Commentary on candidate evidence

The candidate evidence has achieved the following marks for each question of this question papers.

Candidate 1

Question 1

The candidate was awarded **3 marks** because the second moment of area of a triangle is calculated correctly about its base for the first mark, the correct strategy is used to determine the second moment of area of the cross-section for the second mark, and the correct numerical value and units are given for the third mark.

Question 2 (a)

The candidate was awarded **1 mark** because there is an outline of how pumped storage operates for the second mark but no clear statement of it being used to meet sudden increases in demand or to back up intermittent energy supplies when their output drops.

Question 2 (b)

The candidate was awarded **2 marks** because the 3% mechanical loss, both when raising and lowering, is accounted for correctly for the first mark and the final answer is correct for the second mark.

Question 3 (a)

The candidate was awarded **2 marks** because capital cost is not defined as invested money that must be financed for the second mark. However, there are sensible examples of what money would be spent on for the first mark and reasons given for the reduction in capital costs for the third mark.

Question 3 (b)

The candidate was awarded **2 marks** because the time intervals for stages G and H and the float for stage G are all indicated appropriately for the first mark. The critical path is identified correctly for the second mark.

Question 3 (c)

The candidate was awarded **2 marks** because a technique is related to activities on the critical path for the first mark. The means of applying the technique is then given for the second mark.

Question 4 (a)

The candidate was awarded **1 mark** because the maximum drain current is calculated, and the load line drawn on the worksheet correctly for the first mark.

There is no indication of finding the operating (quiescent) point for the second mark. The selected value for V_{GS} is not correct for the third mark.

Question 4 (b)

The candidate was awarded **1 mark** because, having taken the value of V_{GS} as 5 V, the correct ratio of resistor values for R_1 and R_2 is stated in equation 1 for the first mark. There is a mathematical error in the two lines below equation 2 which results in incorrect values for the two resistors, so the second mark is not awarded.

Question 5

The candidate was awarded **4 marks** because the correct data values are extracted and then substituted correctly to determine the switching energy for the first mark. The period of a fixed number of switching events (in 5 ms, on+off 12 times) is interpreted correctly from the pulse-width modulation (PWM) signal for the second mark. The switching frequency is calculated correctly for the third mark. The candidate's solution lacks some clarity, but it does include a necessary division by two of the count of 12 used in the previous solution step and it produces the correct frequency for the final step of the solution. The power dissipation during switching is calculated correctly and a unit applied correctly for the fourth mark.

Question 6 (a)

The candidate was awarded **2 marks** because a correct expression is found for C for the first mark and C is calculated correctly for the second mark.

Question 6 (b)

The candidate was awarded **0 marks** because the increase in capacitance is noted correctly but the effect on the saturation time that this has is not correct.

Question 6 (c)

The candidate was awarded **2 marks** because the original value of 20 µF for the capacitance is substituted to determine V_2, rather than the updated value of 33 µF, so the first mark is not awarded. The value of V_2 is substituted in a correct expression for V_{out} for the second mark and the final expression is correct for the substituted value of V_2 for the third mark.

Question 7 (a)

The candidate was awarded **0 marks** because Young's modulus is found correctly and the mass is halved, but it is not multiplied by g to produce the weight that P represents, so the first mark is not awarded. The substitutions of lengths are not correct, so the second mark is not awarded. The candidate has attempted to convert metres to millimetres but has divided by 1000 instead of multiplying by 1000. The final answer is correct numerically for the values substituted but m is not the correct unit of measure for the substitutions made, so the third mark is not awarded.

Question 7 (b)

The candidate was awarded **1 mark** because the bending moment is calculated correctly allowing for the follow through error for the value for P determined in part (a). However, this value would have to be expressed in Nmm to determine the stress. It is not, so the second mark is not awarded.

Question 7 (c)

The candidate was awarded **1 mark** because there is a direct comparison with the lowest value of ultimate tensile stress (UTS) and a correct determination of safety based on the incorrectly calculated value of stress from part (b).

Question 8 (a)

The candidate was awarded **0 marks** because both the sub-systems have been misidentified, so the subsequent functional descriptions do not match the functional requirements of the system at points A and B.

Question 8 (b)

The candidate was awarded **3 marks** because there is a correct expression of the relationship between input power, output power and the three identified sources of power loss for the first mark. Values are substituted correctly to generate the correct quadratic equation for the unknown secondary winding current for the second mark. The value calculated for the secondary winding current from the quadratic equation is not quite correct, so the third mark is not awarded. However, based on follow-through error for the secondary winding current value, the power dissipated in the secondary winding is then calculated correctly for the fourth mark.

Question 8 (c)

The candidate was awarded **0 marks** because the duty value (read from the table) at any point affects the voltage level at the output pin, not the amount of time for which the voltage level appears at the output pin. The ‘delay’ command within the loop controls how long each voltage level plays out for, and this controls the period of the waveform produced at the output pin.

Question 8 (d)

The candidate was awarded **0 marks** because the selection between the two options is not correct, and the explanation does not then follow.

Question 8 (e)

The candidate was awarded **2 marks** because the torque on the motor gear is calculated for the first mark. The tangential force acting on the motor gear is calculated for the second mark. The total force acting on the gear is not calculated, so the third mark is not awarded. There is a diagram indicating the line of action, but the force is not shown to be acting in the correct direction, so the fourth mark is not awarded.

Question 8 (f)

The candidate was awarded **5 marks** because the components of the gear force are indicated correctly in relation to the other forces acting on the axle for the first mark. There is a correct moment equilibrium equation for each of the two orthogonal planes for the second and third marks. The magnitude of the bearing force is calculated correctly from its components for the fourth mark. The line of action of the bearing force is clearly indicated on a diagram for the fifth mark.

Question 9 (a)

The candidate was awarded **4 marks** because the reactions are calculated correctly for the first mark. The values at all key points on the shear force diagram are also noted in the candidate's working for the question. On the shear force diagram, the reactions are positioned correctly for the second mark. The effects of the point loads are indicated correctly for the third mark. The piecewise-continuous constant slope of the graph arising from the uniformly distributed load has the correct gradient for the fourth mark.

Question 9 (b) (i)

The candidate was awarded **3 marks** because all three terms for the bending moment appear correctly in the first line of the candidate's solution. The terms have been simplified correctly, but this step is not necessary to gain full marks.

Question 9 (b) (ii)

The candidate was awarded **2 marks** because the expression for the bending moment has been differentiated correctly with respect to displacement, x, for the first mark. The value of the derivative is set to zero correctly and the answer is correct for the second mark.

Question 9 (c)

The candidate was awarded **5 marks** because Kirchhoff's current law (KCL) and Ohm's law are applied correctly for both output states for the first two marks. The solution approach for the simultaneous equations is correct for the third mark. R_1 and R_2 are then calculated correctly for the fourth and fifth marks.

Question 9 (d)

The candidate was awarded **2 marks** because 10% is the correct numerical answer and the need to show working is not stipulated in the question. Point (f) in the general marking principles has been applied by the marker.

Question 9 (e)

The candidate did not attempt this question.

Candidate 2

Question 1

The candidate was awarded **1 mark** because the second moment of area of a triangle is calculated correctly about its base for the first mark. However, the strategy for calculating the second moment of area of the cross-section is not correct. The triangles are added, so the axis used to calculate the second moment of area for the first mark does not lie on the central axis of the cross-section, but 10mm from it. The four squares that are added have central axes that lie 15mm from the central axis of the cross-section. The parallel-axis theorem would have to be applied to both for the summative approach to produce the correct value for their second moment of area about the central axis of the cross-section. Therefore, the second and third marks are not available.

Question 2 (a)

The candidate was awarded **2 marks** because there is an outline of how pumped storage operates for the second mark and a clear statement of it being used to meet sudden increases in demand for the first mark.

Question 2 (b)

The candidate was awarded **2 marks** because the 3% mechanical loss, both when raising and lowering, is accounted for correctly for the first mark and the final answer is correct for the second mark.

Question 3 (a)

The candidate was awarded **3 marks** because capital cost is defined as invested money that must be financed for the second mark. There are sensible examples of what money would be spent on for the first mark and reasons given for the reduction in capital costs for the third mark.

Question 3 (b)

The candidate was awarded **2 marks** because the time intervals for stages G and H and the float for stage G are all indicated appropriately for the first mark. Week 13 is not clear, but the hatching is only that of the first attempt - the overwritten vertical hatching appearing in other boxes is not apparent in this box - and the F appears to lie on top of it. The critical path is identified correctly for the second mark.

Question 3 (c)

The candidate was awarded **2 marks** because a technique is related to activities on the critical path for the first mark. The means of applying the technique is then given for the second mark.

Question 4 (a)

The candidate was awarded **1 mark** because the maximum drain current is calculated, and the load line drawn on the worksheet correctly for the first mark. There is no indication of finding the operating (quiescent) point for the second mark. The selected value for V_{GS} is not correct for the third mark.

Question 4 (b)

The candidate was awarded **2 marks** because, having taken the value of V_{GS} as 3 V, the correct ratio of resistor values for R_1 and R_2 is stated for the first mark. The subsequent working leads to correct values of each resistance to produce a V_{GS} of 3 V for the second mark.

Question 5

The candidate was awarded **4 marks** because the correct data values are extracted and substituted correctly to determine the switching energy for the first mark. The period of a fixed number of switching events (in 10 ms, n=12) is interpreted correctly from the pulse-width-modulation (PWM) signal for the second mark. The switching frequency is calculated correctly for the third mark. The power dissipation during switching is calculated correctly and a unit applied correctly for the fourth mark.

Question 6 (a)

The candidate was awarded **2 marks** because a correct expression is found for C for the first mark and C is calculated correctly for the second mark. The answer is given to 3 significant figures rather than 2 but is within the acceptable range (stipulated on the front of the question paper).

Question 6 (b)

The candidate was awarded **0 marks** because changing the capacitance affects the time that the integrator takes to saturate if all other components and voltage values remain the same.

Question 6 (c)

The candidate was awarded **2 marks** because the correct expression for V_2 is found for the first mark. The value of V_2 is substituted in a correct expression for V_{out} for the second mark. The final expression is incorrect for the substituted value of V_2, so the third mark is not awarded.

Question 7 (a)

The candidate was awarded **3 marks** because Young’s modulus is found correctly, the mass is halved, and it is multiplied by g to produce the weight that P represents for the first mark. The substitutions of lengths are correct for the second mark. The final answer is correct for the third mark.

Question 7(b)

The candidate was awarded **2 marks** because the bending moment is calculated correctly for the first mark. The final answer for the stress is correct and the units are correct for the second mark. The answer is given to 4 significant figures rather than 2 but is within the acceptable range.

Question 7 (c)

The candidate was awarded **1 mark** because there is a direct comparison with the lowest value of ultimate tensile strength (UTS) and a correct determination of lack of safety, as well as noting that the upper value of UTS gives an acceptable factor of safety.

Question 8 (a)

This part of the question was not attempted.

Question 8 (b)

The candidate was awarded **2 marks** because the relationships between input power, output power and power losses are not correct, so the first mark is not awarded. The output power is incorrectly calculated assuming no loss in the secondary winding (which is the point of the question) and there is also a transposition error – P_{in} is written as $5x10^6$ rather than $5.2x10^6$ - so the second mark is not awarded. The calculation of secondary current is then a follow-through error for the third mark. The resistive power loss in the secondary coil is calculated correctly based on the incorrect secondary current for the fourth mark.

Question 8 (c)

The candidate was awarded **0 marks** because the proposed strategy to adjust the table values would affect the amplitude or shape of the output signal, but it would not affect its period. Dividing these integer values by 255 would give twelve values of zero in the table if the arithmetic logic unit (ALU) performed integer arithmetic as many microcontrollers do.

Question 8 (d)

The candidate was awarded **1 mark** because the correct option has been selected for the first mark. However, the justification for the option selected is not valid, so the second mark is not awarded.

Question 8 (e)

The candidate was awarded **0 marks** because the torque is calculated for the gear on the bogey axle, rather than the gear on the motor, so the first mark is not awarded. This torque is divided by a diameter rather than a radius to find a tangential force, so the second mark is not awarded. The tangential force is divided by sin20° rather than cos20° to find the force acting on the gear tooth at the mesh, so the third mark is not awarded. There is a diagram indicating a line of action of the force acting on the motor gear tooth, but the direction is not correct, so the fourth mark is not awarded.

Question 8 (f)

The candidate was awarded **5 marks** because the components of the gear force are indicated correctly in relation to the other forces acting on the axle for the first mark. There is a correct moment equilibrium equation for each of the two orthogonal planes for the second and third marks. The magnitude of the bearing force is calculated correctly from its components for the fourth mark. The line of action of the bearing force is indicated on a diagram for the fifth mark. There was enough diagrammatic information in the solution to relate the direction of the two components of the bearing force to the directions of known forces to give a clear sense of the direction of the line of action that the 0.23° indicates.

Question 9 (a)

The candidate was awarded **3 marks** because the reactions are calculated correctly for the first mark. The shear force values at all key points on the shear force diagram are noted on the diagram. On the shear force diagram, the values of the reactions are transposed, so the second mark is not awarded. The effects of the point loads, their magnitudes, are indicated correctly for the third mark. Note that they are not correct in terms of start and end values, but this is a follow-through error arising from the transposition of the reactions. The piecewise-continuous constant slope of the graph arising from the uniformly distributed load has the correct gradient for the fourth mark.

Question 9 (b) (i)

The candidate was awarded **2 marks** because the term for bending moment arising from the distributed load is correct for the first mark. The terms for the reaction and point load have a form that represents bending moments. The term for the point load adds to the term for the distributed load while the term for the reaction subtracts from the other two terms. This is also correct. The forms included produce the correct second term in the simplified version of the bending moment equation and the second mark is awarded on this basis. However, the third mark is not awarded because the constant term in the simplified equation does not appear. The candidate has not taken account of the positions of the point load and the reaction relative to the left-hand end of the beam.

Question 9 (b) (ii)

The candidate was awarded **2 marks** because the expression for the bending moment has been differentiated correctly with respect to displacement, x, for the first mark. There is a follow-through error to consider because the expression for the bending moment developed in Q9(b)(i) lacks a constant value, but this would produce zero in the derivative. The value of the derivative is set to zero correctly and the answer is correct for the second mark.

Question 9 (c)

The candidate was awarded **4 marks** because Kirchhoff's current law (KCL) and Ohm's law are not applied correctly for the higher output state, so the first mark is not awarded. In the candidate's equation 2, the 5.2 in the left-hand term should be 4.25, the voltage at the node. KCL and Ohm's law are applied correctly for the lower output state for the second mark. The solution approach for the simultaneous equations is correct for the third mark. R_1 and R_2 are then calculated correctly for the fourth and fifth marks. The answers for R_1 and R_2 are given to 3 significant figures rather than 2 but this is within the acceptable range.

Question 9 (d)

The candidate was awarded **2 marks** because 10% is the correct numerical answer. However, this candidate has also identified the one pulse in ten pulses possible error that leads to the answer.

Question 9 (e)

The candidate was awarded **0 marks** because, although the candidate has recognised the delay must increase rather than just change, the delay has not been calculated so the marks cannot be awarded.

Candidate 3

Question 1

The candidate was awarded **1 mark** because the second moment of area of a triangle is calculated correctly about its base for the first mark. However, the strategy for calculating the second moment of area of the cross-section is not correct. The triangles are added, so the axis used to calculate the second moment of area for the first mark does not lie on the central axis of the cross-section, but 10mm from it. The two rectangles that are added have central axes that lie 15mm from the central axis of the cross-section. The parallel-axis theorem would have to be applied to both for the summative approach to produce the correct value for their second moment of area about the central axis of the cross-section. The second and third marks are not available.

Question 2 (a)

The candidate was awarded **0 marks** because there is no explanation of how pumped storage operates to complete its function for the second mark. There is a reference to satisfying peak demand. However, it is not clear that it would only be switched to generating electricity at this time for the first mark.

Question 2 (b)

The candidate was awarded **1 mark** because the 3% mechanical loss, both when raising and lowering, is accounted for correctly in the expression for overall efficiency for the first mark. However, the final answer is incorrect – the candidate has used 0.96x0.94x0.93x0.93 in the calculation of the overall efficiency - so the second mark is not awarded.

Question 3 (a)

The candidate was awarded **3 marks** because there are sensible examples of what money would be spent on for the first mark. The idea of equipment bought for the prototype stage being reused in later stages mentioned in the final paragraph suggests money being spent for the long-term and the second mark is awarded. There are reasons given for the reduction in capital costs for the third mark.

Question 3 (b)

The candidate was awarded **0 marks** because the time interval and the float for stage G are correct but the time interval for stage H is not, so the first mark is not awarded. The critical path is not identified correctly for the second mark.

Question 3 (c)

The candidate was awarded **2 marks** because a technique is related to activities on the critical path for the first mark. The means of applying the technique is then given for the second mark.

Question 4 (a)

The candidate was awarded **1 mark** because the maximum drain current is calculated, and the load line drawn on the worksheet correctly for the first mark. There is no indication of finding the operating (quiescent) point for the second mark. The selected value for V_{GS} is not correct for the third mark.

Question 4 (b)

The candidate was awarded **2 marks** because having taken the value of V_{GS} as 4.5 V, the correct ratio of resistor values for R_1 and R_2 is stated for the first mark. The subsequent working leads to correct values of each resistance to produce a V_{GS} of 4.5 V for the second mark.

Question 5

The candidate was awarded **4 marks** because the correct data values are extracted and substituted correctly to determine the switching energy for the first mark. The period of a fixed number of switching events (in 10 ms, n=12) is interpreted correctly from the pulse-width modulation (PWM) signal for the second mark. The switching frequency is calculated correctly for the third mark. The power dissipation during switching is calculated correctly and a unit applied correctly for the fourth mark.

Question 6 (a)

The candidate was awarded **2 marks** because a correct expression is found for C for the first mark and C is calculated correctly for the second mark.

Question 6 (b)

The candidate was awarded **1 mark** because the increase in capacitance is noted and the correct effect that the increase has on the saturation time is given.

Question 6 (c)

The candidate was awarded **3 marks** because the correct expression for V_2 is found for the first mark. The value of V_2 is substituted in a correct expression for V_{out} for the second mark. The final expression is correct for the substituted value of V_2 for the third mark. The solution is given towards the end of this candidate's solutions and a first attempt has been scored through unambiguously so is not considered.

Question 7 (a)

The candidate was awarded **3 marks** because Young's modulus is found correctly, the mass is halved, and it is multiplied by g to produce the weight that P represents for the first mark. The substitutions of lengths are correct for the second mark. The final answer is correct for the third mark. The answer is given to 3 significant figures rather than 2 but is within the acceptable range.

Question 7 (b)

The candidate was awarded **2 marks** because the bending moment is calculated correctly for the first mark. The final answer for the stress is correct and the units are correct for the second mark. The answer is given to 3 significant figures rather than 2 but is within the acceptable range.

Question 7 (c)

The candidate was awarded **1 mark** because there is a direct comparison with the lowest value of ultimate tensile strength (UTS) and a correct determination of lack of safety, as well as noting that the upper value of UTS gives an acceptable factor of safety.

Question 8 (a)

The candidate was awarded **2 marks** because both the rectifier and its function are identified for the first mark. The inverter and its function are identified for the second mark. The final sentence does not refer to the variable nature of the AC frequency noted on the diagram, so was not sufficient for the third mark.

Question 8 (b)

The candidate was awarded **0 marks** because there is no indication of a consideration of power balance for the first mark and no indication of power considerations other than for the secondary winding for the second mark. The core and primary winding losses are ignored. The approach to finding the output current is not correct for the third mark. The answer supplied suggests that the transformer dissipates 250 times more power in the secondary winding than is supplied to the transformer, an impossible outcome. The fourth mark is not awarded.

Question 8 (c)

The candidate was awarded **0 marks** because the ‘delay’ command controlling the period of the sine wave output is not identified for the first mark. The first sentence in the answer is not true – the question states that the pulse-width modulation (PWM) frequency is 15.6 kHz and the AC sine wave has a frequency of 59.5 Hz. The second sentence is a truism but does not explain how this would be done in the program, so the second mark is not awarded.

Question 8 (d)

The candidate was awarded **0 marks** because the selection between the two options is not correct, and the explanation does not then follow.

Question 8 (e)

The candidate was awarded **2 marks** because the torque on the motor gear is calculated for the first mark. The tangential force acting on the motor gear is calculated for the second mark. Although the radial component of the force acting on the gear is calculated, the total force acting on the gear is not calculated, so the third mark is not awarded. There is a diagram indicating the line of action, but the force is not shown to be acting in the correct direction, so the fourth mark is not awarded.

Question 8 (f)

The candidate was awarded **4 marks** because the components of the gear force are indicated correctly in relation to the other forces acting on the axle for the first mark. There is a correct moment equilibrium equation for each of the two orthogonal planes for the second and third marks. The magnitude of the bearing force is calculated correctly from its components for the fourth mark. The angle of the line of action of the bearing force is calculated correctly, but the diagram does not make the line of action of the bearing force clear, so the fifth mark is not awarded.

Question 9 (a)

The candidate was awarded **3 marks** because the solution to the calculation of R_B is given to three significant figures. R_A has been rounded to two significant figures and would be 408 kN to three significant figures, giving $R_B = 417$ kN, so the first mark is not awarded. The values at all key points on the shear force diagram are noted correctly on the diagram, allowing for the values of reactions used. The reactions are positioned correctly for the second mark. The effects of the point loads are indicated correctly for the third mark. The piecewise-continuous constant slope of the graph arising from the uniformly distributed load has the correct gradient for the fourth mark.

Question 9 (b) (i)

The candidate was awarded **3 marks** because all three terms for the bending moment appear correctly in the first line of the candidate's solution. The numerical value used for the reaction is that determined in Q9(a), so is treated by the marker as correct. The terms have been simplified correctly, but this step is not necessary to gain full marks.

Question 9 (b) (ii)

The candidate was awarded **2 marks** because the expression for the bending moment has been differentiated correctly with respect to displacement, x, for the first mark. The value of the derivative is set to zero correctly and the answer is correct for the second mark.

Question 9 (c)

The candidate was awarded **5 marks** because Kirchhoff's current law (KCL) and Ohm's law are applied correctly for both output states for the first two marks. The solution approach for the simultaneous equations is correct for the third mark. R_1 and R_2 are then calculated correctly for the fourth and fifth marks. The answer for R_1 is given to 3 significant figures rather than 2 but is within the acceptable range.

Question 9 (d)

The candidate was awarded **2 marks** because 10% is the correct numerical answer. However, this candidate has also identified the one pulse in ten pulses possible error that leads to the answer.

Question 9 (e)

The candidate was awarded **0 marks** because the adaptation does not address reading the speed to an accuracy of 5% at 5 revs min^{-1}. All the detail in the answer relates to calculations on a value that has been read, and there is no mention of adjusting the program lines that control taking the reading, so the 20% error will remain in the read value.

Candidate 4

Question 1

The candidate was awarded **2 marks** because the second moment of area of a triangle is calculated correctly about its base for the first mark, a correct strategy is used to determine the second moment of area of the cross-section for the second mark, but a mistake is made in determining the numerical value for the final answer, so the third mark is not awarded. The strategy here is subtractive, but the second moment of area is calculated for a half of the beam defined by a vertical central axis and then doubled. The second moment of area of two triangles is subtracted from the second moment of area of a 15mm wide by 40mm deep rectangle and, at this point in the solution, there is a mistake in the calculation of this numerical value. With the dimensions substituted in the subtractive formula (all correct), the value should be $78.333\ldots x10^3$, rather than $958.333\ldots x10^3$. However, the strategy to calculate this value and then double it is valid.

Question 2 (a)

The candidate was awarded **2 marks** because the first sentence of the candidate's response gives a succinct outline of pump-storage operation for the second mark. There is a clear statement of it being used to meet sudden increases in demand in contrast to a different form of electricity generation for the first mark. While the use of colloquialisms ('willy nilly') in technical descriptions or explanations is not encouraged the candidate is not penalised here.

Question 2 (b)

The candidate was awarded **2 marks** because the 3% mechanical loss, both when raising and lowering, is accounted for correctly for the first mark and the final answer is correct for the second mark.

Question 3 (a)

The candidate was awarded **1 mark** because capital cost is not defined as invested money that must be financed for the second mark. There are no project-specific examples of what money would be spent on for the first mark. However, there are reasons given for the reduction in capital costs that are specific to the project for the third mark.

Question 3 (b)

The candidate was awarded **2 marks** because the time intervals for stages G and H and the float for stage G are all indicated appropriately for the first mark. Week 12 is not clear, but the scribbled-out boxes and note to the left of the chart suggest the candidate has moved both stages right by a week. Furthermore, the diagonal line appears to lie over the F and be darker than the other diagonals.. The critical path is identified correctly for the second mark.

Question 3 (c)

The candidate was awarded **2 marks** because a technique is related to activities on the critical path for the first mark. The means of applying the technique is then given for the second mark.

Question 4 (a)

The candidate was awarded **3 marks** because the maximum drain current is calculated, and the load line drawn on the worksheet correctly for the first mark. There is a calculation to find the operating (quiescent) point for the second mark. The selected value for V_{GS} is taken from the construction on the graph using the calculated value of V_{DS} at the operating point for the third mark.

Question 4 (b)

The candidate was awarded **0 marks** because the resistor ratio is not found correctly. A resistor ratio is equated to a ratio between voltage difference and drain current, a term for resistance, so the calculation is invalid.

Question 5

The candidate was awarded **2 marks** because the correct data values are extracted and substituted correctly to determine the switching energy for the first mark. The switching frequency is misinterpreted. The time taken to switch on and off is taken as a period, and the frequency is then calculated as its inverse. This incorrect approach ignores the definition of the frequency in the penultimate sentence of the question. Neither of the second and third marks are awarded. However, the power dissipation during switching is calculated correctly for the switching frequency that the candidate arrives at, and a unit is applied correctly, so the fourth mark is awarded based on a follow-through error for the value of frequency.

Question 6 (a)

The candidate was awarded **2 marks** because a correct expression is found for C for the first mark and C is calculated correctly for the second mark. The answer is given to 3 significant figures rather than 2 but is within the acceptable range.

Question 6 (b)

The candidate was awarded **1 mark** because the increase in capacitance is noted and the correct effect that the increase has on the saturation time is given.

Question 6 (c)

The candidate was awarded **3 marks** because the correct expression for V_2 is found for the first mark. The value of V_2 is substituted in a correct expression for V_{out} for the second mark. The final expression is correct for the substituted value of V_2 for the third mark. The answer is given to 3 significant figures rather than 2 but is within the acceptable range.

Question 7 (a)

The candidate was awarded **2 marks** because Young's modulus is found correctly, the mass is halved, but it is not multiplied by g to produce the weight that P represents, so the first mark is not awarded. The substitutions of lengths and the other parameters are correct for the second mark. The final answer is correct for the third mark. The answer is given to 3 significant figures rather than 2 but is within the acceptable range.

Question 7 (b)

The candidate was awarded **2 marks** because the bending moment is calculated correctly for the first mark. The value of P is not correct, but it is taken from part (a) so it is a follow-through error. The final answer for the stress is correct for the substituted values for the second mark. The answer is given to 3 significant figures rather than 2 but is within the acceptable range.

Question 7 (c)

The candidate was awarded **1 mark** because there is a direct comparison with the lowest value of ultimate tensile strength (UTS) and a correct determination of safety based on the calculated value of stress from part (b).

Question 8 (a)

The candidate was awarded **0 marks** because neither sub-system is named correctly and only the function of the first sub-system is described.
If the first sub-system had been named correctly in addition to the candidate's response, then the first mark could have been awarded. Alternatively, if the function of the second sub-system had been included correctly in addition to the candidate's response, then the second mark could have been awarded.

Question 8 (b)

The candidate was awarded **2 marks** because the relationships between input power, output power and power losses are not correct, so the first mark is not awarded. The output power is incorrectly calculated assuming no loss in the secondary winding (which is the point of the question), so the second mark is not awarded. The calculation of secondary current is then a follow-through error for the third mark. The resistive power loss in the secondary coil is calculated correctly based on the incorrect secondary current for the fourth mark.

Question 8 (c)

The candidate was awarded **2 marks** because the 'delay' command controlling the period of the sine wave output is correctly identified for the first mark and the way in which altering its variable value affects the period of the sine wave output is correctly outlined for the second mark.

Question 8 (d)

The candidate was awarded **0 marks** because the selection between the two options is not correct, and the explanation does not then follow.

Question 8 (e)

The candidate was awarded **2 marks** because the torque on the motor gear is calculated for the first mark. The tangential force acting on the motor gear is not calculated correctly because the diameter of the gear on the bogey axle is used and its value is not expressed in metres, so the second mark is not awarded. The total force acting on the gear is calculated correctly based on the incorrect value of tangential force, for the third mark. There is more than one diagram indicating the line of action of forces at meshing points in the gear train, but the force on the motor gear is not shown to be acting in the correct direction, so the fourth mark is not awarded.

Question 8 (f)

The candidate was awarded **5 marks** because the components of the gear force are indicated correctly in relation to the other forces acting on the axle for the first mark. There is a correct moment equilibrium equation for each of the two orthogonal planes for the second and third marks. The magnitude of the bearing force is calculated correctly from its components for the fourth mark. The line of action of the bearing force is indicated on a diagram for the fifth mark. There was enough diagrammatic information in the solution to relate the direction of the two components of the bearing force to the directions of known forces to give a clear sense of the direction of the line of action that the 0.23° indicates.

Question 9 (a)

The candidate was awarded **4 marks** because the reactions are calculated correctly for the first mark. On the shear force diagram, the reactions are positioned correctly for the second mark. The effects of the point loads are indicated correctly for the third mark. The piecewise-continuous constant slope of the graph arising from the uniformly distributed load has the correct gradient for the fourth mark.

Question 9 (b) (i)

The candidate was awarded **3 marks** because all three terms for the bending moment appear correctly in the first line of the candidate's solution. The terms have been simplified correctly, but this step is not necessary to gain full marks.

Question 9 (b) (ii)

The candidate was awarded **2 marks** because the expression for the bending moment has been differentiated correctly with respect to displacement, x, for the first mark. The value of the derivative is set to zero correctly and the answer is correct for the second mark. The answer is given to 3 significant figures rather than 2 but is within the acceptable range.

Question 9 (c)

The candidate was awarded **2 marks** because the crossed-out value of 0.95 in the sixth line of working is correct. It is replaced with 9.5, which is an error, and the first mark is not awarded. The eighth line of working on the same page shows the correct application of Kirchhoff's current law (KCL) and Ohm's law for the second mark. An error is made in the solution of simultaneous equations in the third line of working where the final term should be negative, so the third mark is not awarded. Two errors are made calculating R_2 in the seventh line of working, so the fourth mark is not awarded. Based on follow through-errors, the value for R_1 has been calculated correctly, so the fifth mark is awarded. The resistances in the equation represent kΩ values.

Question 9 (d)

The candidate was awarded **1 mark** because the answer is correct. However, the candidate's work in arriving at the answer is not correct and the first mark is not awarded. The ratio relating 3/2 (1.5) to a 50% error is not correct. The error in this case is 33% and is found from 1-(n-1)/n. The candidate has had to use 11 pulses rather than 10 to arrive at their answer.

Question 9 (e)

The candidate was awarded **0 marks** because although the candidate has recognised late on in the response that the delay must increase rather than just change, the delay has not been calculated so the first mark is not awarded. The candidate's first sentence is not true because the solution to this problem does not generate decimal values.