ELECTROTECHNOLOGY

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. Fig Q1 shows a d.c. distribution system. The main feeder cable has a resistance (go + return) of $1.3 \times 10^{-3}\ \Omega/m$, and the load cables have a resistance (go + return) of $2.5 \times 10^{-3}\ \Omega/m$.

(a) Calculate EACH of the following:

(i) the voltage at load A; (3)

(ii) the power dissipated at load B; (5)

(iii) the voltage at the main switchboard. (3)

(b) Calculate the length of main feeder cable required to supply an additional 250 V, 300 A load at its rated values directly from the main switchboard. (5)

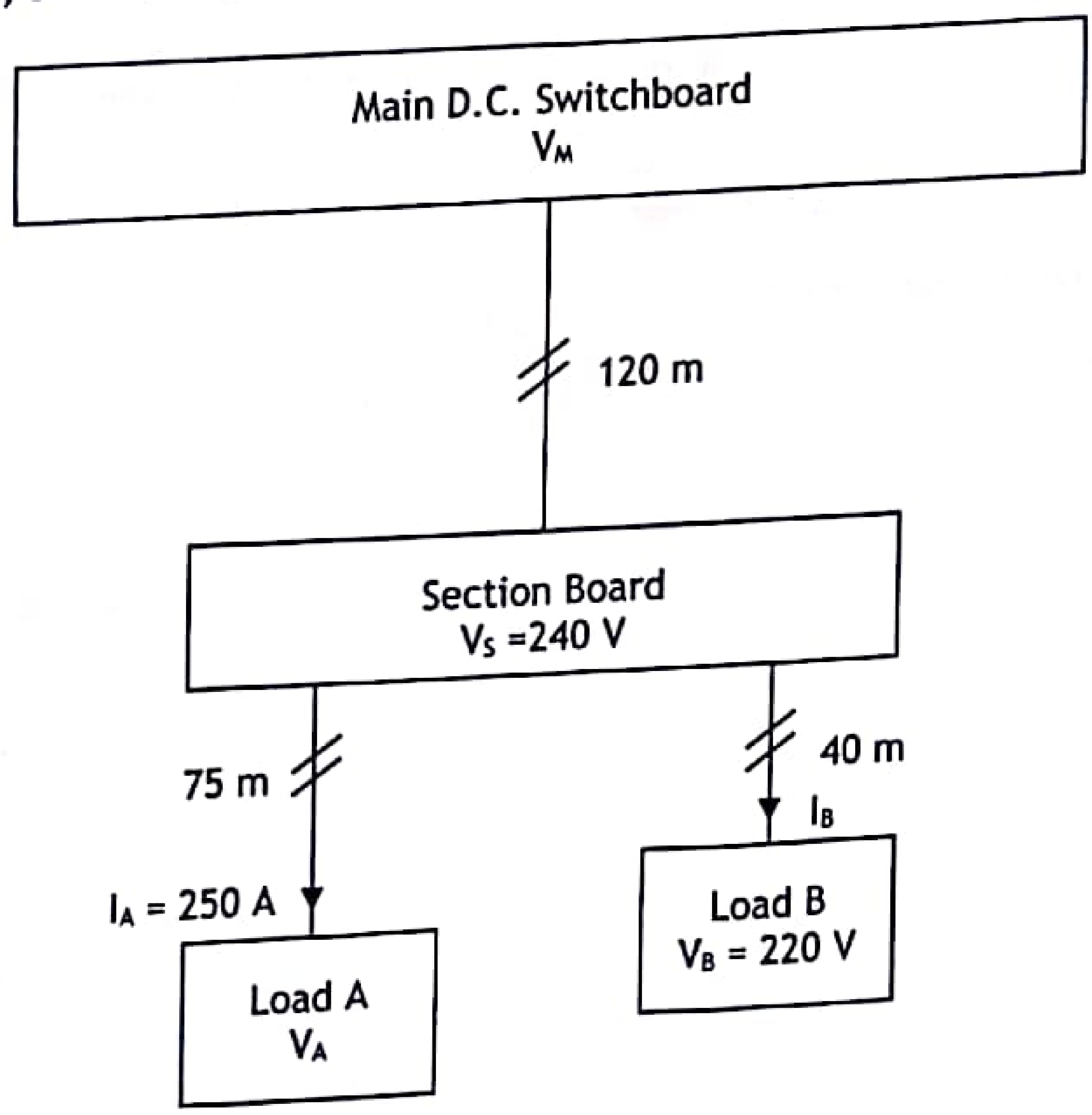

Fig Q1

2. A 39 μF capacitor and a 51 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 4 seconds after switch-on; (3)

(iii) the energy stored in the capacitor 4 seconds after switch-on. (2)

(b) After 4 seconds of charging the supply is switched off and the capacitor is discharged through a 75 kΩ resistor.

(i) Calculate the time taken for the capacitor voltage to fall to 8 V. (3)

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

- the supply voltage and the voltage 4 s after switch-on
- the initial discharge voltage and the time when the voltage has fallen to 8 V. (6)

3. Three loads are connected in star to a three-phase, 4-wire, 690 V supply. The load impedance values are:

$Z_R = 80\angle 45° \ \Omega$ $Z_S = 60\angle -30° \ \Omega$ $Z_T = 40\angle 0° \ \Omega$

(a) Calculate the current in each load. (4)

(b) Calculate the magnitude and phase angle of the neutral current with respect to the S phase voltage. (5)

(c) Sketch, approximately to scale, a labelled phasor diagram to show the relationship between the phase voltages and all currents including angles. (7)

4. With reference to a three-phase induction motor:

(a) explain why the rotor power factor is very low at start; (2)

(b) identify the stator and rotor electrical and magnetic power losses, and state how they are related to current and frequency; (6)

(c) state why the rotor magnetic losses can be ignored when the motor is running; (1)

(d) sketch and label a typical torque/slip characteristic and indicate maximum torque; (3)

(e) describe the relationship between torque and slip for values of slip between the following limits:

- 0 and slip at maximum torque
- slip at maximum torque and 1 (2)

(f) explain the motor coil connections required for a 400/690 V dual voltage motor. (2)

5. A three-phase, 180 kVA, 440 V generator has negligible armature resistance and synchronous reactance of 0.5 Ω/phase. The generator is driven at constant speed with constant excitation and supplies full-load current at rated terminal voltage with a power factor 0.7 lag.

(a) Sketch a labelled phasor diagram to show the relationship between the generated e.m.f., the terminal voltage and the load current. (3)

(b) Calculate the full-load voltage regulation. (6)

(c) Sketch, on common axes, labelled terminal voltage/load current characteristics to show how the terminal voltage changes if the load is suddenly disconnected from the generator when it is operating at full-load and rated terminal voltage for each of the following load power factors (indicate the generated e.m.f. in each case):

- unity
- 0.8 lag
- 0.8 lead. (7)

6. (a) State TWO advantages of using instrument transformers. (2)

(b) Explain why the secondary circuit of a current transformer must not be open circuited whilst the primary is energised. (3)

(c) Worksheet Q6 shows a three-phase high voltage circuit with balanced loading, a voltage transformer (VT), a current transformer (CT) and four instruments.

(i) Label the VT and CT primary and secondary terminals with standard terminal markings. (4)

(ii) Complete the diagram to show how to connect the instrument voltage coils [V V] and current coils [C C] to the voltage and current transformers. (3)

(d) Calculate EACH of the following:

(i) the turns ratio of the VT if the voltage coils of the instruments are rated at 110 V; (1)

(ii) the apparent power in the high voltage circuit if the CT secondary current is 3.7 A. (3)

7. (a) Referring to controls, describe the manual procedure required to synchronise a generator with an existing three-phase supply. (6)

(b) With reference to a check synchroniser:

(i) sketch a labelled block diagram; (4)

(ii) describe the purpose of the blocks in the diagram of Q7(b)(i). (4)

(c) Describe the main risk of poor synchronising. (2)

8. With reference to an electronic Variable Frequency Drive (VFD) for a three-phase induction motor:

(a) describe Pulse-Width Modulation (PWM) and how this technique controls the motor voltage and frequency; (4)

(b) sketch one cycle of a PWM waveform and show the typical average sinusoidal waveform applied to the motor; (3)

(c) explain why the V/f ratio is maintained at a constant value; (2)

(d) sketch a labelled block diagram; (4)

(e) describe the function of EACH block sketched in Q8(c). (3)

9. (a) (i) Sketch the forward and reverse bias characteristics of a Zener diode, label the axes and indicate:

- the Zener voltage
- the maximum and minimum Zener current. (5)

(ii) Referring to the characteristics sketched in Q9(a)(i), explain how the Zener diode can be used to achieve voltage stabilisation. (3)

(b) Fig Q9 shows a simple voltage regulator circuit. The unregulated supply V_S can vary between 21 V and 24 V and the minimum diode current for stable operation is 7 mA.

Calculate EACH of the following for protection of the diode and to maintain stable load voltage:

(i) the minimum value of R_S; (3)

(ii) the minimum power rating of R_S; (2)

(iii) the minimum value of R_L. (3)

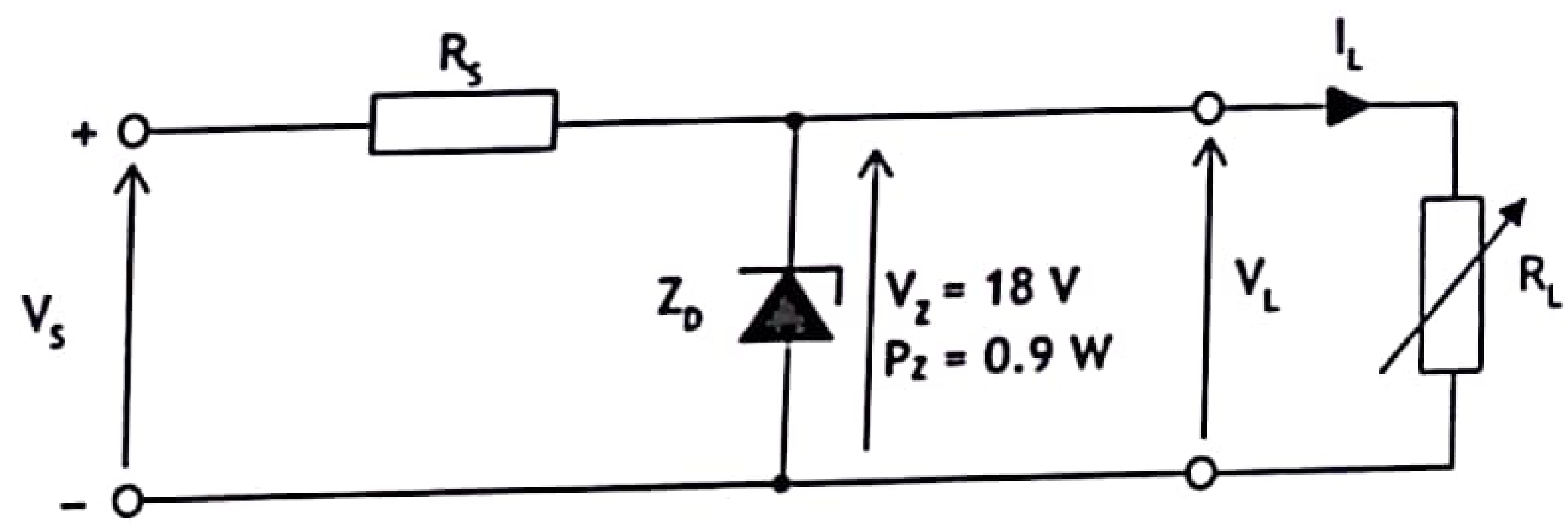

Fig Q9

(This worksheet must be returned with your answer book)

Instrument Transformers