CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

STCW 78 as amended MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-33 - ELECTROTECHNOLOGY

THURSDAY, 24 OCTOBER 2024

0915 - 1215 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper

Examination Paper Inserts

Worksheet Q1 Worksheet Q9

1. Examinations administered by the SQA on behalf of the Maritime & Coastguard Agency.
2. Candidates should note that 96 marks are allocated to this paper. To pass, candidates must achieve 48 marks.
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and all intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

ELECTROTECHNOLOGY

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. Worksheet Q1 shows a four-arm bridge circuit with an external resistor.

   (a) Indicate and label the currents in the four arms of the bridge using I_1, I_2 and I_3. (2)

   (b) Calculate EACH of the following:

      (i) the value of resistor R; (7)

      (ii) the power supplied by the battery; (2)

      (iii) the voltage between B and D if the 300 Ω resistor is removed. (5)

2. Fig Q2 shows a relay coil connected in parallel with a resistor. The relay operates when the current in the coil rises to 50 mA, and is released when the current falls to 5 mA.

   (a) Calculate EACH of the following:

      (i) the time constant of the coil; (2)

      (ii) the time delay from closing the switch S to operation of the relay; (5)

      (iii) assuming that the coil current is at maximum, the time delay from opening the switch S to release of the relay. (5)

   (b) Using approximately scaled axes, sketch a graph of the coil current against time for switch-on, indicating operating current and time, and the final current. (4)

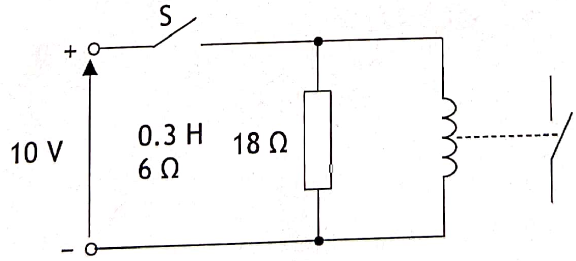

Fig Q2

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3. A three-phase, 690 V, 60 Hz, delta connected load has the following components:

R-S	Resistor	100 Ω
S-T	Coil	$76\angle 82^\circ$ Ω
T-R	Capacitor	33 μF

(a) Sketch and label the circuit diagram and identify voltages and currents. (4)

(b) Calculate the current in each phase. (5)

(c) Sketch a labelled phasor diagram to show the relationship between the phase voltages and currents. (4)

(d) Calculate the supply current in the T line. (3)

4. (a) Sketch and label the equivalent circuit representing one phase of the armature of a three-phase synchronous motor. (4)

(b) A three-phase, star connected, 660 V synchronous motor has an input power of 50 kW and its excitation is adjusted to operate at a power factor 0.8 lead. The phase winding resistance is negligible and the synchronous reactance is 3 Ω/phase.

(i) Sketch a labelled phasor diagram for one phase of the motor to show the relationship between all voltages and the armature current, and indicate the phase and load angles. (6)

(ii) Calculate the generated e.m.f. per phase. (6)

5. Fig Q5 shows a three-phase distribution system schematic.

Calculate EACH of the following:

(a) the total active load; (1)

(b) the total reactive load; (3)

(c) the transformer secondary and primary currents; (6)

(d) the current and power factor of G1 if G2 delivers 720 kW at 0.98 lead. (6)

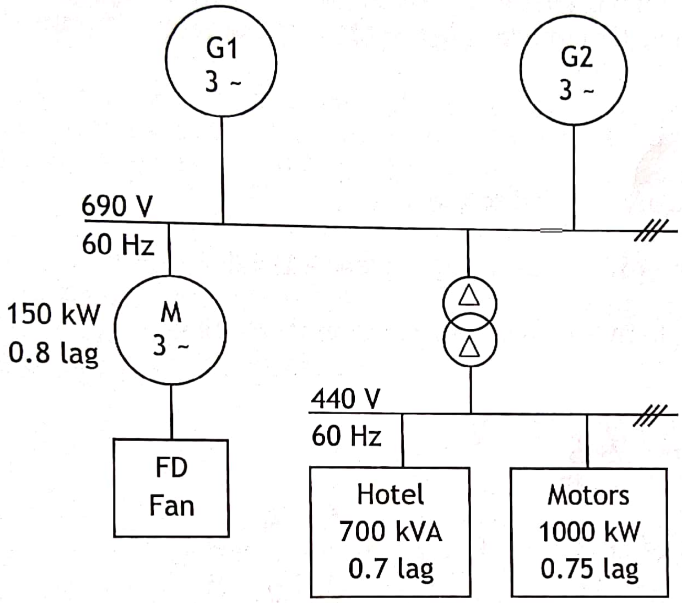

Fig Q5

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6. (a) With reference to starting a three-phase induction motor, compare the use of a star/delta starter with an autotransformer starter, referring to EACH of the following and relative values where appropriate:

(i) phase voltage relative to line voltage; (4)

(ii) starting current relative to full-load current; (4)

(iii) starting torque relative to line voltage; (4)

(iv) cost. (1)

(b) Fig Q6 shows the starting circuit of a three-phase, 440 V autotransformer starter for an induction motor. The motor is connected to the 65% tappings of the autotransformer.

Calculate EACH of the following:

(i) the line voltage V_2 applied to the motor; (1)

(ii) the motor current I_2 if the supply current I_1 is 195 A; (1)

(iii) the current I_C in the common section of each winding. (1)

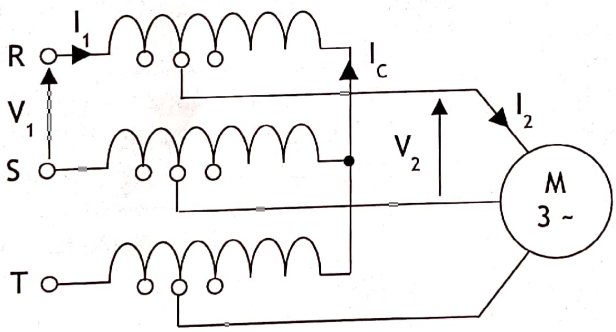

Fig Q6

7. (a) With reference to an Automatic Voltage Regulator (AVR) for a three-phase generator:

(i) state the purpose of the AVR; (1)

(ii) state why voltage droop is required; (2)

(iii) sketch and label the voltage/time characteristic for the AVR to show the required response for a sudden increase in generator load and indicate EACH of the following and their values:

- maximum voltage dip
- maximum recovery time
- maximum steady-state voltage regulation (5)

(b) A 1000 kVA, 6.6 kV, three-phase star connected generator has a synchronous reactance of 20 Ω/phase and negligible resistance. It supplies full-load current at 0.9 power factor lag and rated terminal voltage.

(i) Sketch a labelled phasor diagram to show the relationship between the generated e.m.f., the terminal voltage and the load current. (4)

(ii) Calculate the generated phase e.m.f. (4)

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8. Fig Q8 shows a cage rotor for a three-phase, 4 pole, 60 Hz induction motor which has a full-load speed of 1746 rev/min.

(a) Explain how to determine the direction of the rotor current, and state whether it is *away from* or *towards* the observer for the shaded conductors. (2)

(b) Explain with the aid of a labelled diagram how torque is produced. (5)

(c) Calculate EACH of the following at full-load:

(i) slip; (3)

(ii) the rotor frequency. (2)

(d) Sketch and label a typical torque/slip characteristic for the motor, and indicate EACH of the following:

- starting torque
- pull-out torque
- full-load torque

(4)

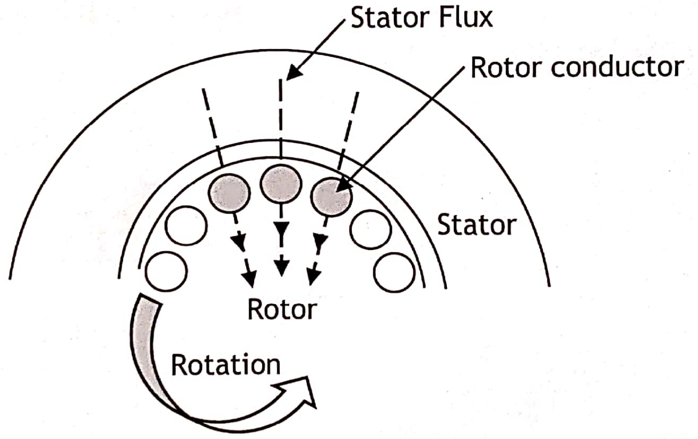

Fig Q8

9. Fig Q9 shows the circuit of a bipolar transistor amplifier.

(a) Identify the type of bipolar transistor. (1)

(b) Worksheet Q9 shows the output characteristics for the transistor. Using the worksheet, indicate, by cross-hatching/shading, the following regions of the characteristics:

(i) saturation; (1)

(ii) cut-off. (1)

(c) Derive the end points of the amplifier load line. (3)

(d) The transistor base bias current is 40 μA and the input signal is a sinusoidal current of 20 μA peak.

Using Worksheet Q9:

(i) draw the load line; (1)

(ii) determine the quiescent values of collector voltage and current; (2)

(iii) determine the r.m.s. values of EACH of the following:

- the load current
- the output voltage (4)

(e) Calculate the signal current gain of the amplifier. (3)

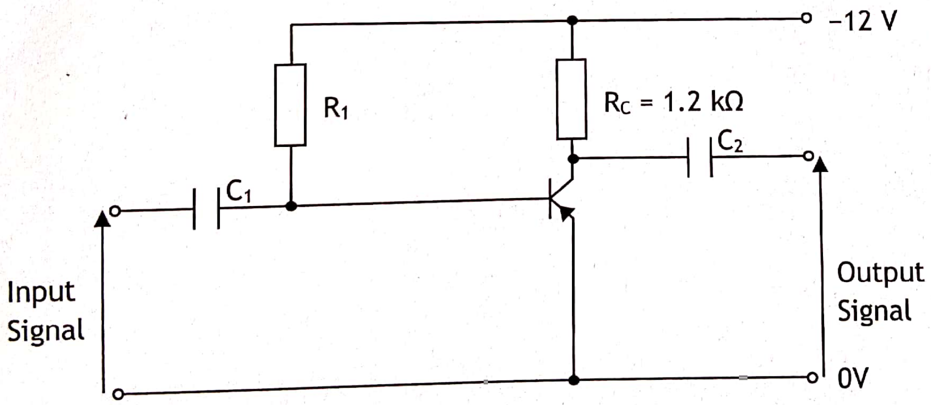

Fig Q9