National
Qualifications
2025

2025 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.

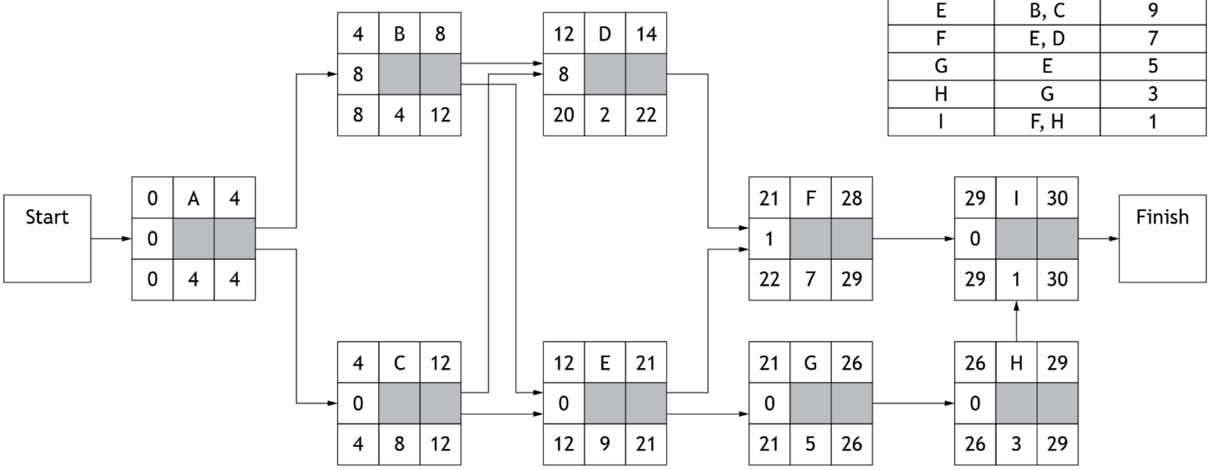
(i) Candidates can answer programming questions in any appropriate programming language. Award marks where the intention of the coding is clear, even where there are minor syntax errors.

(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

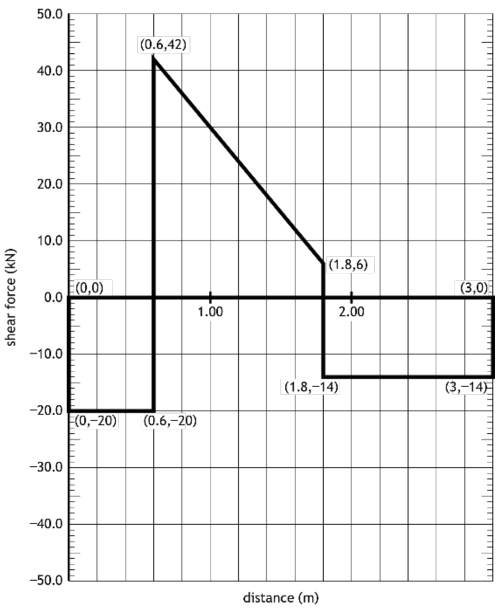
Question			Expected response	Max mark	Additional guidance
1.	(a)	(i)		**1**	Precedence arrows completed correctly.



Stage	Precedent	Time
A		4
B	A	4
C	A	8
D	B, C	2
E	B, C	9
F	E, D	7
G	E	5
H	G	3
I	F, H	1

Question			Expected response	Max mark	Additional guidance
		(ii)		**3**	**1 mark** Latest finish times for each activity correct. **1 mark** Latest start times for each activity correct. **1 mark** Float for each activity correct. Credit must be given for follow through errors for the second and third marks.
		(iii)	A, C, E, G, H, I	**1**	Path selected follows zero floats, which have been sensibly added for third mark in (a) (ii).

Question			Expected response	Max mark	Additional guidance
1.	(b)		**Estimate budget:** This is where the PM needs to sort out the budget and define all the potential costs. To create an appropriate financial plan the PM must have a clear idea about the funds required to sustain the project's resources, equipment, and indirect costs, if any. **Estimate resources required:** The PM must bring into a project the correct materials, equipment, and skills. Planning for correct quantities of each to be available at correct points in the project to ensure project consistency and success during the implementation phase. **Anticipate risks on time:** Identifying the potential for delay at each stage throughout the project is essential. This will help team members calmly approach a roadblock and mitigate the risk at the earliest opportunity, minimising the likelihood of delays to the planned project timeline.	**2**	**1 mark** Identify activity. **1 mark** Justify the activity.

Question			Expected response	Max mark	Additional guidance
2.			$\sum M_A = 0$ $-(20.0\times0.6)+(30.0\times1.2\times0.6)$ $+(20.0\times1.2)-(R_B\times2.4)=0$ $R_B = 14\ kN$ $\sum F_V = 0$ $R_A - 20.0 - (30.0\times1.2)$ $-20.0 + R_B = 0$ $R_A = 62$ kN  	5	**1 mark** Two correct equations of equilibrium. **1 mark** Calculation of R_A and R_B correct value and sign. **Note:** The correct calculation of the two reactions from an incorrect equilibrium equation may yield this mark, provided all forces are multiplied by a distance in the first equation and all forces are considered in the second equation. **1 mark** Correct indication of reactions on shear force diagram. **1 mark** Correct indication of point loads on diagram. **1 mark** Correct indication of UDL on diagram. **Note:** The correct construction of SF diagram using incorrect values of reactions will yield marks.

Question			Expected response	Max mark	Additional guidance
3.			$\eta = \dfrac{P_E + P_H}{P_{in}}$ $P_E + P_H = \eta \times P_{in}$ $P_E + P_H = 0.82 \times 305$ $P_E + P_H = 250.1 \text{ MW}$ $\dfrac{P_H}{P_E} = \dfrac{5}{3}$ $P_H = \dfrac{5}{3} \times P_E$ $P_E + \dfrac{5}{3} \times P_E = 250.1$ $P_E = \dfrac{250.1}{2.\dot{6}}$ $P_E = 93.7875\ MW$ $\eta_E = \dfrac{P_E}{P_{in}}$ $\eta_E = \dfrac{93.7875}{305} = 0.31\ (2\ s.f.)$	3	**1 mark** Calculate total useful output power. **1 mark** Calculate the electrical power output. **1 mark** Calculate the efficiency for electrical power output alone.

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>4.</td><td>(a)</td><td></td><td><table>
<tr><th>Component</th><th>Label</th></tr>
<tr><td>Busbar</td><td>D</td></tr>
<tr><td>Capacitor</td><td></td></tr>
<tr><td>Circuit breaker</td><td>C</td></tr>
<tr><td>Isolating Switch</td><td></td></tr>
<tr><td>Generator</td><td>A</td></tr>
<tr><td>Pylon</td><td></td></tr>
<tr><td>Step-down transformer</td><td></td></tr>
<tr><td>Step-up transformer</td><td>B</td></tr>
<tr><td>Transmission Line</td><td></td></tr>
</table></td><td>2</td><td>1 mark
2 or 3 components identified correctly.

1 mark
4th component identified correctly.</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>A busbar is a common conducting connector from a supply line to two or more circuits at the supply line voltage and distributes current to the circuits.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>A circuit breaker will isolate one section of the transmission system from another at very high speed if there is a current surge, to minimise component damage.</td><td>1</td><td>Do not accept “switch” to isolate sections of the transmission system for maintenance: these are separate devices.</td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
5.	(a)		The (unity gain) inverting amplifier changes the polarity of the output from the summing amplifier, so that the final output is a positive voltage for all input combinations.	1	Ensures the output voltages are positive.
	(b)		Each input has two values. There are four inputs. $2^4 = 16$	1	A statement "16" is sufficient.
	(c)		When V_{out}=10 V, all input lines are at 5 V and $R_0=8R_3$, $R_1=4R_3$, $R_2=2R_3$ $10 = -16\times\left(\frac{5}{8R_3}+\frac{5}{4R_3}+\frac{5}{2R_3}+\frac{5}{R_3}\right)\times-\left(\frac{10}{10}\right)$ $10 = 80\times\frac{15}{8}\times\frac{1}{R_3}$ $R_3 = 15\ \text{k}\Omega$ $R_2 = 30\ \text{k}\Omega$ $R_1 = 60\ \text{k}\Omega$ $R_0 = 120\ \text{k}\Omega$ **OR** $\text{Resolution}, V_{res} = \frac{V_{out}}{2^4-1} = \frac{10}{15}\ V$ This is the voltage output expected when the lsb turns on alone. $V_{res} = -R_f\left(\frac{V_0}{R_0}\right)\times\left(-\frac{10}{10}\right)$ $\frac{10}{15} = 16\left(\frac{5}{R_0}\right)$ $R_0 = 120\ \text{k}\Omega$ $R_1 = 60\ \text{k}\Omega$ $R_2 = 30\ \text{k}\Omega$ $R_3 = 15\ \text{k}\Omega$	3	**1 mark** $10 = 16\times\left(\frac{5}{8R_3}+\frac{5}{4R_3}+\frac{5}{2R_3}+\frac{5}{R_3}\right)$ **1 mark** Calculate R_3. **1 mark** Determine remaining resistor values R_2, R_1 and R_0. **OR** **1 mark** Calculate $V_{res,}$ the voltage resolution of the D-A converter. $\frac{10}{15} = \frac{2}{3}$ V **1 mark** Calculate R_0. **1 mark** Determine remaining resistor values R_1, R_2 and R_3.

Question			Expected response	Max mark	Additional guidance
6.	(a)		$f = \frac{1}{2\pi RC}$ Highest frequency requires lowest values of resistance and capacitance. $R_{\text{min}} = 680 \times (1 - 0.01)$ $R_{\text{min}} = 680 \times 0.99$ $C_{\text{min}} = 5.6 \times 10^{-6} \times (1 - 0.05)$ $C_{\text{min}} = 5.6 \times 10^{-6} \times 0.95$ $f = \frac{1}{2\pi(680 \times 0.99)(5.6 \times 10^{-6} \times 0.95)}$ $f = 44.4$ Hz f = 44 Hz (2 s.f.)	**2**	**1 mark** Apply tolerance correctly to values of resistance and capacitance. **1 mark** Calculate maximum frequency. **Note:** Second mark is available for either: nominal frequency (41.8 (42) Hz) **OR** minimum frequency (39.4 (39) Hz).
	(b)		For stable oscillation, gain=3 The resistive feedback loop represents non-inverting amplifier arrangement, so $3 = 1 + \frac{20}{R_1}$ $R_1 = 10\ \text{k}\Omega$	**1**	Resistor ratio must be two, so R_1 is 10 kΩ. A statement of the value is sufficient.
	(c)		The signal is attenuating, so the gain is too low, which means the value of R_1 is too large.	**1**	Resistor is too large.

Question			Expected response	Max mark	Additional guidance
7.	(a)		$\sum F_V = 0$ $-W + \omega L = 0$ $\omega = \frac{W}{L} = \frac{102 \times 9.8}{2.5} = 399.84$ $\omega = 400\ Nm^{-1}\ (2s.f.)$	**1**	Vertical force equilibrium to determine the UDL.
	(b)		$I = \frac{bd^3}{12}$ $I = \frac{0.69 \times 0.075^3}{12}$ $= 24.2578... \times 10^{-6}$ $= 24.26... \times 10^{-6}\ m^4$ Working in N and m, The deflection is based on a cantilever of length 0.5L: $\frac{L}{2} = \frac{2.5}{2} = 1.25\ m$ $\delta = \frac{\omega L^4}{8EI}$ $\delta = \frac{400 \times 1.25^4}{8 \times 3.25 \times 10^9 \times 24.26 \times 10^{-6}}$ $= 1.548... \times 10^{-3}\ m$ $= 1.5$ mm (2 s.f.) **OR** Working in N and mm, $24\ \times 10^{-6}\ m^4 = 24\ \times 10^6\ \text{m}m^4$ $1.25\ m = 1.25 \times 10^3$ mm $400\ Nm^{-1} = 400 \times 10^{-3}\ Nmm^{-1}$ $3.25 \times 10^9\ Nm^{-2} = 3.25 \times 10^3\ Nmm^{-2}$ $\delta = \frac{400 \times 10^{-3} \times (1.25 \times 10^3)^4}{8 \times 3.25 \times 10^3 \times 24.26 \times 10^6}$ $= 1.548...\ \text{m}m$ $= 1.5$ mm (2 s.f.)	**3**	**1 mark** Calculation of second moment of area. **1 mark** Selection of correct deflection formula and substitution of variables having consistent units. **1 mark** Final answer and units. **Note:** If 2.5 is substituted, rather than 1.25, for the length of the cantilever and all other substitutions are correct, then award the third mark, but not the second. Answer will be: 24.768… mm, 25 mm (2 s.f.) If each substitution has the correct numerical value, but the orders of magnitude between variables are not consistent, then award the third mark, but not the second.

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>8.</td><td></td><td></td><td>PBASIC

flag = PORTB | %01111100
flag = %11111111 | %01111100
flag = %11111111

flag = PORTB & %01111100
flag = %11111111 & %01111100
flag = %01111100

flag = PORTB ^ %01111100
flag = %11111111 ^ %01111100
flag = %10000011

Using the second command, bitwise AND, produces the required value in flag.

ARDUINO

flag = PORTD | 0b01111100
flag = 0b11111111 | 0b01111100
flag = 0b11111111

flag = PORTD & 0b01111100
flag = 0b11111111 & 0b01111100
flag = 0b01111100

flag = PORTD ^ 0b01111100
flag = 0b11111111 ^ 0b01111100
flag = 0b10000011

Using the second command, bitwise AND, produces the required value in flag.</td><td>3</td><td>1 mark
Any two of the three logical outcomes correct.

1 mark
Third logical outcome correct.

1 mark
Statement of correct logic to use to fit the specification (must be supported by working).</td></tr>
</table>

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>9.</td><td>(a)</td><td></td><td>Load in y- direction due to pulley tensions (vertically down)
$F_y = 66.9\sin 32^\circ + 334.5\sin 56^\circ$
$F_y = 312.76$ N

Load in z- direction due to pulley tensions (out of page)
$F_z = 66.9\cos 32^\circ + 334.5\cos 56^\circ$
$F_z = 243.78$ N

$\sum M_A = 0$
$(R_{By} \times 0.082) + (305 \times 0.309)$
$-(312.76 \times 0.041) = 0$

$R_{By} = -992.949...$ N

$\sum M_A = 0$
$(R_{Bz} \times 0.082)$
$-(243.78 \times 0.041) = 0$

$R_{Bz} = 121.86$ N

Reaction in Bearing B

$R_B = \sqrt{R_{By}{}^2 + R_{Bz}{}^2}$
$R_B = \sqrt{(-992.95)^2 + 121.86^2}$
$R_B = 1000.6$

$R_B = 1.0$ kN (2 s.f.)</td><td>5</td><td>1 mark
Resolve forces given at LHE in ‘vertical’ direction and ‘horizontal’ direction to find a resultant in each.

1 mark
Correct equation of equilibrium in ‘vertical’ direction.

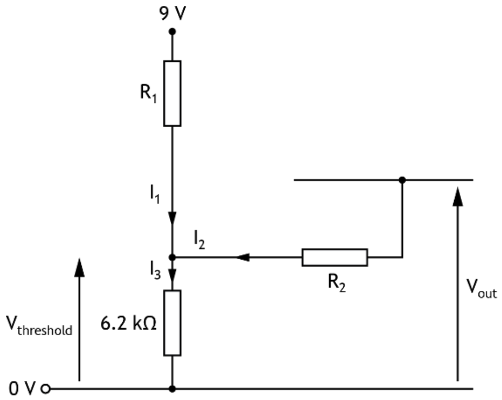
1 mark
Correct equation of equilibrium in ‘horizontal’ direction.

1 mark
Solve both equilibrium equations correctly for components of the reaction at B.

1 mark
Magnitude of reaction at B. Answer and unit.</td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
9.	(b)		For the drive pulley $T = (F_{max} - F_{min}) \times \frac{D}{2}$ $T = (334.5 - 66.9) \times \frac{0.05}{2}$ $T = 6.69$ Nm $P = 2\pi nT$ $P = 2\pi \times \frac{400}{50} \times \frac{175}{60} \times 6.69$ $P = 980$ W (2 s.f.) **OR** For the driven pulley $T = (F_{max} - F_{min}) \times \frac{D}{2}$ $T = (334.5 - 66.9) \times \frac{0.400}{2}$ $T = 53.52$ Nm $P = 2\pi nT$ $P = 2\pi \times \frac{175}{60} \times 53.52$ $P = 980$ W (2 s.f.)	**2**	**1 mark** Expression to calculate the torque on the drive pulley is correct. **1 mark** Calculate the power transmitted to the drive wheel. **Note:** The answer may be produced by considering the driven pulley with appropriate change to pulley diameter and using the 175 revs min^{-1} directly.
	(c)		$156^{\circ} = \frac{156}{360} \times 2\pi$ =2.7227 rad $e^{\mu\theta} = e^{(0.8 \times 2.7227)}$ $e^{\mu\theta} = 8.8300...$ $\frac{F_{max}}{F_{min}} = \frac{334.5}{66.9}$ $\frac{F_{max}}{F_{min}} = 5$ For no slipping, $\frac{F_{max}}{F_{min}} \leq e^{\mu\theta}$ $5 \leq 8.8300...$ So, belt does not slip.	**2**	**1 mark** Choice of smaller contact angle on drive rather than driven pulley. **1 mark** Comparing ratio of the belt tensions to the ratio at which slip will occur. The ratio is less, so the belt does not slip. Second mark is available if first mark is not awarded because 204° is used as the angle.

Question			Expected response	Max mark	Additional guidance
9.	(d)		$T = 80 \times 10^{-6}$ s $D = \dfrac{50 \times 10^{-6}}{80 \times 10^{-6}} = \dfrac{5}{8}$ $P_C = \dfrac{1}{3} DR_{DS(on)} (I_{ON}{}^2 + I_{ON} \times I_{OFF} + I_{OFF}{}^2)$ $P_C = \dfrac{1}{3} \times \dfrac{5}{8} \times 0.15(1.0^2 + (1.0 \times 1.2) + 1.2^2$ $P_C = 113.75 \times 10^{-3}$ W $f = \dfrac{1}{T} = 12.5 \times 10^3$ Hz $P_{SW} = \dfrac{1}{2} \times f \times V_{OFF} (T_{ON} I_{ON} + T_{OFF} I_{OFF})$ $P_{SW} = \dfrac{1}{2} \times 12.5 \times 10^3 \times 110 \times$ $(40 \times 10^{-9} \times 1.0 + 45 \times 10^{-9} \times 1.2)$ $P_{SW} = 64.625 \times 10^{-3}$ W $P = P_C + P_{SW}$ $P = 178.375 \times 10^{-3}$ $P = 180$ mW (2 s.f.)	**3**	**1 mark** Correct substitutions to calculate power loss during conduction. **1 mark** Correct substitutions to calculate power loss during switching. **1 mark** Correct answer and unit.
	(e)	(i)	(Step-down) transformer and (full wave) rectifier.	**1**	Do not accept step-up transformer.
		(ii)	The transformer steps down the voltage from 230 V AC, producing low-voltage AC. The (full wave) rectifier converts AC to DC (at a slightly lower voltage than the peak AC voltage)	**2**	**1 mark** Description of transformer function, which indicates that the voltage is reduced. **1 mark** Description of rectifier function, which indicates that the voltage is converted from AC to DC.

Question			Expected response	Max mark	Additional guidance
9.	(f)		 Kirchhoff's Current law at non-inverting terminal: $\frac{9-V_{th}}{R_1}+\frac{V_{out}-V_{th}}{R_2}-\frac{V_{th}-0}{6.2}=0$ Upper threshold: $\frac{9-5.2}{R_1}+\frac{7.5-5.2}{R_2}-\frac{5.2-0}{6.2}=0$ $\frac{3.8}{R_1}+\frac{2.3}{R_2}=\frac{5.2}{6.2}......(1)$ Lower threshold: $\frac{9-2.7}{R_1}+\frac{0-2.7}{R_2}-\frac{2.7-0}{6.2}=0$ $\frac{6.3}{R_1}-\frac{2.7}{R_2}=\frac{2.7}{6.2}......(2)$ Add 2.7x(1) to 2.3x(2): $\frac{2.7\times3.8}{R_1}+\frac{2.3\times6.3}{R_1}=$ $\frac{2.7\times5.2}{6.2}+\frac{2.3\times2.7}{6.2}$ $\frac{99}{4\times R_1}=\frac{405}{124}$ $R_1=7.5\dot{7}$ Sub in eqn (1) $\frac{3.8}{7.5\dot{7}}+\frac{2.3}{R_2}=\frac{5.2}{6.2}$ $R_2=6.82$ $R_1=7.6\ \text{k}\Omega$ (2 s.f.) $R_2=6.8\ \text{k}\Omega$ (2 s.f.)	**5**	**1 mark** Current equilibrium for upper threshold condition. $V_{out}=7.5\ V,\ V_{th}=5.2$ V **1 mark** Current equilibrium for lower threshold condition. $V_{out}=0$ V, $V_{th}=2.7$ V If threshold voltages are transposed, first mark is not available, but second mark may be awarded. **1 mark** Begin to solve simultaneous equations appropriately. **1 mark** First resistor value correct. **1 mark** Second resistor value correct.

Question			Expected response	Max mark	Additional guidance
10.	(a)		Second moment of area of a hollow section is the second moment of area of outer – second moment of area of inner. In this case: $I_{xx} = \frac{BD^3}{12} - \frac{bd^3}{12}$ $I_{xx} = \frac{0.2 \times 0.4^3}{12} - \frac{0.18 \times 0.36^3}{12}$ $I_{xx} = 366.8266...10^{-6}$ $I_{xx} = 367 \times 10^{-6}\ \text{m}^4\ (3\ \text{s.f.})$ $I_{xx} = 367 \times 10^{6}\ \text{mm}^4$	2	**1 mark** Identify correct second moment of area formula and method for hollow section. **1 mark** Correct calculation.

<table>
<tr><th colspan="3">Question</th><th>Expected response</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>10.</td><td>(b)</td><td></td><td>Stress in a beam
$$\sigma = \frac{My}{I}$$
Perform calculation for fully extended and fully retracted and compare. In each position, M and I are different.

Fully extended:
$$M = \sum_{sections} mgx$$
where x is distance of centre of gravity from left hand end.

$M = M_{PART\ A} + M_{PART\ B} + M_{PART\ C}$
$M = (121.6 \times 9.8 \times 0.5)$
$+(108.8 \times 9.8 \times 1.5)$
$+(96.0 \times 9.8 \times 2.5)$

$M = 4.5472 \times 10^3$ Nm

$\sigma = \dfrac{4.5472 \times 10^3 \times \dfrac{0.400}{2}}{366.8 \times 10^{-6}}$

$\sigma = 2.4793893...\ MNm^{-2}$

Fully retracted, x for each section is the same.
$M = \left(\sum_{sections} mg\right)x$
$M = M_{PART\ A} + M_{PART\ B} + M_{PART\ C}$
$M = (121.6 \times 9.8 \times 0.5)$
$+(108.8 \times 9.8 \times 0.5)$
$+(96.0 \times 9.8 \times 0.5)$

$M = 1.59936 \times 10^3$ Nm

$I = (366.8 + 262.9 + 180.8) \times 10^{-6}$

$\sigma = \dfrac{1.59936 \times 10^3 \times \dfrac{0.400}{2}}{810.5 \times 10^{-6}}$

$\sigma = 394.660...\ kNm^{-2}$</td><td>6</td><td>1 mark
Bending moment for extended arm.

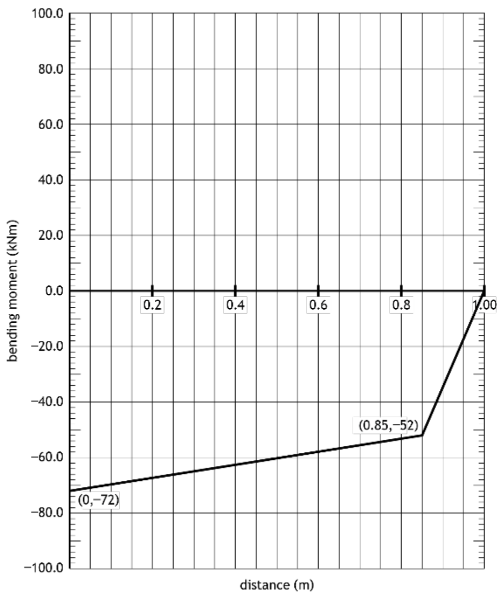
1 mark
Stress for extended arm.

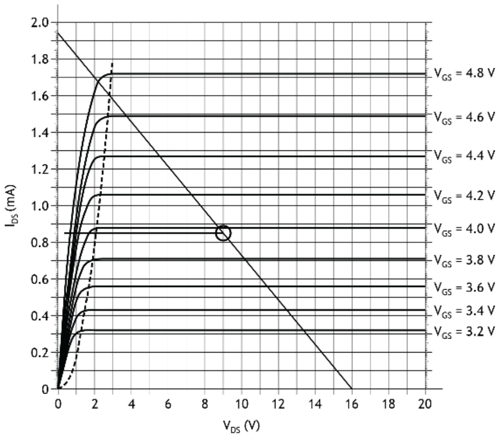
1 mark
Bending moment for retracted arm.

1 mark
Second moment of area for retracted arm.

1 mark
Stress for retracted arm.</td></tr>
</table>

Question			Expected response	Max mark	Additional guidance
10.	(b)		**(continued)**		
			$Ratio = \dfrac{2.4793893... \times 10^6}{394.660... \times 10^3}$ $Ratio = 6.28$ (2 s.f.) **OR** $\dfrac{\sigma_{EXTENDED}}{\sigma_{RETRACTED}} = \dfrac{\dfrac{M_{EXTENDED} \times y_{max}}{I_{EXTENDED}}}{\dfrac{M_{RETRACTED} \times y_{max}}{I_{RETRACTED}}}$ $\dfrac{\sigma_{EXTENDED}}{\sigma_{RETRACTED}} = \dfrac{\dfrac{M_{EXTENDED}}{I_{EXTENDED}}}{\dfrac{M_{RETRACTED}}{I_{RETRACTED}}}$ Determination of moments and second moment of areas as in first solution.		**1 mark** Stress ratio. **OR** **1 mark** Bending moment for extended arm. **1 mark** Ratio M/I for extended arm. **1 mark** Bending moment for retracted arm. **1 mark** Second moment of area for retracted arm. **1 mark** Ratio M/I for retracted arm. **1 mark** Stress ratio.

Question			Expected response	Max mark	Additional guidance
10.	(c)		$\sum M_{LHE} = 0$ $M_s - 320 \times 0.85 + 344 \times 1 = 0$ $M_S = -72$ kNm Splitting the beam at x=0.85 m and considering equilibrium of the right-hand end of the beam. $\sum M_{x=0.85} = 0$ $M_B + 344 \times 0.15 = 0$ $M_B = -51.6$ kNm **OR** Splitting the beam at x=0.85 m and considering equilibrium of the left-hand end of the beam. Establish F_s by considering equilibrium of entire beam. $\sum F_s = 0$ $F_s + 320 - 344 = 0$ $F_S = 24$kN Then: $\sum M_{x=0.85} = 0$ $M_s + F_s \times 0.85 - M_B = 0$ $M_B = -72 + 24 \times 0.85$ $M_B = -51.6$ kNm 	3	**1 mark** Calculate M_{S}. **1 mark** Calculate bending moment at 0.85m. **1 mark** 0<x<0.85 m BM varies linearly from -72 kNm to -51.6 kNm. 0.85<x<1.0 m BM varies linearly from -51.6 kNm to 0 kNm. If graph is a reflection on the distance axis, then award the third mark.

Question			Expected response	Max mark	Additional guidance
10.	(d)		 I_D = 850 μA (0.85 mA) (840μA-860μA) V_{GS} =3.95 V (3.93-3.97 V)	2	**1 mark** Plot Load line correctly for a determined value of I_D (1.94mA). **1 mark** State values for I_D and V_{GS}. **Note:** I_D and V_{GS} for the quiescent point can be found without the load line when V_{DS}=9 V is given: $I_D = \frac{16.0 - V_{out}}{8.25 \times 10^3}$ $I_D = \frac{16.0 - 9.0}{8.25 \times 10^3}$ $I_D = 85\ \mu A \quad (0.85\ mA)\ (2\ s.f.)$ Using $I_D = 0.85$ mA and V_{DS}=9 V on the graph allows the value of V_{GS} to be found since the characteristic curves are flat in the saturation region at V_{DS}=9 V.

Question			Expected response	Max mark	Additional guidance
10.	(e)		Kirchhoff's Current Law at Gate: $\frac{16-3.95}{R_1}-\frac{3.95-0}{R_2}=0$ $R_1=\frac{241}{79}\times R_2 \ldots\ldots(1)$ Design Rule: $\frac{R_1\times R_2}{R_1+R_2}=85.0\ldots\ldots(2)$ Sub eqn(1) in eqn(2): $\frac{\frac{241}{79}\times R_2\times R_2}{\frac{241}{79}\times R_2+R_2}=85\ldots\ldots(3)$ $\frac{241}{320}\times R_2=85$ $R_2=112.863\ldots$ $R_1=344.303\ldots$ $R_1=344\ \text{k}\Omega\ (3\ \text{s.f.})$ $R_2=113\ \text{k}\Omega\ (3\ \text{s.f.})$	**3**	**1 mark** Determine the ratio of the required resistor values. **1 mark** Substitute for one resistance in the equation for parallel resistance. **1 mark** Determine values for R_1 and R_2.
	(f)		Minimum value = 0 Maximum value = 2^{10}-1=1023	**1**	

Question			Expected response	Max mark	Additional guidance
10.	(g)		$pos = INT(\frac{1.225}{5.0} \times 1023)$ $pos = 250$ **ARDUINO** $pos = pos + 750$ $pos = 1000$ Time on, T_{on}, is (250+750) μs = 1ms Time off is (2000-1000) μs +18 ms Time off is 1+18=19 ms **PBASIC** $pos = pos + 750$ $pos = 1000$ Time on, T_{on}, is (250+750) μs = 1ms Time off is (2000-1000) μs +18 ms Time off is 1+18=19 ms Period, T = Time on +Time off Period, T = 1 ms + 19 ms = 20 ms $f = \frac{1}{T} = \frac{1}{20 \times 10^{-3}} = 50$ Hz Duty cycle $= \frac{T_{on}}{T} = \frac{1}{20} = 5\%$	**3**	**1 mark** Determine time on. (pos =250 **or** 251) **1 mark** Calculate frequency. (50 Hz for both 250 **and** 251) **1 mark** Calculate duty cycle. (5.005% for 251)

[END OF MARKING INSTRUCTIONS]