STAFFORDSHIRE POLYTECHNIC
DEPARTMENT OF MECHANICAL AND COMPUTER AIDED ENGINEERING

Session 1989/90

BEng(HONS) DEGREE IN MECHANICAL ENGINEERING
BEng(HONS) DEGREE IN COMPUTER AIDED ENGINEERING

Electrical Engineering BM1C/M

Date: Thursday, 21st June 1990
Time: 9.30am - 12.30pm
Time Allowed: 3 hours Examiner: C.J. Boycott

This paper contains 8 questions; each of which carries equal marks. Students should present solutions to any 5 questions.

Formulae sheets are attached. Students may use any formula without proof unless specifically requested for a proof in a question.

1 a) Find the voltage V_{AC} for the circuit shown in Fig. Q1a. (6 marks)

b) Find the mean and Rms values of the waveform shown in Fig. Q1b. (6 marks)

c) When R (of Fig. Q1c) is 2Ω the ammeter reads 0.5A. What will the ammeter read when R is 0.56Ω? (8 marks)

2 a) For the circuit shown in Fig. Q2a write down BUT DO NOT SOLVE:

i) the mesh equations using the loop currents shown.
ii) the node equations taking 0 as the reference node. (10 marks)

b) For the circuit shown in Fig. Q2b find V_{A0} and I. (10 marks)

3. a) State Thevenins theorem. (5 marks)

b) Given that the Thevenin equivalent circuit of a network is as shown in Fig. Q3 deduce the Norton equivalent circuit. (3 marks)

c) A network of impedances and sources of alternating emf has two terminals. The open circuit voltage at the terminals is 260V and the short circuit current is 20A.

When a coil of 11Ω reactance and negligible resistance is connected across the terminals 13A flows in the coil. Find the circuit impedance behind the terminals in the form $(R \pm jX)\Omega$. (12 marks)

4 a) Show from first principles that the energy stored in a capacitor C is given by 1/2 CV^2, where V is the final voltage across the capacitor. Assume the capacitor is initially uncharged. (5 marks)

b) Define time constant for a series CR circuit. (3 marks)

c) A 100μF capacitor is charged through a 500Ω resistor from a 1kV dc supply.
How long does it take for the capacitor to:

i) reach 50% of its final charge
ii) reach 50% of its final stored energy

Assume the capacitor is initially uncharged. (12 marks)

5 a) If the supply voltage V = (200 +j30) volts and the supply current I = (5-j2) amps, find the power and power factor of the circuit. (7 marks)

b) Working from first principles show that the resonant frequency of the circuit shown in Fig. Q5a is:

$$f = \frac{1}{2\pi\sqrt{LC}}$$ (4 marks)

c) For the circuit shown in Fig. Q5b find:

i) C to give resonance
ii) V_C at resonance
iii) Circuit Q factor (9 marks)

6 a) 3 identical 30Ω resistors are connected in delta to a 415V 3-phase 50Hz supply. Find the total power dissipated. Find also the total power dissipated when one resistor goes open circuit. (7 marks)

b) Find the current in the neutral wire, of the circuit shown in Fig. Q6, if the balanced 3-phase supply has a <u>phase</u> voltage of 100V. Assume RYB phase rotation and take V_{RN} as reference. (13 marks)

7 a) Working from first principles show that the Emf equation of a transformer is given by:

$$E = 4.44fN\phi_{max}$$

where f = supply frequency (Hz)
N = number of turns
ϕ_{max} = maximum core flux (Wb) (5 marks)

Q7 continued overleaf........

Q7 cont.....

b) A single phase transformer takes 1A in the primary, at a power factor of 0.4 lag, when on no-load, with a primary supply of 200V. If a load of 50A at a power factor of 0.8 lag is now taken from the secondary, find the total primary current and power factor.

Transformer turns ratio $\frac{N_1}{N_2} = 2$ (9 marks)

c) i) Explain why the core of a transformer is laminated.

ii) Explain why the cross sectional area of a transformer core is stepped, rather than circular or rectangular. (6 marks)

8 a) Working from first principles show that the Emf and torque equations of a dc motor are given by $E = K\phi\omega$ and $T = K\phi I_a$.

where ϕ = mean flux per pole (Wb)
ω = speed of rotation (rad/sec)
I_a = armature current (amps). (8 marks)

b) A 250V dc shunt motor takes 80A and runs at 600 rev/min.
$R_f = 50\Omega$ and $R_a = 0.1\Omega$.
Iron, friction and windage losses are 2.2kW.
Find i) nett output power
ii) efficiency
iii) nett torque (8 marks)

c) Explain why it is necessary to have a resistor in series with the armature during starting. (4 marks)

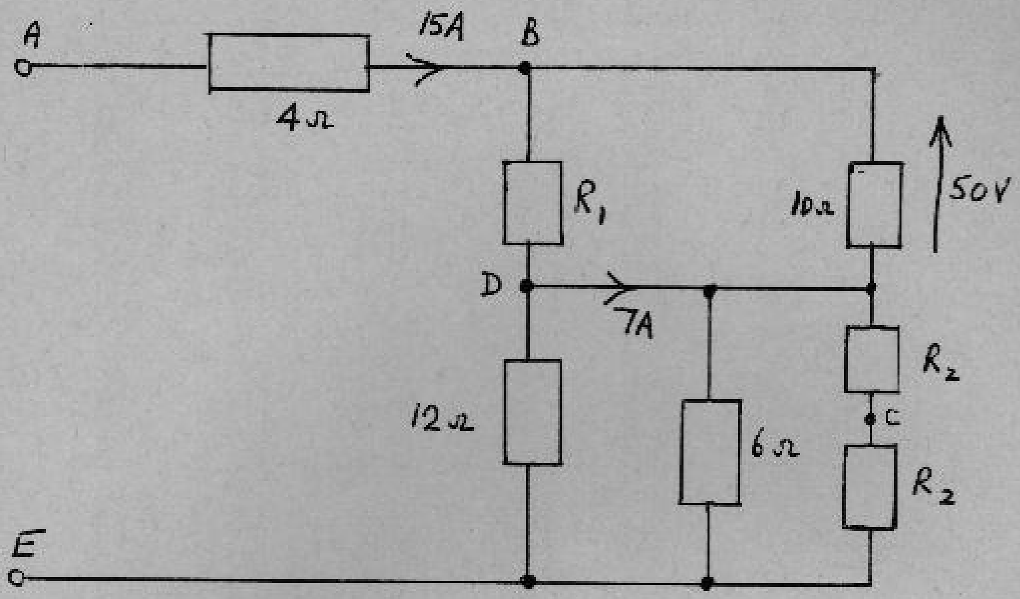


fig Q1a

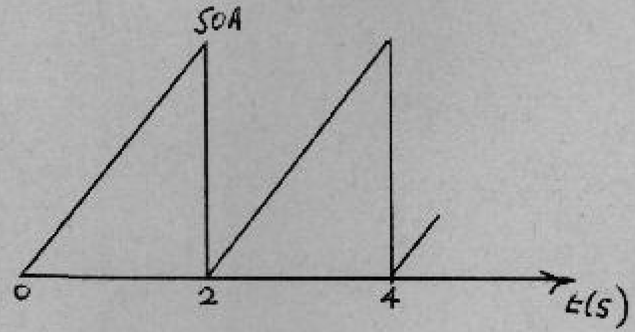


fig Q1b

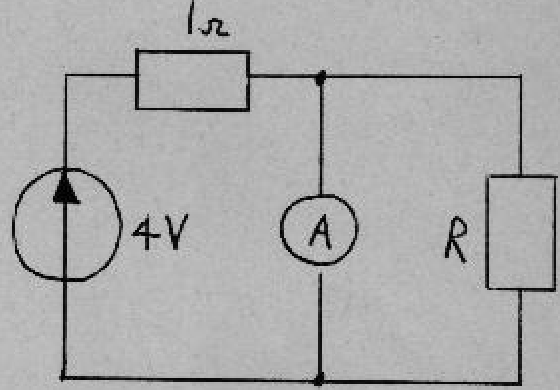


fig Q1c

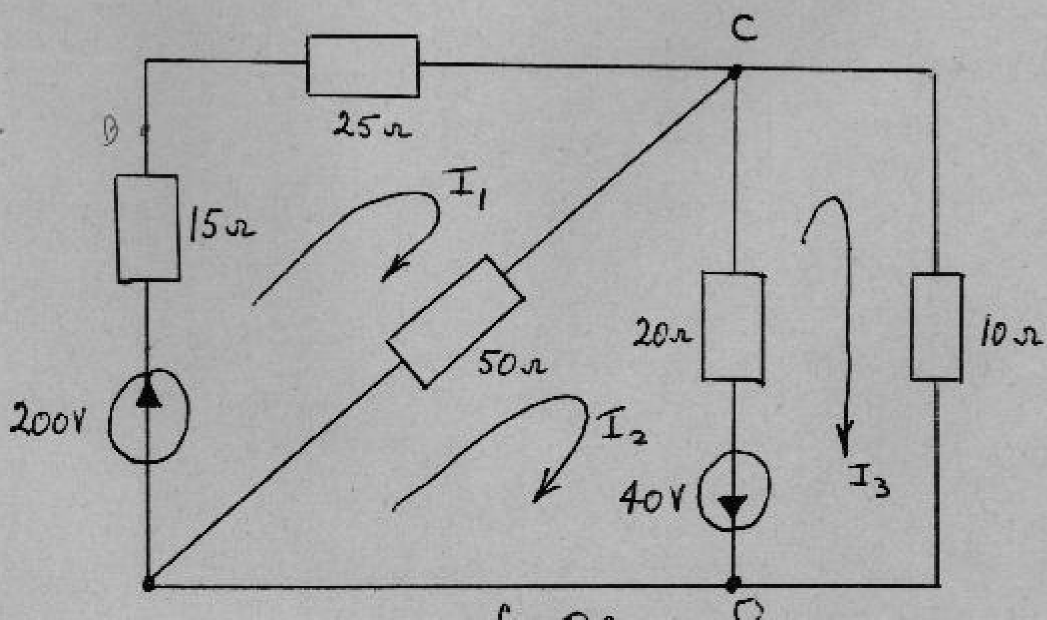


fig Q2a

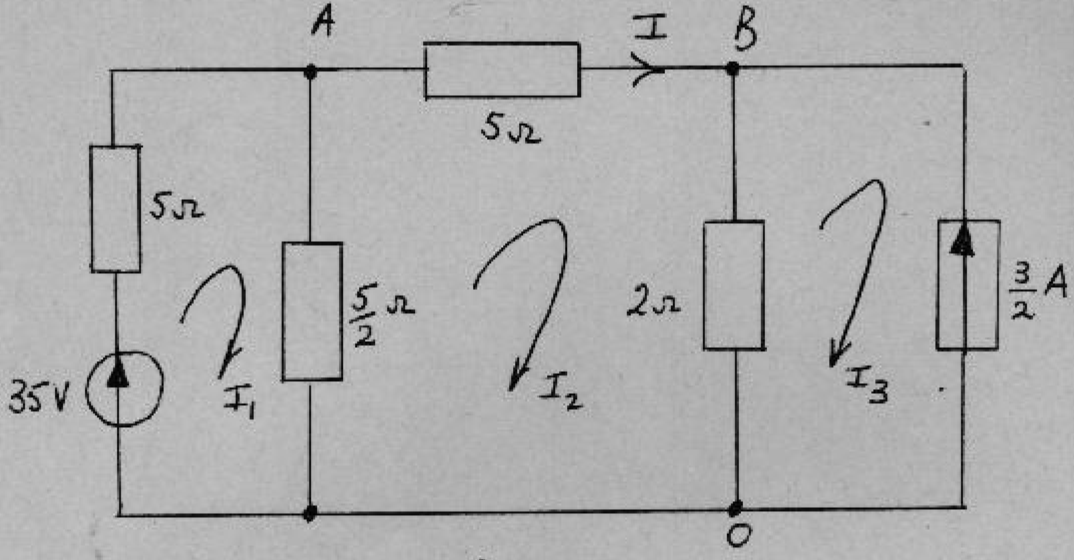


fig Q2b

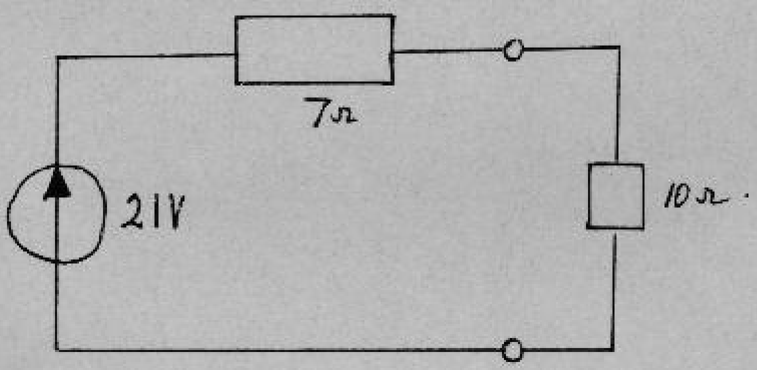


fig Q3

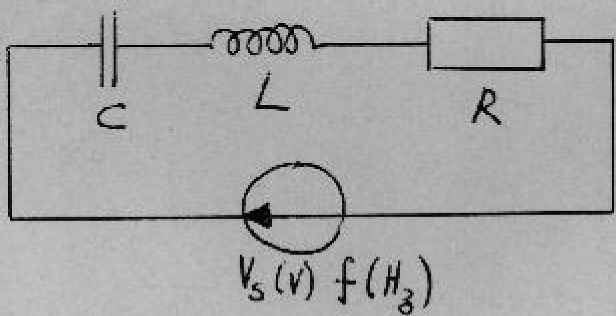


fig Q5a

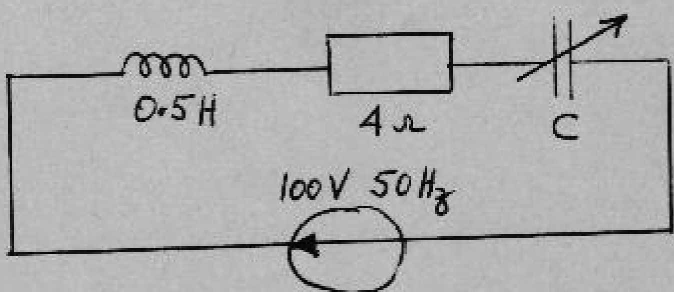


fig Q5b

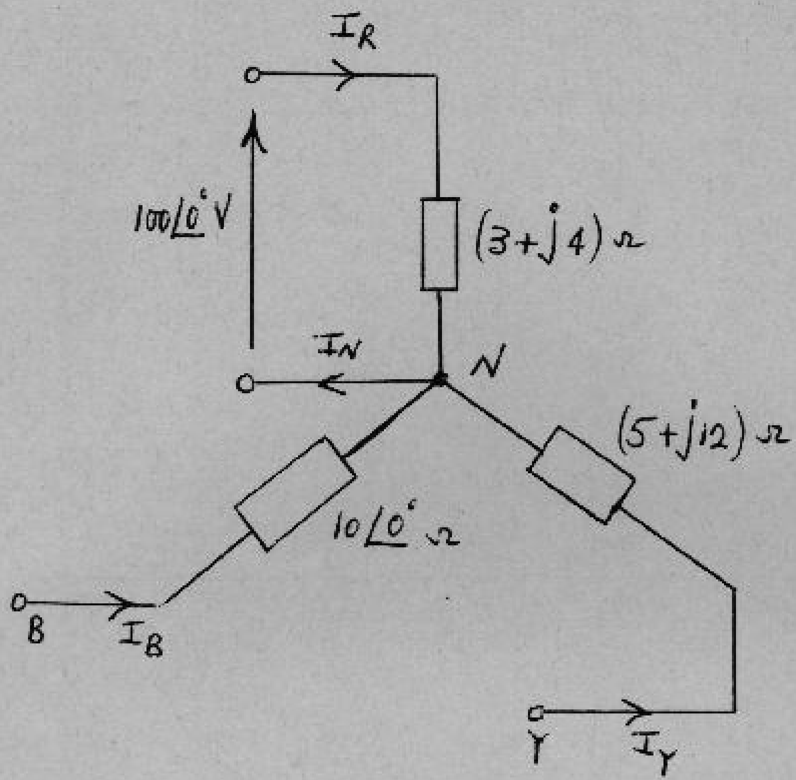

I_R
$100\angle 0^\circ$ V
$(3+j4)\,\Omega$
I_N
N
$(5+j12)\,\Omega$
$10\angle 0^\circ\,\Omega$
B
I_B
Y
I_Y

fig Q6

Formulae Sheet (for BM1 Electrical Engineering)

Impedances in series $Z = Z_1 + Z_2 + Z_3 + \ldots\ldots\ldots\ldots$

Impedances in parallel $\frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \ldots\ldots\ldots\ldots$

For a function $y = f(x)$

$$\text{Mean} = \frac{\text{Area under curve of } f(x) \text{ in 1 repetition}}{\text{Base length of 1 repetition}}$$

$$\text{Rms} = \sqrt{\frac{\text{Area under curve of } f(x)^2 \text{ in 1 repetition}}{\text{Base length of 1 repetition}}}$$

For a pure inductor $v = \frac{Ldi}{dt}$

For a pure capacitor $q = Cv$ or $\frac{dq}{dt} = i = \frac{Cdv}{dt}$

For sinusoidal supplies

$$|X_L| = 2\pi fL \quad \text{and} \quad |X_c| = \frac{1}{2\pi fC}$$

$$X_L = +j|X_L| \qquad X_c = \frac{1}{j|X_c|} = \frac{-j}{|X_c|}$$

$$|Z| = \sqrt{R^2 + (X_L - X_c)^2}, \; Z = R + j(X_L - X_c) = R \pm jX$$

$$Y = \frac{1}{z} = G \pm jB$$

For single phase circuits

$$\text{Power} = |V||I|\cos\phi \qquad \text{VAR} = |V||I|\sin\phi$$

$$\text{VA} = |V||I|$$

where ϕ is the angle betwen V & I

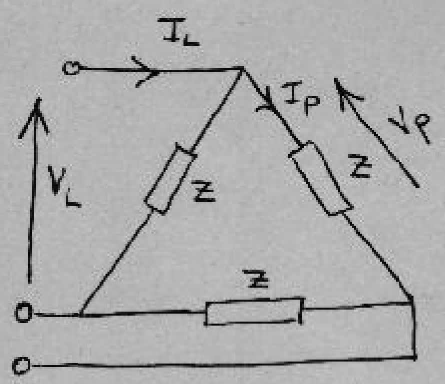
If V & I are in complex form then

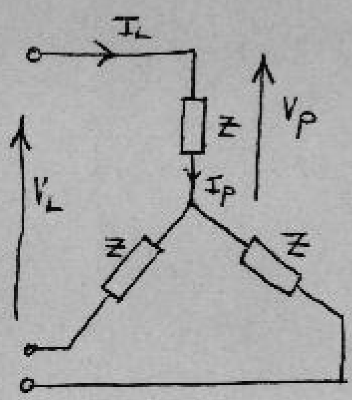
Power = Real VI* where I* is the complex conjugate of I.
Volt Amperes = Imaginary VI*.

For a balanced 3 phase circuit

Power $= \sqrt{3}\,|V_L||I_L|\cos\phi$

VA $= \sqrt{3}\,|V_L||I_L|$ VAR $= \sqrt{3}\,|V_L||I_L|\sin\phi$





$I_L = \sqrt{3}\, I_P$

$V_L = V_p$

$V_L = \sqrt{3}\, V_p$

$I_L = I_p$

Series and Parallel resonance - implies that the circuit power factor is unity.

For a series circuit, Q factor = $\dfrac{\text{Voltage across C (or L) at resonance}}{\text{Supply voltage}}$

For a CR series circuit with a dc supply.

$$\left.\begin{aligned} v_c &= V(1 - \exp(-t/RC)) \\ i &= \frac{V}{R}\exp\left(\frac{-t}{RC}\right) \end{aligned}\right\} \text{when charging C}$$

For an LR series circuit with a dc supply.

$$\left.\begin{aligned} v_L &= V \exp\left(\frac{-Rt}{L}\right) \\ i &= \frac{V}{R}\left(1 - \exp\left(\frac{-Rt}{L}\right)\right) \end{aligned}\right\} \text{ when current is rising}$$

For a transformer

$$E = 4.44\, fN\phi_{max} \qquad \frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1'}$$

For a dc motor

$$E = \frac{P\phi\omega Z}{2\pi a}, \; E = K\phi\omega \quad , \qquad T = K\phi I_a$$