{-2} =$ $196\times10^{3}\ N\ \times\left[\frac{10^{3}\text{mm}}{1\text{ m}}\right]^{2}\times\frac{1}{1\text{ mm}^{2}}$ $=196\times10^{9}\ N\ m^{-2}$ $r=$ 1.0 m $p=100\ \times10^{3}\ N\ m^{-2}$ $E=196\ \times10^{9}\ N\ m^{-2}$ $\delta=15\times10^{-3}$ m $Z=\frac{100\ \times10^{3}\times1.0^{4}}{64\times15\times10^{-3}}=104.1\dot{6}\times10^{3}$ $Z=\frac{196\times10^{9}\times t^{3}}{12\times(1-0.3^{2})}=104.1\dot{6}\times10^{3}$ $t=\sqrt[3]{\frac{104.1\dot{6}\times10^{3}\times12\times(1-0.3^{2})}{196\times10^{9}}}$ $t=17.97\times10^{-3}...$ $t=18\times10^{-3}m$ (2 s.f.)	**4**	Solution using mm as unit of length. 1 mark - extract E from data table **and** convert kN m^{-2} to N mm^{-2} for the pressure given. Convert radius from m to mm. 1 mark - rearrange first equation so that Z is the subject and substitute values for pressure, radius and deflection. 1 mark - rearrange second equation so that 't' is the subject, and substitute values for Z, E and Poisson's ratio. 1 mark - answer and unit (mm). **OR** Solution may use metres rather than millimetres as unit of length. 1 mark - extract E from data table **and** convert kN mm^{-2} to N m^{-2}. Convert deflection from mm to m. 1 mark - rearrange first equation so that Z is the subject and substitute values for pressure, radius and deflection. 1 mark - rearrange second equation so that 't' is the subject, and substitute values for Z, E and Poisson's ratio. 1 mark - answer and unit (m).

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>7.</td><td></td><td></td><td>Graph 4

The outer loop creates a decreasing value for the duty of the PWM signal that is produced at the output pin, so the output voltage decreases.

The inner loop creates the time interval that a voltage at the output pin is produced for. This time decreases each time the voltage reduces.

The rate at which the voltage decreases therefore increases.

OR

Graph 4

The outer loop controls output voltage at pin 3.

The inner loop creates a time delay, so the voltage output is constant for a short interval.

Both the voltage and the time delay decrease for each step of the outer loop, so the voltage decreases at an increasing rate.</td><td>4</td><td>1 mark - select correct graph.

1 mark - identify that the outer loop is decrementing the variable, starting at a high value, and reducing to a low value and that the variable controls the output voltage.

1 mark - identify that the inner loop is creating a time interval for which the ‘analogue’ voltage appears at the output pin and that this time interval is reduced for each iteration of the outer loop.

1 mark - the effect is that the voltage at the pin decreases at an increasing rate.</td></tr>
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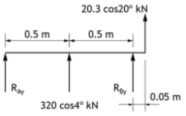
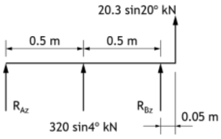
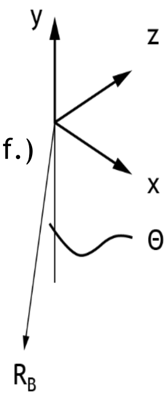
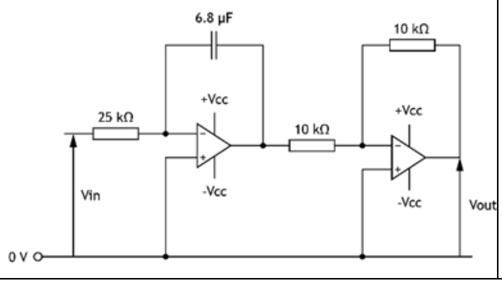
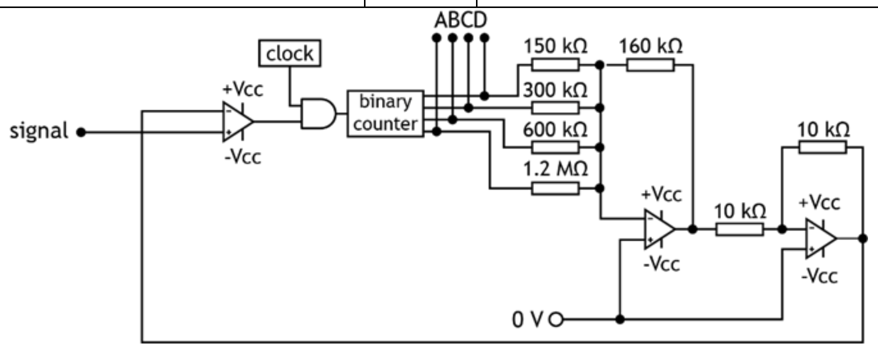
Section 2

Question			Expected response	Max mark	Additional guidance
8.	(a)		Power is conserved in the gear mesh. $P = 2\pi nT$ $T = \dfrac{P}{2\pi n}$ $T = \dfrac{12 \times 10^3}{2\pi \times \left(\dfrac{120}{60}\right)}$ $T = 954.929...\ N\ m$ $F_t = \dfrac{T}{r}$ $F_t = \dfrac{954.929...}{\left(\dfrac{0.125}{2}\right)}$ $F_t = 15278.87....$ $F_t = 15\ kN$ (2 s.f.) $F_r = F_t \times \tan 20^\circ$ $F_r = (15278.87....) \times \tan 20^\circ$ $F_r = 5561.055...$ $F_r = 5.6\ kN$ (2 s.f.)	**3**	1 mark - calculate torque. 1 mark - calculate tangential force on gear. 1 mark - calculate radial force on gear.

Question			Expected response	Max mark	Additional guidance
8.	(b)		x-y plane  $\sum M_A = 0$ $-320\cos 4^\circ \times 0.50 - R_{By} \times 1.0$ $- 20.3\cos 20^\circ \times 1.05 = 0$	**6**	1 mark - decomposition of 320 kN force correct in relation to two planes. 1 mark - decomposition of 20.3 kN gear contact force correct in relation to two planes.
			$R_{By} = -179.63\ldots$ kN		1 mark - correct moment equilibrium in x-y plane derived.
			x-z plane  $\sum M_A = 0$ $-320\sin 4^\circ \times 0.50 - R_{Bz} \times 1.0$ $+20.3\sin 20^\circ \times 1.05 = 0$ $R_{Bz} = -3.8708\ldots$ kN		1 mark - correct moment equilibrium in x-z plane derived. 1 mark - correct magnitude of the reaction at bearing B.
			$\lvert R_B \rvert = \sqrt{{R_{By}}^2 + {R_{Bz}}^2}$ $\lvert R_B \rvert = \sqrt{(-179.63\ldots)^2 + (-3.8708\ldots)^2}$ $\lvert R_B \rvert = 179.671\ldots$ $\lvert R_B \rvert = 180\ kN$ (2 s.f.) $\theta = \tan^{-1}\left(\dfrac{-3.8708\ldots}{-179.63\ldots}\right)$ $\theta = 1.23\ldots^\circ = 1.2^\circ$ (2 s.f.)  		1 mark - correct angle of the reaction at bearing B. The sense of the angle in relation to the system must be clear.

Question			Expected response	Max mark	Additional guidance
8.	(c)		Smaller diameter rollers will deflect more under the action of the rolling contact force (deflection need to be minimised as it affects the uniformity of the thickness of the rolled sheet). Adding support rollers will reduce deflection (thus producing rolled sheets of constant thickness). The smaller the roller diameter then the more it deflects because of a reduced second moment of area. Adding support rollers effectively increases the second moment of area of the roller system to reduce the deflection.	**2**	1 mark - relate a small diameter to an increase in deflection and the addition of larger rollers leading to a reduction in deflection. From data booklet: $\delta = \frac{5\omega L^4}{384EI}$ or $\delta = \frac{\omega L^4}{384EI}$ 1 mark - reference to second moment of area and its reduction as diameter reduces explains the increase in deflection and the need for the larger rollers to eliminate this increase in deflection. "Stiffness reduces as diameter of cross-section reduces" – accept for first mark, although "stiffness" is not a property that is required knowledge in the course.

Question			Expected response	Max mark	Additional guidance
8.	(d)	(i)	$V_{out} = -\frac{1}{RC}\int V_{in}dt$ $7.5 = -\frac{1}{R\times 6.8\times 10^{-6}}\int_0^{250\times 10^{-3}}(5)dt \times (-1)$ $R = \frac{1}{7.5\times 6.8\times 10^{-6}}\left[5t\right]_0^{250\times 10^{-3}}$ $R = \frac{5\times 250\times 10^{-3}}{7.5\times 6.8\times 10^{-6}}$ $R = 24.5098\ldots\times 10^3$ $R = 25\ k\Omega$ (2 s.f.) **OR** $V_{out} = -\frac{1}{RC}\int V_{in}dt$ $V_{out} = -\frac{1}{RC}\int (5)dt$ $V_{out} = -\frac{1}{RC}5t + k$ *When* t=0, $V_{out} = 0 \Rightarrow k = 0$ *When* t=250×10^{-3}, $V_{out} = 7.5$ $R = -\frac{5\times 250\times 10^{-3}}{7.5\times 6.8\times 10^{-6}}\times(-1)$ $R = 24.5098\ldots\times 10^3$ $R = 25\ k\Omega$ (2 s.f.)	3	1 mark - a recognition appears somewhere in working for R that a gain of -1 must be applied to either the integrator output, or input to produce the output required from the input. …… $-7.5 = -\frac{1}{R\times 6.8\times 10^{-6}}\int_0^{250\times 10^{-3}}(5)dt$ …… …… *When* t=250×10^{-3}, $V_{out} = -7.5$ $-7.5 = -\frac{5\times 250\times 10^{-3}}{R\times 6.8\times 10^{-6}}$ …… If either of the above forms appear, this mark can be awarded if a second stage is added to the circuit diagram in the next part of the question. 1 mark - integrates 5 to 5t. Urd1 mark - answer and units.
		(ii)		2	1 mark - circuit diagram for integrator with component values. 1 mark - circuit diagram for unity gain inverting amplifier with component values.

Question			Expected response	Max mark	Additional guidance
8.	(e)		$V_o = -R_f\left(\frac{V_1}{R_1}+\frac{V_2}{R_2}+\ldots\right)$ $4-bit$ D-A converter, msb is line D, lsb is line A. $V_o = -R_f\left(\frac{V_D}{R_1}+\frac{V_C}{2R_1}+\frac{V_B}{4R_1}+\frac{V_A}{8R_1}\right)\times(-1)$ When all inputs are on, $V_A \ldots V_D = 5.0\ V,\ V_o = 10.0\ V$ $10 = -160\times\frac{5.0}{R_1}\left(1+\frac{1}{2}+\frac{1}{4}+\frac{1}{8}\right)\times(-1)$ $R_D = R_1 = 150\ k\Omega$ $R_C = 2R_1 = 300\ k\Omega$ $R_B = 4R_1 = 600\ k\Omega$ $R_A = 8R_1 = 1.2\ M\Omega$	**4**	1 mark - calculate resistance required for either msb, as shown, or determine resistance required for lsb shown here: $resolution: \frac{10}{2^4-1} = \frac{2}{3}\ \text{V}$ for lsb: $V_o = -\frac{R_f}{R_A}\times V_A\times(-1)$ $\frac{2}{3} = \frac{160\times10^3}{R_A}\times 5$ $R_A = 1.2\times10^6\ \Omega$ 1 mark - calculate other three resistor values required for D-A converter. $R_B = \frac{R_A}{2} = 600\times10^3\ \Omega$ $R_C = \frac{R_A}{4} = 300\times10^3\ \Omega$ $R_D = \frac{R_A}{8} = 150\times10^3\ \Omega$ 1 mark - draw circuit diagram for summing amplifier showing required resistor values connected to correct input lines. 1 mark - draw circuit diagram for unity gain inverting amplifier.
					

Question			Expected response	Max mark	Additional guidance
9.	(a)		$F = \frac{480 \times 10^3 \times 9.8}{2} = 2.352 \times 10^6$ N $R_A = R_B = \frac{F}{2} = 1.176 \times 10^6$ N $\omega = \frac{2.352 \times 10^6}{6} = 392 \times 10^3$ Nm^{-1} $0 \le x \le 1.2$ $M = -\omega \frac{x^2}{2}$ *When* x=0, M=0 When x=1.2, M= $-392 \times 10^3 \times \frac{(1.2)^2}{2}$ $M = -282 \times 10^3$ $M = -280$ kNm (2 s.f.) $1.2 \le x \le 3$ $M = -\omega \frac{x^2}{2} + R_A(x - 1.2)$ When x=3, M= $-392 \times 10^3 \times \frac{(3)^2}{2} + 1.176 \times 10^6 \times 1.8$ $M = 353 \times 10^3$ Nm $M = 350$ kNm (2 s.f.)	5	1 mark - calculate the distributed load and the reactions acting on the beam. 1 mark - recognise that the bending moment at x=0 is 0 Nm (a statement is enough). 1 mark - expression for the bending moment for $0 \le x \le 1.2$. 1 mark - expression for the bending moment for $1.2 \le x \le 3$. 1 mark - correct values for bending moment at x=1.2 and x=3. Note: final 3 marks can be awarded if the values for bending moment at x=1.2 and x=3 are given correctly, without an explicit formula. If bending moment equations and magnitudes at 1.2m and 3m are correct, but the signs are opposite to the solution, then award full marks because a sign convention for bending moment has not been stated in the question.

Question			Expected response	Max mark	Additional guidance
9.	(b)		$\frac{M}{I}=\frac{\sigma}{y}$ $I \geq \frac{M}{\sigma} \times y$ $\sigma = UTS / 2.5 = 680 / 2.5 = 272\ N\ \text{mm}^{-2}$ $I \geq \frac{368 \times 10^6}{272} \times y$ $When\ y = \frac{406}{2} = 203\ mm$ $I \geq \frac{368 \times 10^6}{272} \times 203 = 27465 \times 10^4\ \ mm^4$ $When\ y = \frac{457}{2} = 228.5\ mm$ $I \geq \frac{368 \times 10^6}{272} \times 228.5 = 30900 \times 10^4\ \ mm^4$ OR $\sigma = M \times \frac{y}{I}$ $\sigma = 368 \times 10^6 \times \frac{203}{24502 \times 10^4} = 305\ \text{Nmm}^{-2}$ $\sigma = 368 \times 10^6 \times \frac{203}{27481 \times 10^4} = 272\ \text{Nmm}^{-2}$ $\sigma = 368 \times 10^6 \times \frac{228.5}{29597 \times 10^4} = 284\ \text{Nmm}^{-2}$ $\sigma = 368 \times 10^6 \times \frac{228.5}{33536 \times 10^4} = 251\ \text{Nmm}^{-2}$ Use beam section 2 (accept beam section 4).	4	1 mark - determine the correct safe working stress (272 N mm^{-2}) using the data booklet and required factor of safety. 1 mark - determine maximum distance from neutral axis of beam. **EITHER** 1 mark - determine required second moment of area for beam for the two beam depths. **OR** 1 mark - determine stress level in each beam. 1 mark - select beam 2, based on valid working (accept beam section 4 provided numerical values are shown for 2 and 4 to aid the selection).

Question			Expected response	Max mark	Additional guidance
9.	(c)		Possible factors: Sourcing of materials, their extraction or creation, and their processing requirements. Component materials selected based on the amount of energy required to produce the components in the design, the polluting effects of by-products created in the manufacture and use of the materials as well as any required mechanical and physical properties. Design for manufacture to minimise tools and energy required. Selecting materials and processes to minimise the energy required to manufacture each component, and considering the tools required, which may themselves involve mined materials (eg ceramic cutters). Design for efficient, robust operation. Reliability of all components essential to the operation of the system should be determined through testing. Design for recycling at end of life. Materials in design components can be separated for re-use at the end of the useful life of the components, but the amount of energy required to do so would be considered.	**2**	1 mark - identification of an appropriate factor relevant to sustainable design that would be considered during design. 1 mark - a comment on how it would be considered.

Question			Expected response	Max mark	Additional guidance
9.	(d)		$T_2 = 0{\cdot}7\ R_2\ C$ $0{\cdot}7\ R_2 \times 750 \times 10^{-9} = 0.02 \times 35 \times 10^{-3}$ $R_2 = 1.3\ k\Omega$ $T_1 = 0{\cdot}7\ (R_1 + R_2)\ C$ $0{\cdot}7\ (R_1 + 1.\dot{3} \times 10^3) \times 750 \times 10^{-9}$ $= 0.98 \times 35 \times 10^{-3}$ $R_1 = 64\ k\Omega$	2	1 mark - determine value for R_2. 1 mark - determine value for R_1.
	(e)		$T_{on} = 1.1\ (R_3 + R_V)\ C$ $1.1\ (R_3 + 0) \times 750 \times 10^{-9} = 1 \times 10^{-3}$ $R_3 = 1.2\ k\Omega$ $T_{on} = 1.1\ (R_3 + R_V)\ C$ $1.1\ (1.2 \times 10^3 + R_V) \times 750 \times 10^{-9} = 5 \times 10^{-3}$ $R_V = 4.9\ k\Omega$	3	1 mark - set R_V=0 to determine value for R_3. 1 mark - determine value for R_3. 1 mark - determine value for R_V.
	(f)		163 is the lowest permissible value of the “input angle” variable while 220 is its maximum permissible value. The values are the integer part of the calculation below. $163 = \left(\frac{230}{359} \times 255\right)$ $220 = \left(\frac{310}{359} \times 255\right)$ These lines ensure that the ‘input angle’ lies within the correct range even if the potentiometer is turned beyond the angle limits.	2	1 mark - indicate how the two values relate to the maximum and minimum potentiometer angles. A calculation need not be shown because the wording of the question does not explicitly require it. 1 mark - state that the program lines act to limit the value of the variable ‘input angle’ to the range of values between these two limits.

Question			Expected response	Max mark	Additional guidance
9.	(g)		**ARDUINO** The values calculated for ‘mark’ are 630 and 860, which means ‘space’ values are 19370 and 19140. These are permissible values for the variables as they are defined, but the delayMicroseconds(us) command only takes values in the range 0-16383, so delayMicroseconds(mark) works, but delayMicroseconds(space) does not work because the value for the variable ‘space’ is too large. **PBASIC** The values calculated for ‘mark’ are 630 and 860, which means ‘space’ values are 19370 and 19140. These are permissible values for the variables as they are defined, but the pausemicro microseconds command only takes values in the range 0-16383, so pausemicro mark works, but pausemicro space does not work because the value for the variable ‘space’ is too large.	**2**	1 mark - identify the values generated for variables ‘mark’ and ‘space’. 1 mark - note that the variable ‘space’ takes too large a value for the specification of the delay function parameter.

[END OF MARKING INSTRUCTIONS]