National
Qualifications
2016

Engineering Science

Advanced Higher

Finalised Marking Instructions

SQA
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General Marking Principles for Advanced Higher Engineering Science

This information is provided to help you understand the general principles you must apply when marking candidate responses to questions in this Paper. These principles must be read in conjunction with the detailed marking instructions, which identify the key features required in candidate responses.

(a) Marks for each candidate response must always be assigned in line with these General Marking Principles and the Detailed Marking Instructions for this assessment.

(b) Marking should always be positive. This means that, for each candidate response, marks are accumulated for the demonstration of relevant skills, knowledge and understanding: they are not deducted from a maximum on the basis of errors or omissions.

(c) If a specific 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.

(d) Where a candidate makes an error at an early stage in a multi-stage calculation, credit should normally be given for correct follow-on working in subsequent stages, unless the error significantly reduces the complexity of the remaining stages. The same principle should be applied in questions which require several stages of non-mathematical reasoning.

(e) All units of measurement will be presented in a consistent way, using negative indices where required (eg ms^{-1}). Candidates may respond using this format, or solidus format (m/s), or words (metres per second), or any combination of these (eg metres/second).

(f) Answers to numerical questions should normally be rounded to an appropriate number of significant figures. However, the mark can be awarded for answers which have up to two figures more or one figure less than the expected answer.

(g) Unless a numerical question specifically requires evidence of working to be shown, full marks should be awarded for a correct final answer (including unit) on its own.

(h) A mark can be awarded when a candidate writes down the relevant formula **and** substitutes correct values into the formula. No mark should be awarded for simply writing down a formula, without any values.

(i) Credit should be given where a labelled diagram or sketch conveys clearly and correctly the response required by the question.

(j) Marks should be awarded regardless of spelling as long as the meaning is unambiguous.

(k) Candidates may answer programming questions in any appropriate programming language. Marks should be awarded, regardless of minor syntax errors, as long as the intention of the coding is clear.

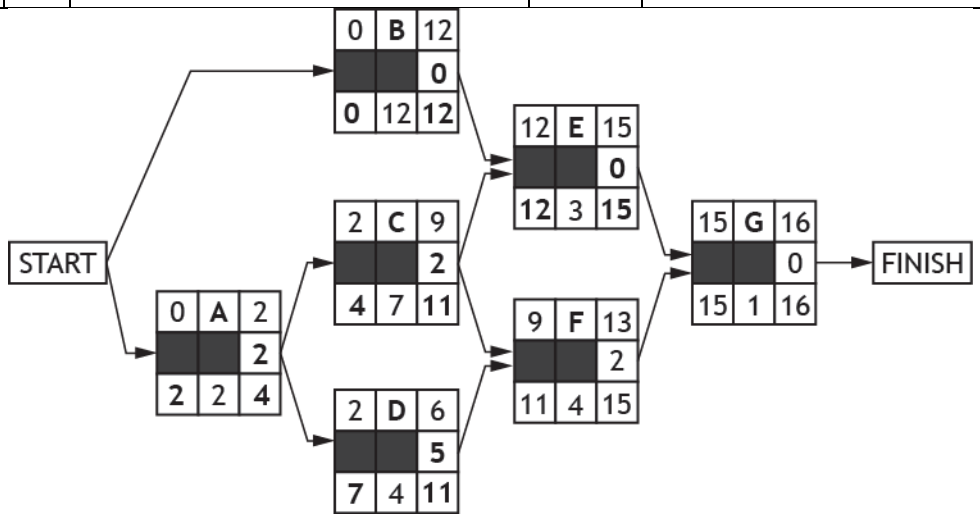
(l) Where a question asks the candidate to "explain", marks should only be awarded where the candidate goes beyond a description, for example by giving a reason, or relating cause to effect, or providing a relationship between two aspects.

(m) Where separate space is provided for rough working and a final answer, marks should normally only be awarded for the final answer, and all rough working ignored.

(n) The number of significant figures expressed in a final answer should be equivalent to the least significant data value given in the question. Answers that have two more or one less figure than this will be accepted.

Detailed Marking Instructions for each question

Section 1

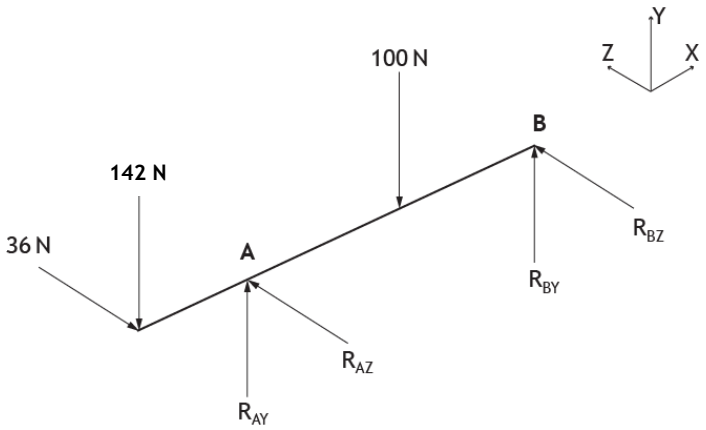
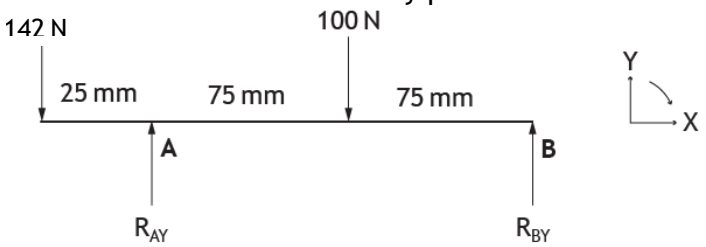
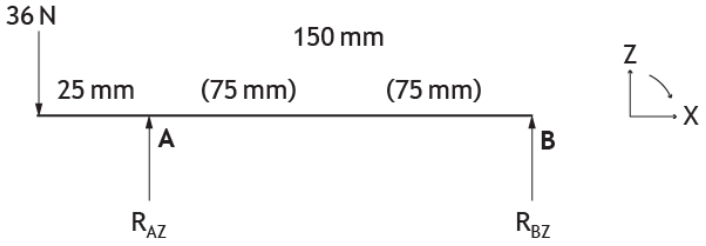
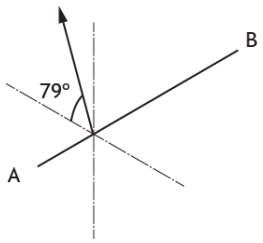
Question			Expected Answer(s)	Max Mark	Additional Guidance
1.	(a)		Critical path **BEG**	**3**	1 mark – latest start and finish times A–E 1 mark – floats A–E 1 mark – critical path
					
	(b)		• Transfer labour from any of A, C, D (or F) to ensure that B and E are not delayed. • Transfer resources from any of A, C, D (or F) to ensure that B and E are not delayed. • Hire/buy additional equipment to ensure that B and E are not delayed. • Authorise overtime necessary for staff working on B and E in advance. • Carefully monitor and manage stages B, E and G to ensure no delays. • Contract suppliers to incentivise prompt supply of resources for all stages but particularly B, E and G.	**2**	Any two relevant points

Question			Expected Answer(s)	Max Mark	Additional Guidance
2.	(a)		$I_{xx} = (I_{xx})_{square} - 2(I_{xx})_{hollow}$ $I_{xx} = \left(\frac{BD^3}{12}\right)_{square} - 2\left(\frac{bd^3}{12}\right)_{hollow}$ $I_{xx} = \left(\frac{50^4}{12}\right)_{square} - 2\left(\frac{10\times 30^3}{12}\right)_{hollow}$ $I_{xx} = 475833\cdot 3\text{mm}^4$ $I_{xx} = 476000\text{mm}^4$	**3**	1 mark for setting of equation 1 mark for getting internal dimensions 1 mark for solution including units If a candidate only works out I_{xx} for the outside dimensions, only 1 mark is available.
	(b)		$\partial = \frac{FL^3}{3EI}$ $\partial = \frac{75\times 500^3}{3\times 2\cdot 6\times 10^3 \times 475833\cdot 3}$ $= 2\cdot 53\text{mm}.(3s.f.)$	**2**	1 mark for selection correct equation and for substitution 1 mark solution including units Students to gain marks if correct approach using incorrect I value from part (a)

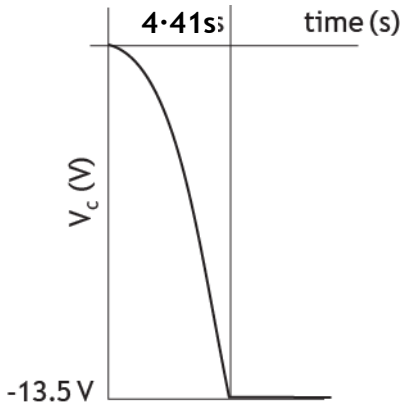
Question			Expected Answer(s)	Max Mark	Additional Guidance
3.	(a)		**A = Transformer:** Used to step-up transmission voltages to a suitable voltage. **B = Circuit Breaker:** A mechanical device for making or breaking a circuit and protecting transmission systems. They cut off current instantly in the event of a system failure due to lightning or other issues. **C: Bus Bar:** The bus bar is the component of the switchgear which is the connection point. The incoming and outgoing feeders originate and terminate on the bus bar.	**3**	1 mark – for correctly describing each part. Minimum requirements: **Transformer** – steps voltage up (correct relative to context) **Circuit Breaker** – device for cutting off current in a circuit. **Bus Bar** – a connection point for multiple lines.
	(b)		$I = 14000/230 = 60{\cdot}8$ A Power Loss = $I^2 R$ Power Loss = $60{\cdot}8^2 \times 0{\cdot}0727 = 269$ W Efficiency = P_{out}/P_{in} $= (14000)/ (14000 + 269)$ $= 98{\cdot}1\%$	**2**	1 mark – calculating power loss 1 mark – calculating the efficiency correctly Line efficiency = $\frac{\text{power for consumer}}{\text{power for consumer} + \text{line loss}}$

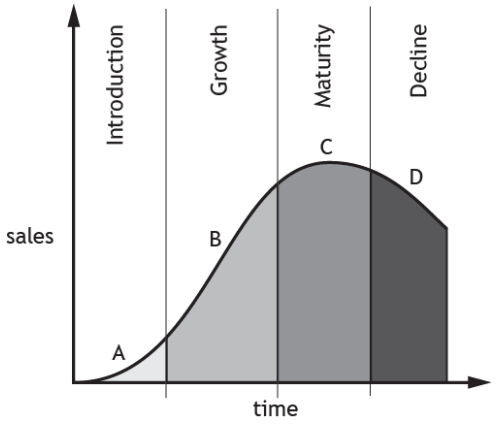
Question		Expected Answer(s)	Max Mark	Additional Guidance
4.		**KCL around node B** $I_{AB} = I_{BD} + I_{BC}$ $\frac{12 - V_B}{50} - \frac{V_B}{20} + \frac{V_B - V_D}{40}$ Multiply both sides by 200 $4(12 - V_B) = 10V_B + 5(V_B - V_D)$ $48 - 4V_B = 15V_B - 5V_D$ Rearrange to get $5V_D - 19V_B = -48$ eqn ❶ **KCL around node D** $I_{DC} = I_{AD} + I_{BD}$ $\frac{V_D}{100} - \frac{12 - V_D}{30} + \frac{V_B - V_D}{40}$ Multiply both side by 1200 $12V_D = 40(12 - V_D) + 30(V_B - V_D)$ $12V_D = 480 - 70V_D + 30V_B$ Rearrange to get $82V_D - 30V_B = 480$ eqn ❷ Use elimination method (or substitution method) to solve simultaneous equations. Multiply eqn ❶ by 82 $82(5V_D - 19V_B = -48)$ $410\ V_D - 1558V_B = -3936$ Multiply eqn ❷ by −5 $-5(82V_D - 30V_B = 480)$ $-410V_D + 150V_B = -2400$ Add together to eliminate V_D $-1408V_B = -6336$ **$V_B = 4{\cdot}5$ V** Substitute this value in eqn ❶ $5V_D - 19(4{\cdot}5) = -48$ **$V_D = 7{\cdot}5$ V**	**5**	**1 mark** – for KCL statements at nodes B & D $\frac{12 - V_B}{50} - \frac{V_B}{20} + \frac{V_B - V_D}{40}$ $\frac{V_D}{100} - \frac{12 - V_D}{30} + \frac{V_B - V_D}{40}$ **1 mark** – for eqn ❶ **1 mark** – for eqn ❷ **1 mark** – for correct use of elimination method or substitution method **1 mark** – for correct values of **V_B = 4·5v and V_D = 7·5 V**

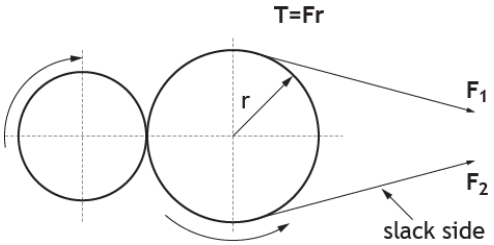
Question			Expected Answer(s)	Max Mark	Additional Guidance
5.	(a)		**D= 30/50 = 0·6** **From the graph I_B = 0·24 A, I_A 0·16 A** $I_{DS(on)} = 0 \cdot 6\sqrt{\frac{0 \cdot 24^2 + (0 \cdot 16 \times 0 \cdot 24) + 0 \cdot 16^2}{3}}$ $\boldsymbol{I_{DS(on)} = 0 \cdot 121A}$ $P_{conduction\,loss} = 0 \cdot 121^2 \times 0 \cdot 2 = 2 \cdot 92mW$	**3**	1 mark – calculating the duty from the graph 1 mark – calculating I_{DS} 1 mark – calculating the conduction power loss
	(b)		This would cause a momentary short circuit – a very low resistance (0·4 Ω) – between the supply lines. This can be avoided by building in a short delay between switching from one pair of MOSFETs to the other.	**2**	1 mark – description of the potential of a short circuit 1 mark – explanation of how to avoid it.

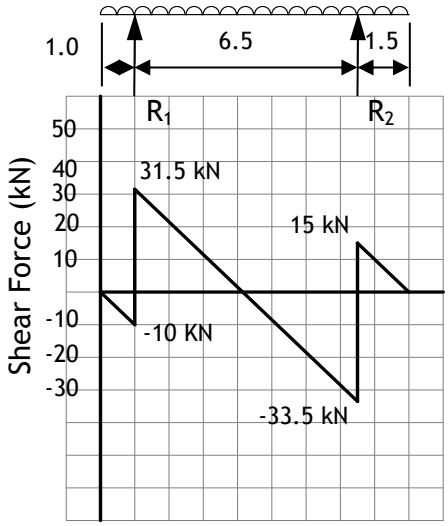
Question			Expected Answer(s)	Max Mark	Additional Guidance
6.			Calculate the forces acting on the pulley Horizontally $\Sigma F_x = 72\sin 30^o = 36$ N Vertically $\Sigma F_y = -80 + (-72\cos 30^o) = -142{\cdot}4$ N	**1**	
			FBD  		
			Consider the forces in the x – y plane  		
			$\Sigma M_B = 0$ $-(142{\cdot}4 \times 0{\cdot}175) + (R_{Ay} \times 0{\cdot}15) - (100 \times 0{\cdot}075) = 0$ $R_{Ay} = 216$ N	**1**	
			Consider the forces in the x – z plane  		
			$\Sigma M_B = 0$ $-(36 \times 0{\cdot}175) + (R_{Az} \times 0{\cdot}15) = 0$ $R_{Az} = 42$ N	**1**	
			$R_A = \sqrt{216^2 + 42^2} = 220N\,(3sf)$	**1**	
			 $\theta = \tan^{-1}\left(\frac{216}{42}\right)$ $= 79^\circ$	**1**	A clear sense of the orientation of the calculated angle required for this mark, not just its value.

Section 2

Question			Expected Answer(s)	Max Mark	Additional Guidance
7.	(a)	(i)	$V_B = 2t$	**1**	
		(ii)	$V_C = -\frac{1}{1\cdot 2\times 10^{6}\times 1\cdot 2\times 10^{-6}}\int 2t\ dt$ $V_C = -0\cdot 694\int 2t\ dt$ $V_C = -0\cdot 694t^{2}$	**2**	1 mark – substitution of V_B, resistor and capacitor values 1 mark – final simplified answer
		(iii)	Saturation occurs at −13·5 V Time at saturation, t = 4·41 s  	**3**	1 mark – axes labelled correctly and negative parabola 1 mark – −13·5 saturation voltage is shown by flat portion of graph 1 mark – 4·41 s time of saturation
		(iv)	$2t - \frac{1}{680\times 10^{3}\times 4\cdot 7\times 10^{-6}}\int V_A dt$ $\frac{d}{dt}(2t) = \frac{1}{680\times 10^{3}\times 4\cdot 7\times 10^{-6}}V_A$ $2 = -0\cdot 313V_A$ $V_A = -6\cdot 39V$	**2**	1 mark – equating the two 2t with the integral expression 1 mark – solving the equation for V_A

Question			Expected Answer(s)	Max Marks	Additional Guidance
	(b)		 Introduction – • Emphasis on product design and development. • Frequent design changes and production process changes Growth – • Minor product design changes will be made in response to feedback from customers/ retailers. • Long production runs mean that design will focus on improving the manufacturing process and cutting costs whilst improving quality/reliability. Maturity – • Additional design features will be added in an attempt to maintain sales and interest in this model of the drone. • Further design changes made to cut costs to help fund research and development of new products • The design of the next, new, drone will be underway with lessons learned from the sale/ development of the current model. Decline – • Design changes to the existing drone will stop • All resources will be targeted on design of the new drone for imminent introduction.	**3**	1 mark identifying an area correctly 2 marks for describing the design strategy for area identified **Examples of specific activity may be accepted as evidence of understanding if relevant to the selected stage.**

Question			Expected Answer(s)	Max Marks	Additional Guidance
	(c)		$P = \frac{2\pi NT}{60}$ $T = \frac{P}{\frac{2\pi N}{60}}$ $T_1 = \frac{P}{\frac{2\pi 1000}{60}} = 0.477\ Nm$ $T_2 = T_1 \times \frac{30}{24} = 0.477 \times \frac{30}{24}$ $T_2 = 0.597\ Nm$ $T_{pulley} = (F_1 - 0.2F_1) \times \frac{D}{2}$  $0.597 = 0.8F_1 \times 0.05$ $F_1 = 14.9\ N$ $F_2 = 0.2F_1 = 0.2 \times 14.9 = 3.00\ N$	**4**	1 mark – calculating the output torque T_2 1 mark – developing the formula for F_1 1 mark – calculating F_1 1 mark - calculating F_2

Question			Expected Answer(s)	Max Marks	Additional Guidance
8.	(a)		Effect of UDL = 90 kN UDL = 10kNm^{-1} Take moments about R_1 $R_2 \, x \, 6.5 \; = \; 90 \, x \, 3.5$ $R_2 \; = \; 48.5 \, kN \; (3sf)$ $R_1 \; = \; 90 - 48.5 \; = \; 41.5 \, kN \; (3sf)$ $\omega = 10 \; kNm^{-1}$  	**5**	1 mark – explicit/implicit recognition that the UDL is 10 kNm^{-1} 1 mark – calculating the reactions 1 mark –1 m, –10 kN and 31·5 kN 1 mark – 7·5 m, –33·5 kN and 15 kN 1 mark – vertical, horizontal and sloping lines identified as in diagram shown.
	(b)		$1 \leq x \leq 7.5$ $\frac{dM}{dx} = F_S = -10x + 41.5$ $For \; a \; maximum, \frac{dM}{dx} = 0$ $-10x + 41.5 = 0$ $x = 4.15m$ $BM = 41.5(x-1) - \frac{10x^2}{2}$ $If \; x \; = \; 4.15 \; m$ $BM = 41.5(4.15-1) - \frac{10 \times 4.15^2}{2}$ $BM = 44.6 \; kNm \; (3sf)$	**3**	1 mark - calculate position of maximum bending moment, 4·15 m from LHE 1 mark – develop expression for $BM = 41.5(x-1) - \frac{10x^2}{2}$ 1 mark - final value of BM = 44·6 kNm Graphical approach for first mark Position of maximum bending moment occurs when SF = 0. This occurs between SF=31·5 kN (1m from LHE) and SF = –33·5 kN (7·5 m from LHE) a 6·5 m distance, this is a gradient of -65/6·5 or –10 kN/m (the UDL). Therefore the SF is 0 kN at 31·5/10 = 3·15 m add this to 1 m position to get a position of 4·15m from LHE – the point of maximum bending moment.

Question			Expected Answer(s)	Max Marks	Additional Guidance
	(c)		$0 \leq x \leq 1$ $x = 0, BM = 0\ kNm$ $x = 1, BM = -5x^2 = -5\ kNm$ $1 \leq x \leq 7{\cdot}5$ $BM = 41.5(x-1) - \frac{10x^2}{2}$ $x = 7.5$ $BM = 41.5(7.5-1) - 5 \times 7.5^2$ $= -11.5\ kNm$ $x = 9, BM = 0\ kNm$	**2**	1 mark – BM = 0 kNm at x = 0 and x = 9 1 mark – BM at x = 1, −5 kNm & BM at x = 7·5, −11·5 kNm
	(d)		Both valves could be opened and the beam lifted without correction of the difference in position. The problem occurred if the position of cylinder A was lower than cylinder B. This caused the value of diff to be negative. The line *if pos_A>pos_B* establishes which cylinder is higher than the other and calculates the value of diff so that it is always positive (or zero)	**3**	1 mark – explaining that the beam would be lifted uneven, without correction 1 mark – explaining the problem of diff being negative 1 mark – explaining how the if condition ensures that diff is always positive in magnitude.
	(e)		Section B checks if cylinder A is higher than cylinder B and outwith the tolerance. If TRUE, valve A is closed, valve B is opened and the warning light comes on. Section C – the lines following the else command will be carried out if cylinder B is higher than cylinder A. and outwith the tolerance. If TRUE Valve A is opened, valve B is closed and the warning light comes on.	**2**	1 mark – explaining what the if condition checks **and** what the outcome is if true, ie cylinder B side is raised up to level the beam. 1 mark – explaining the condition for the program entering the else condition **and** the outcome of this, ie cylinder A side is raised up to level the beam.

[END OF MARKING INSTRUCTIONS]