National
Qualifications
2017

2017 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

<table>
<tr><th colspan="3">Question</th><th>Expected answer(s)</th><th>Max mark</th><th>Additional guidance</th></tr>
<tr><td>1.</td><td>(a)</td><td></td><td>On-costs
• Employer National Insurance Contributions
• Employer pension contributions
• Preliminary site work (to ensure compliance with Health & Safety legislation)

These are costs which the company has to pay and has no control over. They are usually controlled by government legislation, eg the government will set the percentage rate that employers have to pay towards an employee's pension or NI

Indirect Costs
• Rent and rates for administration office
• Office supplies
• Public liability insurance

These are costs which cannot be directly attributable to a specific part or project but are necessary for the organisation to operate. For example the office will need supplies of stationery which may be used in the administration of multiple projects and other unrelated activities.</td><td>3</td><td>1 mark: correct identification of each cost

1 mark: for definition of each cost

1 mark: for use of examples to back up the definition

OR

1 mark: Accurate definition and exemplification of one type of cost, but not the other, 1 mark total</td></tr>
<tr><td></td><td>(b)</td><td></td><td>
<table>
<tr><td>Activity</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td></tr>
<tr><td>A</td><td>A</td><td>A</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>G</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>G</td><td>G</td><td>G</td><td>G</td><td>g</td><td>g</td></tr>
<tr><td>H</td><td></td><td></td><td>H</td><td>h</td><td>h</td><td>h</td><td>h</td><td>h</td><td>h</td><td>h</td><td>h</td><td>h</td><td>h</td><td>h</td><td></td><td></td></tr>
<tr><td>I</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>I</td><td>I</td><td>i</td><td>i</td><td>i</td><td>i</td></tr>
</table>
</td><td>2</td><td>1 mark: tasks F, G, H and I without float added correctly

1 mark: floats added correctly</td></tr>
</table>

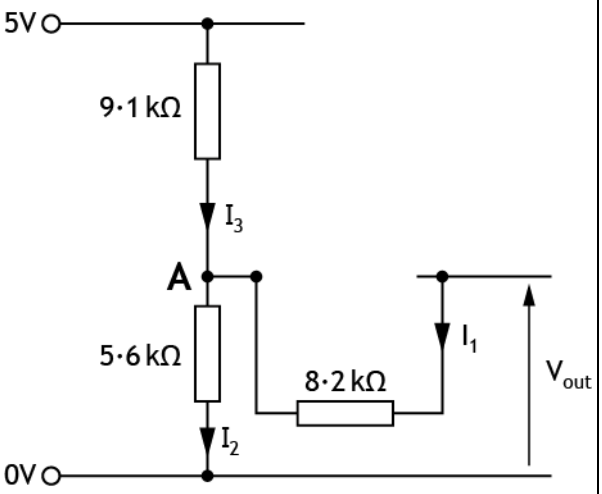
Question			Expected answer(s)	Max mark	Additional guidance
2.	(a)		Environmental Impact Advantages: • In the long run, if no more fossil fuels are used to generate electricity and crucially in transport, there will potentially be large reductions in air pollution which may benefit wildlife and may have health benefits for Denmark's citizens. Disadvantages: • Large number of on-shore and/or off-shore wind turbines, solar power farms and hydro schemes will need to be built which will affect the land and sea environment and may have an impact on wildlife and human lives during the building and on-going running of schemes. • People living near such schemes may have their views spoilt and animal habitats at best will be disturbed and at worst destroyed. Social Impact Advantages: • Many jobs in the renewable sector will be secured and new jobs will be created whilst new schemes are being built. Disadvantages: • This may or may not offset job losses in industries producing/handling/using fossil fuels, eg people employed in traditional fossil fuelled power stations, refining oil into fuel for transport may lose their jobs.	**3**	1 mark: a clear discussion of the potential environmental advantages and disadvantages to the Danish environment if the government meet their goal 1 mark: a clear discussion of the potential social advantages and disadvantages to Danish society if the government meet their goal

Question			Expected answer(s)	Max mark	Additional guidance
2.	(a)		**(continued)** Economic Impact Advantages: • Denmark may become practically immune from fluctuating oil prices and this may give their economy some security. Electricity will be able to be exported through country-country interconnections, especially when demand is low in Denmark or production is higher compared to demand. Disadvantages: • The cost of power may be permanently increased as the government and producers try to recoup the high cost of the investment they have made in renewable energy.		1 mark: a clear discussion of the potential economic advantages and disadvantages to the Danish economy if the government meet their goal Answers must demonstrate insight and knowledge at AH level. Answers must provide a balance of statements in each area to gain each mark – cannot be all positive or all negative.

Question			Expected answer(s)	Max mark	Additional guidance
2.	(b)		Challenges: • Keeping the base load serviced is a huge challenge for renewables because of the intermittent/ weather dependent nature of electricity generation – especially with wind. • Renewable schemes like wind and solar & tidal, do not produce energy on demand and especially in the case of wind, are intermittent in the level of energy produced hour to hour, day to day. • Meeting peak demand requires schemes which can be switched into the grid at very short notice. With renewables, this can only really be done by either storing energy or by running at high over capacity. Solutions: • Over capacity is one option where the company builds many more schemes than is necessary to meet base demand by placing them in different locations around the country and at sea where there is a higher chance of generation meeting base demand and varying weather/wind patterns. • Hydro schemes offer the possibility of storing energy using pump storage where excess energy from wind/solar can be used to pump water to the top reservoir ready to be released at a moment's notice to meet peak demand. • Sharing generation with other countries and building the infrastructure necessary with interconnectors across countries provides greater energy security as this widens the capture area for wind & solar energy in particular. • Excess wind energy can be used to generate hydrogen by electrolysis which allows the hydrogen gas to be stored and burned in gas power stations – this can be used to meet peak and base load demand.	**2**	1 mark: discussion of a challenge faced by Energinet.dk in meeting base and peak demand 1 mark: discussion of a sensible solution to that challenge to meet both base and peak demand Response must be specific to engineering challenges/ solutions.

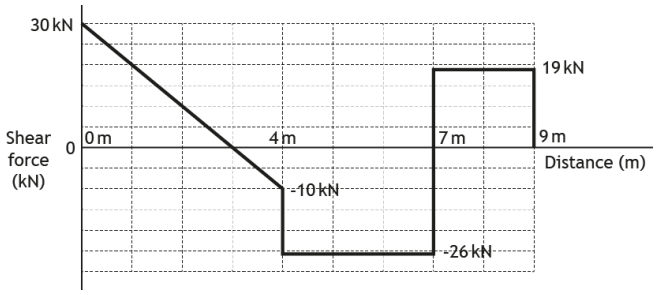
Question			Expected answer(s)	Max mark	Additional guidance
3.			$\frac{\sigma}{y} = \frac{E}{R}$ $E = 196 \times 10^3\ Nmm^{-2}$ $y = \frac{0 \cdot 794}{2} = 0 \cdot 397\, mm$ $R = \frac{500}{2} + \frac{0 \cdot 794}{2} = 250 \cdot 397\ mm$ $\sigma = \frac{Ey}{R} = \frac{196 \times 10^3 \times 0 \cdot 397}{250 \cdot 397} = 310 \cdot 755$ σ = 311 Nmm^{-2} (3 *s.f.*)	**3**	1 mark: Equation rearranged for stress and *E* value from data tables 1 mark: *y* and *R* value based on diameter of drum and radius of wire (For this mark, there must be evidence that the radius of the wire has been considered. This may be by stating that the radius of the wire is so small that its omission will not affect the final answer.) 1 mark: correct answer and units

Question			Expected answer(s)	Max mark	Additional guidance
4.			$\frac{1}{2} I_{xx\text{circle}} = \frac{1}{2} \times \frac{\pi D^4}{64} = \frac{1}{2} \times \frac{\pi \times 60^4}{64} = 318086 \cdot 25\text{mm}^4$ $I_{xxrectangle} = \frac{BD^3}{12} = \frac{100 \times 60^3}{12} = 1800000\text{mm}^4$ $2I_{triangle} = 2 \times \frac{bh^3}{12} = 2 \times \frac{100 \times 30^3}{12} = 450000\text{mm}^4$ $I_{xx} = \frac{1}{2} I_{xxcircle} + 1_{xxrectangle} + 2I_{triangle}$ $1_{xx} = 318086 \cdot 25... + 1800000 + 450000$ $\text{I}_{xx} = 2 \cdot 57 \times 10^6 \text{mm}^4 \left(3s.f.\right)$	**4**	1 mark: correct calculation for semicircle 1 mark: correct calculation for rectangle 1 mark: correct calculation for triangle 1 mark: correct calculation and units

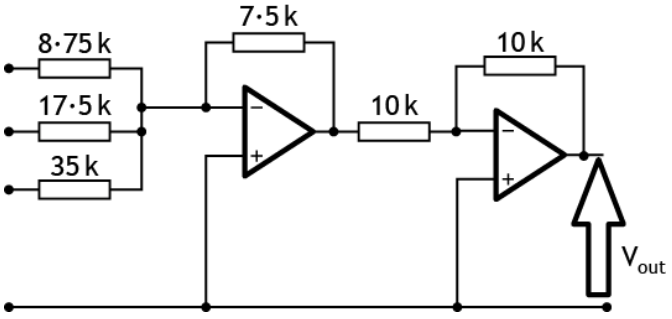
Question			Expected answer(s)	Max mark	Additional guidance
5.			 **V_{out} = 3·5V** $I_2 = I_1 + I_3$ $\frac{V_A}{5\cdot6\text{k}} = \frac{3\cdot5 - V_A}{8\cdot2\text{k}} + \frac{5 - V_A}{9\cdot1\text{k}}$ Multiply through by (5·6k × 8·2k × 9·1k) to eliminate fractions $(8\cdot2\text{k}\times9\cdot1\text{k})V_A = (5\cdot6\text{k}\times9\cdot1\text{k})(3\cdot5 - V_A) + (5\cdot6\text{k}\times8\cdot2\text{k})(5 - V_A)$ $74\cdot62V_A = 178\cdot36 - 50\cdot96V_A + 229\cdot6 - 45\cdot92V_A$ $171\cdot5V_A = 407\cdot96$ V_A = 2·38V – upper cut-off **V_{out} = 0.2V** $74\cdot62V_A = 50\cdot96(0\cdot2 - V_A) + 229\cdot6 - 45\cdot92V_A$ $74\cdot62V_A = 10\cdot192 - 50\cdot96V_A + 229\cdot6 - 45\cdot92V_A$ $171\cdot5V_A = 239\cdot792$ V_A = 1·40V– lower cut-off	**5**	1 mark: Kirchhoff's current law applied on the basis of a diagram 1 mark: Ohm's law used for unknown currents 1 mark: removing the fractional parts and simplifying the expression 1 mark: correct substitution of two distinct output voltage values 1 mark: correct answer for upper and lower value of V_A Third mark does not depend on approach to simplification; the expected answer given is an example.

Question			Expected answer(s)	Max mark	Additional guidance
6.			$F = \frac{mg}{5} = \frac{120 \times 9 \cdot 8}{5} = 235 \cdot 2N,$ $L = 300 - 25 = 275\text{mm}$ From data booklet $E = 0 \cdot 9 \times 10^3 Nmm^{-2},$ $I = 14 \cdot 5 \times 10^4 = 145 \times 10^3 \text{mm}^4$ Or, if I is calculated for given cross-section $E = 0 \cdot 9 \times 10^3 Nmm^{-2},$ $I = 14 \cdot 95 \times 10^4 = 149.5 \times 10^3 \text{mm}^4$ $\delta = \frac{FL^3}{3EI} = \frac{235 \cdot 2 \times 275^3}{3 \times 0 \cdot 9 \times 10^3 \times 145 \times 10^3}$ $= 12 \cdot 5\text{mm (3sf)}$ $(12.1\text{mm for calculated I})$	**3**	1 mark: load and length values for one leg 1 mark: E and I values from data booklet 1 mark: correct deflection formula, substitutions and answer with unit

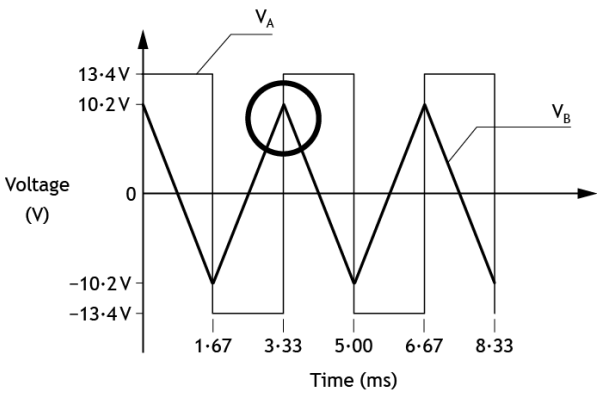
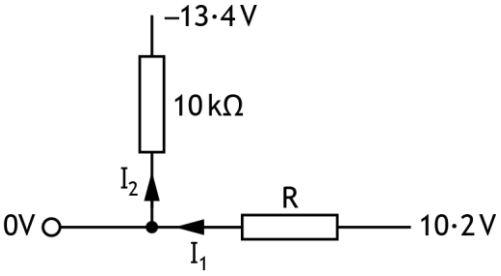
Question			Expected answer(s)	Max mark	Additional guidance
7.	(a)		$F_2 = F_1 \div e^{\mu\theta} = 1000 \div e^{0{\cdot}3\times\pi} = 389{\cdot}6....\text{N}$ speed = 955 ÷ 60 = 15·91$\dot{6}$ *revs* s^{-1} $T\left(Torque\right) = \left(1000 - 389{\cdot}6..\right) \times \frac{0{\cdot}15}{2}$ $P = 2\pi n\left(F_1 - F_2\right) \times r$ $= 2\pi \times 15{\cdot}91\dot{6} \times \left(1000 - 389{\cdot}6..\right) \times \frac{0{\cdot}15}{2}$ $= 4578{\cdot}8...W$ *P* = 4·58 *kW* (3 *s.f.*)	**3**	1 mark: lower value of tension 1 mark: torque calculation correct 1 mark: correct answer with unit
	(b)		An increase in either the coefficient of friction or the contact angle increases the value of $e^{\mu\theta}$ and so increases the ratio of the cable tensions. If the higher tension remains fixed, then this reduces the lower tension. The difference in tensions therefore increases and so the torque and, consequently, the transmitted power increases.	**2**	1 mark: correct reference to the equation representing the ratio of cable tensions 1 mark: correct consequence of either increase argued from the perspective of effect on torque and power

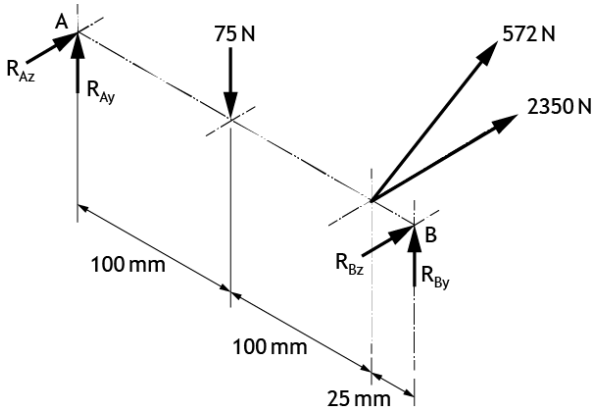
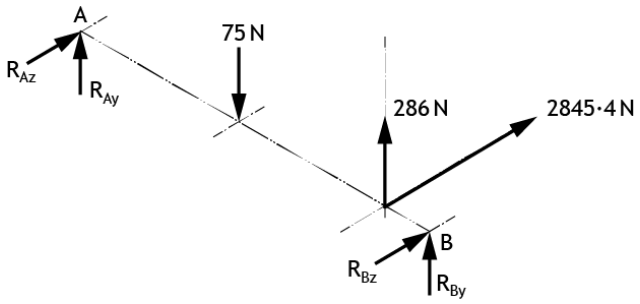
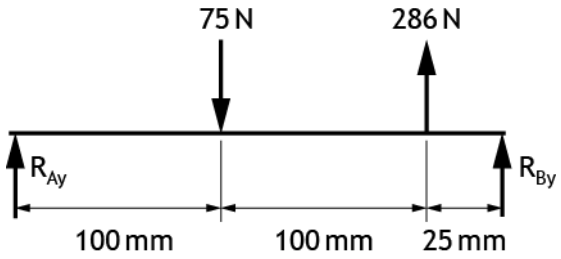
Question			Expected answer(s)	Max mark	Additional guidance
8.	(a)		$\sum M_A = 0$ $(10\times 4)\times 2 + 16\times 4 - R_B \times 7 + 19\times 9 = 0$ $R_B = 45kN$ $\sum F_y = 0$ $R_A - (10\times 4) - 16 + R_B - 19 = 0$ $R_A = 30kN$  	**4**	1 mark: calculation of unknown reactions 1 mark: representation of UDL from 30 kN to (-10) kN 1 mark: representation of point loads 1 mark: representation of reaction at B
	(b)	(i)	For $0 \le x < 4$ $M_B = 30x - 10x\left(\frac{x}{2}\right)$ $M_B = 30x - 5x^2$	**1**	$M_B = -30x + 5x^2$ accepted
		(ii)	For $4 \le x < 7$ $M_B = 30x - 10 \times 4 \times (x - 2) - 16 \times (x - 4)$ $M_B = -26x + 144$	**1**	

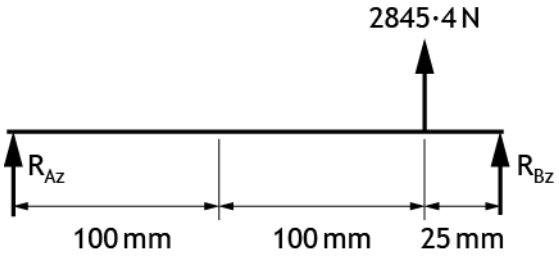
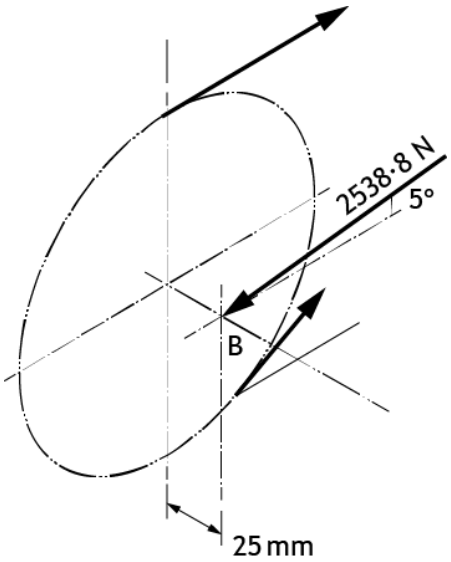
Question			Expected answer(s)	Max mark	Additional guidance
8	(c)		For $0 \le x < 4$ $F_s = 30 - 10x$ When $F_s = \left(\frac{dM}{dx}\right) = 0$, $30 - 10x = 0$ $x = 3m$ When $x = 3m$ $M_B = 30 \times 3 - 10 \times 3 \times \left(\frac{3}{2}\right)$ $M_B = 45kNm$ When $F_S = 0, x = 7\text{m}$ When $x = 7\,m$ $M_B = 30 \times 7 - 10 \times 4 \times (7-2) - 16 \times (7-4)$ $M_B = -38kNm$ Bending Moment with highest magnitude $M_B = 45kNm$, $x = 3\,m$	**3**	1 mark: locations for $F_S = 0$ 1 mark: magnitude of bending moments at $x = 3\,m$ and $x = 7\,m$ 1 mark: selection of bending moment with greatest magnitude If only one of the bending moments is calculated, then only one mark is available.
	(d)		The power inverter converts the DC signal from the DAC into an AC signal which is required by the SPD film to operate	**2**	1 mark: noting that the microcontroller/DAC is a DC system and that the SPD smart glass requires an AC signal 1 mark: stating that the inverter converts a DC signal into and AC signal

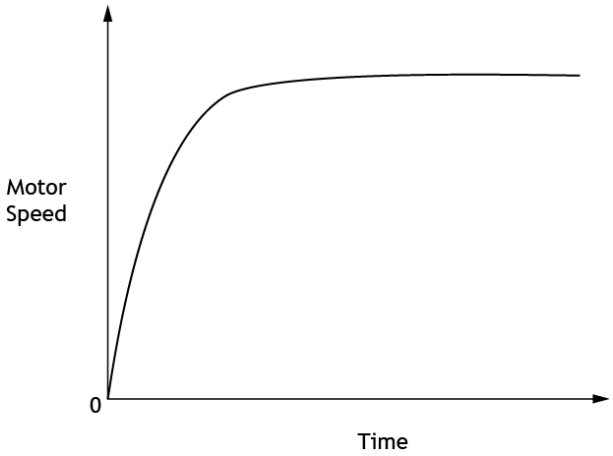
Question			Expected answer(s)	Max mark	Additional guidance
8.	(e)		$V_0 = -R_f\left(\frac{V_0}{R_0}+\frac{V_1}{R_1}+\frac{V_2}{R_2}\right)$ $7.5 = -R_f\left(\frac{5}{R_0}+\frac{5}{R_1}+\frac{5}{R_2}\right)$ $R_1 = \frac{R_0}{2}, R_2 = \frac{R_0}{4}$ - substitute in for R_1 and R_2 $7.5 = -5R_f\left(\frac{1}{R_0}+\frac{2}{R_0}+\frac{4}{R_0}\right)$ $\frac{7.5}{5} = -\frac{7R_f}{R_0}$ $\frac{7.5}{35} = -\frac{R_f}{R_0}$ Choose 7.5kΩ for R_f and 35kΩ for R_0 to satisfy the ratio above. R_1 = 35kΩ ÷ 2 = 17.5kΩ R_2 = 35kΩ ÷ 4 = 8.75kΩ Final circuit diagram (including -1 gain second inverting op-amp using 10k resistors) lsb=35k  	**4**	1 mark: circuit diagram: 3-input summing amplifier 1 mark: inverting amplifier gain is either unity, or is correct for first-stage gain 1 mark: calculations correct for summing amplifier feedback and input resistors 1 mark: input resistor ratios on first stage correct for lsb to msb and in kΩ range

Question			Expected Answer(s)	Max Mark	Additional Guidance
9.	(a)		$A_v = 1 + \frac{R_2}{R_1}$ Set gain to 3, by choosing R_1 = 10kΩ and R_2=20kΩ $f = \frac{1}{2\pi RC}$ $RC = \frac{1}{2\pi f} = \frac{1}{2\pi \times 50} = 3.183 \times 10^{-3}$ Rearrange and substitute R = 10kΩ $C = \frac{1}{2\pi \times 50 \times 10{,}000}$ ***C* = 318 *nF*** (other viable answer eg $C = 470\ nF, R = 6.8\ k\Omega$)	**3**	1 mark: choose values of R_1 and R_2 to give the ratio 1:2 and so a gain of 3. Resistor values in the kΩ range 1 mark: substitute for frequency to find the relationship between R & C values 1 mark: select a value of resistor R and calculate C correctly, or vice versa. Include units with answer Any other viable answer should be accepted eg $C = 470\ nF, R = 6.8\ k\Omega$
	(b)		$\Delta V_\circ = -\frac{1}{10 \times 10^3 C} \int_0^{\frac{T}{2}} 13 \cdot 4 dt$ $(-10 \cdot 2) - 10 \cdot 2 = -\frac{1}{10 \times 10^3 C} \int_0^{1 \cdot 67 \times 10^{-3}} 13 \cdot 4 dt$ $-20 \cdot 4 = -\frac{1}{10 \times 10^3 C} \left[13 \cdot 4t\right]_0^{1 \cdot 67 \times 10^{-3}}$ $-20 \cdot 4 = -\frac{13 \cdot 4 \times 1 \cdot 67 \times 10^{-3}}{10 \times 10^3 C}$ *C* = 110*nF* (3 *s.f.*)	**3**	1 mark: identify the change in voltage over the first half-cycle, the duration of the half-cycle and the value of input voltage that is being integrated 1 mark: calculating C

Question			Expected answer(s)	Max mark	Additional guidance
9.	(b)		**(continued)**  Take V_A at the instant it changes from -13·4 V to +13·4V. V_A = -13·4 V V_B = 10·2 V  At the instant of change, V_+ = 0 V At the node between resistors, $\sum I = 0$ $I_1 = I_2$ $\frac{10 \cdot 2 - 0}{R} = \frac{0 - (-13 \cdot 4)}{10k}$ $R = \frac{10k \times 10 \cdot 2}{13 \cdot 4}$ R = 7·61kΩ		1 mark - correct use of Kirchhoff's Law at node between the two resistors

Question			Expected answer(s)	Max mark	Additional guidance
9.	(c)		Resolve belt tensions into component forces $F_z = 572\cos30^\circ + 2350 = 2845{\cdot}36\ldots\ N$ $F_y = 572\sin30^\circ = 286\ N$   x – y plane  $\sum M_A = 0$ $75 \times 100 - 286 \times 200 - R_{By} \times 225 = 0$ $R_{By} = -220{\cdot}\dot{8}\ N$	**5**	1 mark: resolve belt tensions into components 1 mark: calculate component of bearing reaction in x-y plane 1 mark: calculate component of bearing reaction in x-z plane 1 mark: calculate magnitude of bearing reaction 1 mark: calculate angle of bearing reaction in relation to an identified datum

Question			Expected answer(s)	Max mark	Additional guidance
9.	(c)		**(continued)** x – z plane  $\sum M_A = 0$ $-2845{\cdot}4 \times 200 - R_{Bz} \times 225 = 0$ $R_{BZ} = 2529{\cdot}24 N$ Magnitude of resultant in Bearing B. $R_B = \sqrt{(-220{\cdot}8)^2 + (-2529{\cdot}24)^2}$ $R_B = 2{\cdot}54$ k*N (3 s.f.)* Acting at an angle of $\tan^{-1}\left(\frac{220{\cdot}8}{2529{\cdot}24}\right) = 4{\cdot}99° (3s.f.)$  		

Question			Expected answer(s)	Max mark	Additional guidance
9.	(d)	(i)		**2**	1 mark: for logarithmic rise 1 mark: for rise to a continuous value
		(ii)	As the speed increases and actual speed gets closer to target speed, the error will reduce. Since duty is proportional to the error, the wheelchair will never reach the target speed if the duty drops too low to continue accelerating the chair. The speed is being controlled, not the position, so there is always a need for a duty signal to drive the motor in this proportionally controlled system, hence the steady state error.	**2**	1 mark: explaining the link between the duty and the error 1 mark: explaining that the stead-state error is necessary to produce a duty signal and maintain the speed

[END OF MARKING INSTRUCTIONS]