CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

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

040-33 - ELECTROTECHNOLOGY

THURSDAY, 19 OCTOBER 2023

0915 - 1215 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper

Examination Paper Inserts

Worksheet Q4 Worksheet Q7

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

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ELECTROTECHNOLOGY

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets

1. A 2-core ring main is 1000 m long and the ends, A and E, are supplied at 220 V. Three loads are connected to the ring main at B, C and D as shown in Table Q1.

	LOAD (Amps)	DISTANCE FROM END A (metres)
B	100	250
C	300	500
D	180	800

Table Q1

The cable resistance (go + return) is 0.04 Ω/km.

(a) Sketch a labelled line diagram of the ring main and loads. (2)

(b) Calculate EACH of the following:

(i) the current in each section of the cable; (9)

(ii) the voltage at each load; (3)

(iii) the total power supplied. (2)

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2. A 100 μF capacitor and an 82 kΩ resistor are connected in series to a 24 V d.c. power supply.

(a) Calculate EACH of the following:

(i) the instantaneous current when the supply is switched on; (2)

(ii) the capacitor voltage 5 seconds after switch-on; 10.95 (3)

(iii) the charge stored in the capacitor 5 seconds after switch-on. 6.001×10^{-3} (2)

(b) After 5 seconds of charging the supply is switched off, the 82 kΩ resistor is replaced with 27 kΩ through which the capacitor discharges.

(i) Calculate the time taken for the capacitor voltage to fall to 4 V. 2.7 (3)

(ii) Using approximately scaled axes, sketch graphs of capacitor voltage against time for charge and discharge indicating EACH of the following:

- the supply voltage
- the voltage 5 seconds after switch-on
- initial discharge voltage
- the time when the voltage is 4 V. (6)

3. A 690 V, 60 Hz three-phase load consists of identical coils having inductance 0.2 H and resistance 50 Ω connected in star. Three identical capacitors arranged in delta are connected in parallel with the load to raise the supply power factor to 0.9 lag.

Calculate EACH of the following:

(a) the capacitor value; (14)

(b) the percentage change in supply current due to the capacitors. (2)

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4. Fig Q4 shows the supply current waveform for a three-phase, 60 Hz induction motor.

(a) Using Worksheet Q4 indicate EACH of the following for instants A and B:

(i) the direction of the currents in the coils;

(ii) the position of the stator magnetic field. (3)

(b) Explain, with the aid of a labelled sketch, how torque is produced when a cage rotor is located inside the stator. (2)

(6)

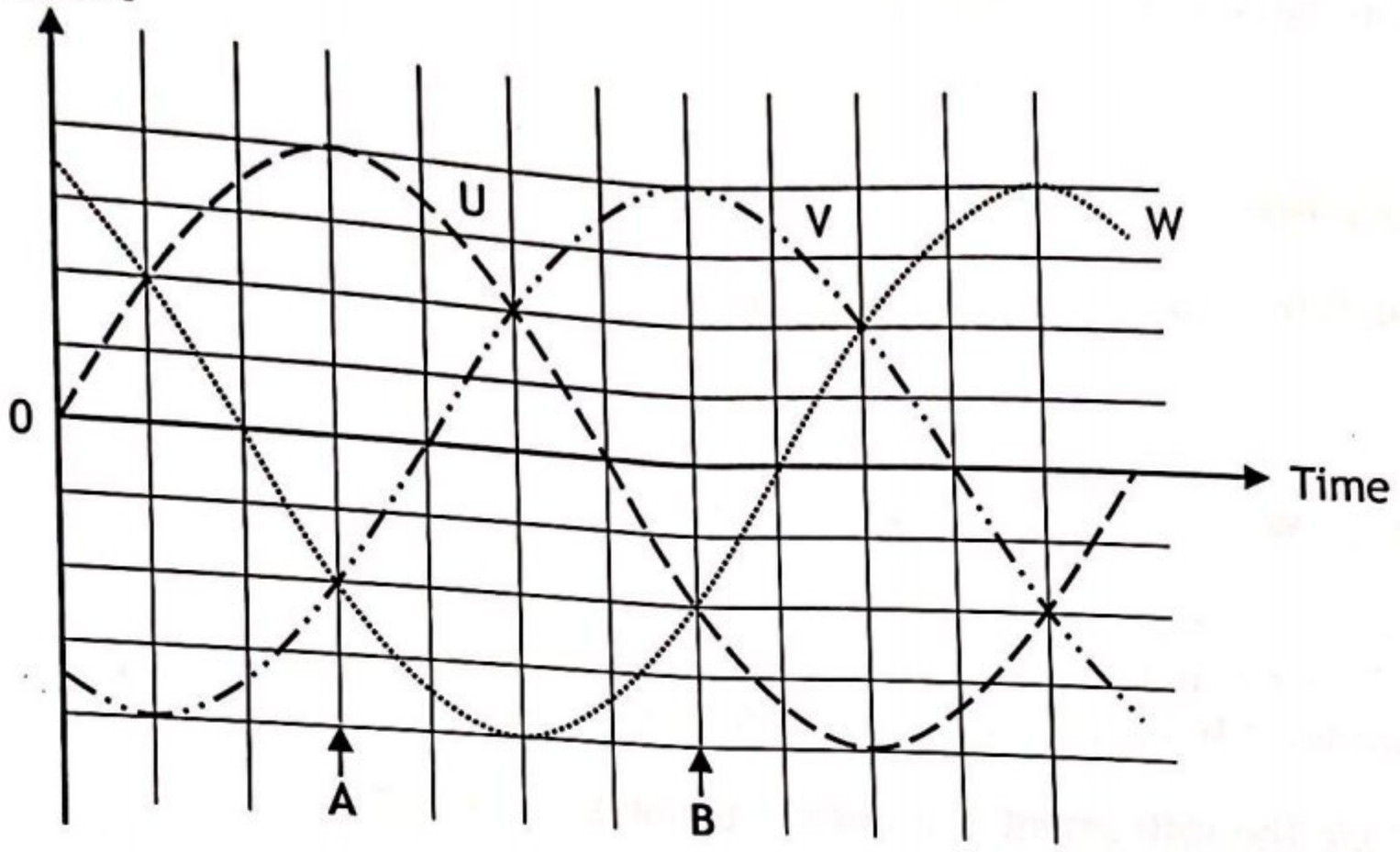

Fig Q4

(c) Calculate EACH of the following for the motor:

(i) synchronous speed; (2)

(ii) the rotor speed at 0.05 slip. (3)

5. Two three-phase diesel generators operate in parallel and supply the following loads:

- lighting and heating 1200 kW, 0.85 lag
- induction motors 2500 kW, 0.8 lag
- synchronous motor 700 kW, 0.9 lead.

DG1 supplies 2000 kW at a power factor 0.8 lag.

Calculate EACH of the following:

(a) the reactive power (kVAr) supplied by generator DG2; -795.63 (8)

(b) the power factor of generator DG2; 0.55 (4)

(c) the busbar voltage if the supply current is 867 A. 1690.5 (4)

6. (a) State TWO reasons for using instrument transformers. (2)

(b) Sketch a labelled circuit diagram showing how a 30:1 voltage transformer and a 300:1 current transformer are used to connect a voltmeter, ammeter and wattmeter to busbars supplied from a three-phase, 3.3 kV generator.

Include the instrument transformer terminal markings. (7)

(c) The voltmeter and ammeter in Q6(b) read 3300 V and 900 A respectively at 60% full-load, 0.8 power factor lag.

Calculate EACH of the following:

(i) the voltage across the wattmeter voltage coil; (1)

(ii) the current in the wattmeter current coil; (1)

(iii) the wattmeter reading; (2)

(iv) the apparent power rating of the generator. (3)

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7. Two three-phase, six-pole generators operate in parallel to share a ship's load. Both generators have linear governor and AVR characteristics.

Using Worksheet Q7:

(a) determine the busbar frequency; (3)

(b) without changing the speed droop, and maintaining the frequency determined in Q7(a), re-draw the governor characteristics to achieve equal sharing of the active load and state the values of the required no-load speed settings; (4)

(c) determine the busbar voltage; (1)

(d) without changing the no-load voltage, and maintaining the busbar voltage determined in Q7(c), re-draw the AVR characteristics to achieve equal sharing of the reactive load and state the values of the required voltage droop settings; (4)

(e) determine the original power factor of generator G2. (4)

8. (a) Sketch a cross-sectional diagram of a three-phase, cage rotor induction motor. (4)

(b) Using the sketch in Q8(a), identify the following parts:

(i) rotor bar; (1)

(ii) rotor end ring; (1)

(iii) laminated stator core; (1)

(iv) stator cooling fin. (1)

(c) Sketch and label a torque/speed characteristic for the motor in Q8(a), and indicate EACH of the following:

- synchronous speed
- pull-out torque
- starting torque. (5)

(d) With reference to a three-phase induction motor, state the equation for EACH of the following:

(i) synchronous speed; (1)

(ii) slip; (1)

(iii) frequency of the rotor e.m.f. (1)

9. Fig Q9 shows a bipolar common emitter transistor amplifier.

(a) State EACH of the following:

(i) the type of transistor; (1)

(ii) the polarity of V_{CC} with respect to 0 V. (1)

(b) Explain the purpose of EACH of the following components:

(i) resistor R_E; (2)

(ii) resistor R_C; (1)

(iii) capacitor C_2; (1)

(iv) capacitor C_E. (2)

(c) The base signal current of the amplifier is given by $i_b = 7.5\sin\omega t$ μA, and the transistor has a current gain of 800.

(i) Sketch and label the base and collector signal current waveforms to show their phase relationship, and indicate peak current values. (5)

(ii) Calculate the r.m.s. value of the output signal voltage. (3)

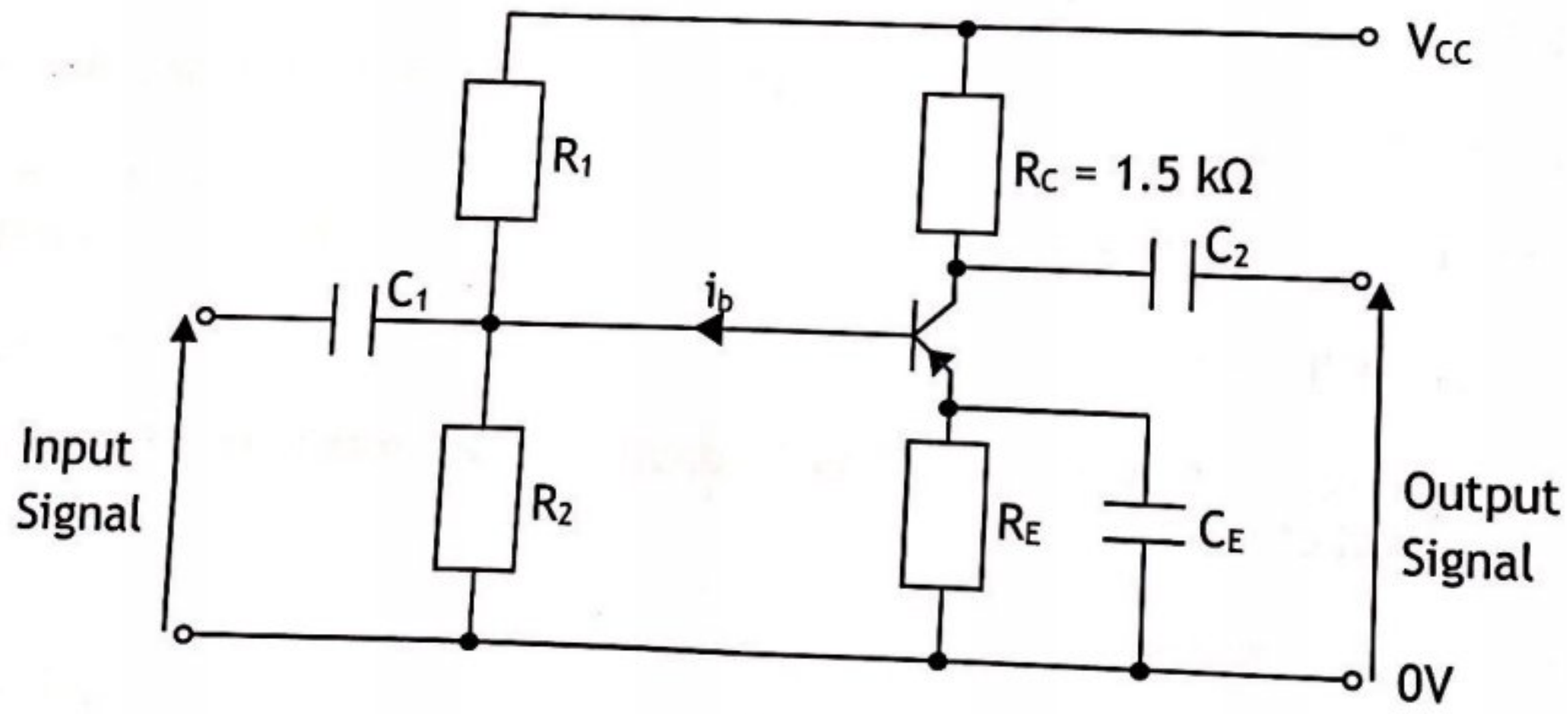

Fig Q9