(b) (i) Derive the dimensional equation of power using the fundamental quantities.

(ii) The energy density in a capacitor is given by the expression

$W \alpha \varepsilon^a V^b d^c$

where;

ε = permittivity of dielectric medium

V = voltage between plates

d = distance between plates

Using dimensions of quantities in LMTI system of units determine the value of a, b and c.

(12 marks)

(c) A moving iron instrument has full scale deflection of 125 mA. It is converted into a 250 V voltmeter using a series resistance. After carrying a steady current of 100 mA for a long time the resistance of the coil increases from 200 Ω to 230 Ω due to self heating. Calculate the error due to self heating when a voltage of 250 V is applied continuously.

(5 marks)

2. (a) Describe the **two** common faults that are likely to occur in electric cables. (2 marks)

(b) A differential amplifier used in signal conditioning has two inputs of 5 mV and 3 mV. Determine the amplifier gain.

(3 marks)

(c) (i) State any **two** applications of a Q-meter.

(ii) With aid of circuit and phasor diagrams derive the Q-factor of a coil connected in series with a capacitor.

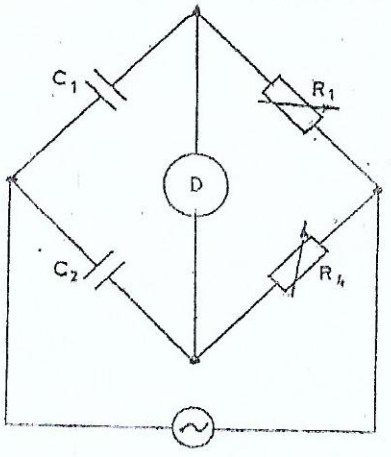
(11 marks)

(d) The insulation resistance of a cable having no conducting sheath is measured using the loss of charge method. An electrostatic voltmeter of infinite resistance is connected between the cable conductor and earth forming a joint capacitance of 680 pF. After charging, the voltage falls from 240 volts to 60 volts in $1\frac{1}{2}$ minutes. Determine the insulation resistance of the electric cable.

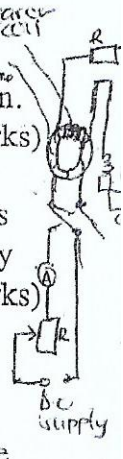
(4 marks)

3. (a) Figure 1 shows the Desauty bridge for measurement of capacitance, where R_1 and R_2 are variable resistances and C_2 is a known standard capacitor. Derive the expression for the unknown capacitance C_1.

(6 marks)



(b) With the aid of a diagram describe the measurement of flux density in a ring specimen. (8 marks)



(c) The iron loss in a ferromagnetic material is 270 watts at 50Hz. The eddy current loss component is 5 times the hyteresis loss component. Determine the value of frequency at which the iron loss will be double if the flux density is kept constant. (6 marks)

4. (a) (i) State any two areas of application of high voltage testing in electrical engineering.

(ii) With the aid of a diagram describe the measurement of RMS values of voltage using the transformer ratio method. (8 marks)

(b) A 1000/5A 50 Hz current transformer has a secondary burden of non-inductive impendance of 1.6 Ω. The primary winding has one turn. Calculate the flux in the core. (4 marks)

(b) A potential transformer, ratio 1000/100 volts has the following constants:

Primary resistance = 94 Ω
Primary reactance = 66 Ω
Secondary resistance = 0.80 Ω
Total equivalent reactance = 110 Ω
No load current = 0.02 A at 0.4 p.f. lagging;

Determine the phase angle error at no load. (8 marks)

5. (a) A moving coil instrument used as voltmeter has a coil of 200 turns with a width of 0.04 m and active length of 4 cm and the gap flux density is 0.10 wb/m^2. If the total resistance of the instrument is 200 k Ω; Determine the torque exerted by the control spring to read full scale deflection of 300 V. (5 marks)

(b) A correctly adjusted single phase 240 V energy meter has a meter constant of 660 revolutions per kwh. Determine the speed of the disc for a current of 12 A at power factor of 0.8 lagging. (3 marks)

(c) An electrostatic voltmeter consists of two attracted plates, one movable and the other fixed. Both the plates are provided with guard rings so as to make the edge effects negligible. An application of 9 kV between the plates results in pull of 4 x 10^{-3} N on the movable plate. If the change in position of the movable plate is 1 mm and its diameter is 100 mm, determine the change in capacitance. (7 marks)

(d) With the aid of a diagram describe the operation of a vibrating reed frequency meter. (5 marks)

6. (a) (i) With the aid of phasor diagram, prove that the power P is given by the expression $P_T = \frac{\cos\phi}{\cos\phi \cos(\phi - \beta)} \times P$

for an electrodynamoter wattmeter

where:

P = Actual wattmeter reading

$\cos\phi$ = power factor of the circuit

β = angle of lag between current and voltage. (12 marks)

(b) The inductive reactance of the pressure coil circuit of wattmeter is 0.4% of its resistance at normal frequency. Neglecting the effect of capacitance; calculate the percentage error and correction factor due to the reactance of a load at 0.707 power factor lagging. (8 marks)

7. (a) State any **two** advantages of semi-conductor strain gauges over metallic gauges. (2 marks)

(b) With the aid of a block diagrams describe the elements of digital data acquisition systems. (8 marks)

(c) A piezo electric crystal having a thickness of 2.5 mm and voltage sensitivity of 0.055 V-M/N is subjected to a pressure of 1.2 MN/m^2. If the permittivity of the crystal is 40.6 x 10^{-12} F/M, calculate,

(i) the output voltage;

(ii) sensitivity of the set up. (4 marks)

(d) The output of a linear variable differential transformer is connected to a voltmeter through an amplifier whose amplification factor is 300. The sensitivity of the linear variable differential transformer and that of the whole setup is 1000 mV/mm. The voltmeter scale has 100 divisions and the scale can be read to $\frac{1}{5}$ of a division. Determine:

(i) the displacement of the LVDT core;

(ii) resolution of the instrument. (6 marks)

8. (a) State **three** advantages of recorders in measurement systems. (3 marks)

(b) With aid of a labelled diagrams describe the operation of a potentiometric recorder. (8 marks)

(c) A tape recorder has a gap of 6.0 μm and has a satisfactory response at 60 KHz. If the recorded wavelength is greater than 3 times the gap of the recorder, determine the speed of the tape. (3 marks)

(d) With the aid of a circuit diagrams explain how the effect of temperature changes in ammeters may be eliminated. (6 marks)

9. (a) Explain any **three** safety precautions observed when using electrical instruments in hazardous areas.

(6 marks)

(b) (i) Explain the term calibration as used in measuring instrument.

(ii) With aid of a labelled diagram describe the procedure of calibrating a voltmeter.

(9 marks)

(c) An energy meter rated 240 V, 20 A has meter constant of 1800 revolutions per kWh. The meter is tested at half full load at rated voltage and is found to make 80 revolutions in 10 seconds. If the power factor is unity , determine the meter error at this load.

(5 marks)

(a) (i) With reference to measurements define the following terms:

I Unit

II Dimension

(ii) State any two examples of a (i). (4 marks)

(b) In an electric circuit the relationship between resistance R, voltage V and power P is given by the expression, $R \propto V^m P^n$.
Using electromagnetic system of units determine the constants 'm' and 'n'.
(4 marks)

(c) (i) With the aid of a circuit diagram describe the procedure for calibrating an industrial voltmeter.

(ii) Table 1 shows values obtained during a test on an industrial grade ammeter whose range is 0 – 10A.

I Plot the calibration curves for this instrument.

II If the specified tolerance of this instrument is ±1% of full scale deflection; determine from the curves whether it conforms to this tolerance. (12 marks)

Table 1

Industrial grade	0	1	2	3	4	5	6	7	8	9	10
Precision grade	0	0.95	1.85	2.9	3.9	4.95	6	7.05	8.1	9.05	10.05

2. (a) (i) State any two disadvantages of low accuracy in the Ammeter – voltmeter method for measurement of medium resistance.

(ii) A cable is tested by the loss of charge method using a ballistic Galvanometer and gave the following results:

- Discharged immediately after electrification, the deflection is 300 divisions.
- Discharged 30 seconds after electrification, the deflection is 200 divisions.

If the ballistic Galvanometer is connected in parallel with a resistance of 10MΩ and the number of divisions indicated is 150, calculate the insulation resistance of the cable. (9 marks)

(b) With the aid of a labelled circuit diagram derive the expression for low resistance measurement using Kelvin's double bridge. (8 marks)

(c) In measurement of resistance by substitution method a standard 0.5MΩ resistor is used. The Galvanometer has a resistance of 10KΩ and gives deflection as follows:-

(i) with standard resistor, 41 divisions;
(ii) with unknown resistor, 51 divisions;

Calculate the value of the unknown resistance. (3 marks)

3. (a) With the aid of a circuit diagram describe the operation of a single phase volt ampere reactive meter. (4 marks)

(b) With the aid of circuit and phasor diagrams, derive the expression for power factor in a three phase circuit using the two wattmeter method. (7 marks)

(c) A 240volts, 5A, single phase energy meter has a registration constant of 1500 revolutions per kilowatt hour. It is tested using a 240V, 5ampere wattmeter having 600 division and a stop watch. The wattmeter can be read to one tenth of a division while the stop watch can be read to 0.02 seconds. When tested at full load, the meter takes 98.01 seconds to complete 50 revolutions. If the human error in timing is ±0.025 seconds and the wattmeter is accurate to within 0.045% of its full scale deflection, estimate the limit of the meter error. (9 marks)

(a) (i) With the aid of a circuit diagram describe the 'Method of Reversals' for determination of hysteresis loop of a magnetic material.

(ii) Derive the expression for the total iron losses in a magnetic material. (Assume the form factor is constant) (14 marks)

(b) The measured values of iron loss at a given value of maximum flux density are 18watts at 40Hz and 30watts at 60Hz. The test specimen weighs 15kg. If the maximum flux density remains constant, calculate at 50Hz the following losses in watts per kilogram:

(i) Hysteresis
(ii) Eddy current (6 marks)

(a) With the aid of equivalent circuit and phasor diagrams, derive the expression for the actual voltage transformation ratio of a potential transformer. (15 marks)

(b) A potential transformer has:
Primary impedance $Z_p = (400 + j700)\ \Omega$
Secondary Impedance $Z_s = (0.85 + j2.5)\ \Omega$

The primary voltage is 1800 volts and the secondary burden of the transformer is 60VA at 0.65 power factor lagging. Neglecting the magnetisation and core loss current, calculate the actual voltage ratio. (5 marks)

6. (a) (i) Describe any four precautions taken when using sphere gaps for measurement of high voltages.

(ii) With the aid of a diagram explain the 'Sphere Gap' method for measurement of peak values of voltages. (9 marks)

(b) With the aid of a labelled diagram explain the operation of Weston type Electro-dynamometer synchroscope. (6 marks)

(c) With the aid of a diagram derive the expression for RMS value of high voltage across a load using the compensated capacitive potential divider method. (5 marks)

7. (a) (i) State any three advantages of semi-conductor over metal strain gauges.

(ii) With the aid of a labelled block diagram describe a digital data recording system. (8 marks)

(b) (i) Explain the principle of operation of a tape recorder.

(ii) With the aid of a diagram explain the operation of a potentiometric recorder. (9 marks)

(c) A Thermistor has a resistance of 3.52KΩ at 0°C and 726Ω at 58°C. The resistance temperature relationship is given by

$R_T = PRo.\ell^{Q/T}$

If room temperature is 25°C calculate the constants P and Q. (3 marks)

8. (a) (i) State any three advantages of linear variable differential transformer.

(ii) The output of an LVDT is connected to a 6V voltmeter through an amplifier whose amplification factor is 300. An output of 3.5mV appears across the terminals of the LVDT when the core moves through a distance of 0.6mm. If the milli-voltmeter scale has 200 divisions and can be interpolated to one fifth of a division calculate:

I Sensitivity of LVDT
II Sensitivity of the whole set up
III Resolution of the instrument (7 marks)

(b) With the aid of a circuit diagram derive the expression for mutual inductance using maxwells method. (8 marks)

(c) Figure 1 shows schering bridge, at balance calculate the value of:

(i) Capacitance C_1

(ii) dielectric loss angle of capacitor C_1 (5 marks)

$\tan\delta = \omega C_1 r_1$

$\delta = \tan^{-1} \omega C_1 r_1$

$\omega = 2\pi f = 2\pi \times 50$

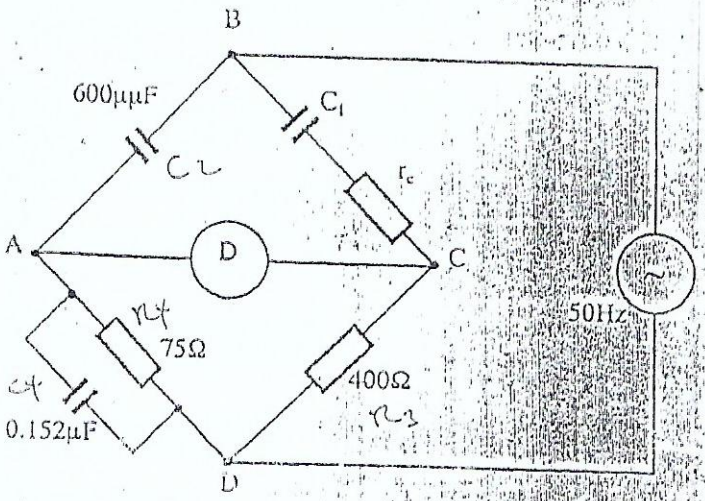


Figure 1

(a) (i) State any two advantages of electronic voltmeters.

(ii) With the aid of a diagram explain the operation of a vibrating reed frequency meter. (8 marks)

(b) With aid of diagrams explain the operation of a Ramp Digital voltmeter. (8 marks)

(c) The torque of an ammeter varies as the square of the current through it. If a current of 5A produces a deflection of 90°, calculate the deflection for a current of 3A when the instrument is controlled by the following methods:

(i) Spring

(ii) Gravity (4 marks)

1 (a) With the aid of a labelled phasor diagram, describe the procedure followed in constructing the circle diagram of a three-phase induction motor. (9 marks)

(b) A 400 V, 13.62 kW, three-phase star-connected 1440 rpm, 4 pole induction motor gave the following results during a test;

no-load test: 400V, 20A, 1200W
blocked rotor test: 100V, 45A, 2800W.

If the stator dc resistance per phase is 0.01 ohm, the ratio of ac to dc resistance is 1:6 and the friction and windage losses are 320 Watts, determine the:

(i) parameters of the approximate equivalent circuit;
(ii) input power;
(iii) power factor;
(iv) gross torque;
(v) output power;
(vi) efficiency.

(11 marks)

2 (a) Explain the following terms with reference to synchronous motors:

(i) pull-in torque;
(ii) pull-out torque;
(iii) running torque.

(3 marks)

(b) Describe the following methods of starting synchronous motors:

(i) provision of damper winding;
(ii) operating a pilot exciter as a dc motor.

(7 marks)

(c) A 3-phase star-connected 6.6kV synchronous motor has a synchronous reactance per phase of 20-ohm and negligible resistance. If the load input is 915kW at normal voltage and the induced emf is 8942V, determine, using phasor diagram, the:

(i) line current;
(ii) power factor.

(10 marks)

3 (a) Explain the necessity for starters in dc shunt motors. (3 marks)

(b) With the aid of a labelled diagram of a dc motor starting resistances, show that the starting resistance is given by the expression $R_1 = K^n R_a$; where K is a constant, R_a is the armature resistance and 'n' is the number of resistance sections. (9 marks)

1. (a) Derive the dimensions of the following quantities using the electromagnetic system of units:

(i) magnetising force;
(ii) potential difference;
(iii) inductance. (10 marks)

(b) The power loss per unit centimeter of a wire is given by the following expression:

$$W \alpha \rho^{p} B^{q} f^{r} d^{s}$$

where:

ρ	=	resistivity
B	=	maximum flux density
f	=	frequency
d	=	diameter of the wire

Using MKSA system of units determine the value of P, Q, V and S. (6 marks)

(c) The resistance of a circuit is found by measuring the current flowing and the power fed into the circuit. If the limiting errors in the measurement of power and current are respectively ± 0.5% and ±1.2%; determine the limiting error in the measurement of resistance. (4 marks)

2. (a) Explain any four factors that affect medium resistance measurement using the wheatstone bridge. (4 marks)

(b) (i) Describe with the aid of diagrams the murray loop test for localization of faults in underground cables.

(ii) A length of cable is tested for insulation resistance by the loss of charge method. An electrostatic voltmeter of infinite resistance is connected between the cable conductor and earth, forming a joint capacitance of 620pF. After charging, the voltage falls from 240V to 96V in 2 minutes.
Calculate the insulation resistance of the cable. (9 marks)

(c) With the aid of circuit and phasor diagrams explain the operation of a single phase electrodynamometer type power factor meter.

(7 marks)

3. (a) Explain three types of detectors used in a.c. bridges. (3 marks)

(b) Explain any:

(i) three precautions necessary when using a.c. bridges;

(ii) three methods of reducing errors in a.c. bridges. (6 marks)

(c) Figure 1 shows a Heaviside Mutual Inductance bridge.

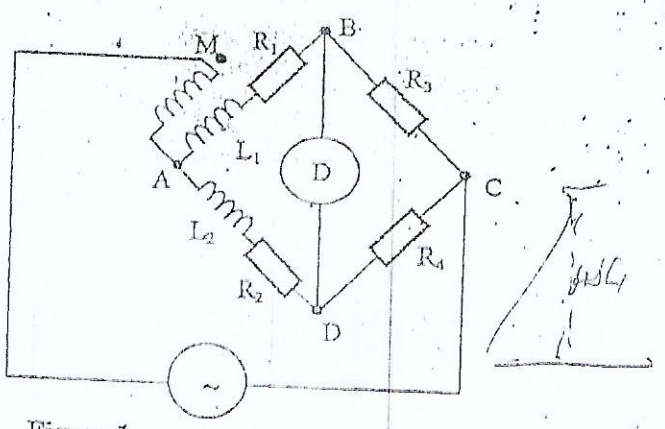


Figure 1

(i) Derive the expression for the balance condition for unknown inductance L_2

(ii) Draw the phasor diagram at balance.

(iii) If the values of $L_1 = 3H$, $L_2 = 5H$, $R_3 = 4\Omega$, $R_4 = 6\Omega$, $R_2 = 7.2\Omega$ and $R_1 = 1\Omega$.
Calculate the value of mutual inductance 'M'.

(11 marks)

4. (a) Describe the alternating current method of determining the core losses in magnetic materials.

(4 marks)

(b) With the aid of a diagram derive the expression for the measurement of flux using the fluxmeter. (12 marks)

(c) A fluxmeter has the following constants:

flux density in the air gap	=	10mwb/m²
Number of turns	=	60
Length of the coil	=	8 cm,
Width of coil	=	1.85 cm

A search coil fo 20 turns and cross-sectional area of $2.5 \times 10^{-4}m^2$ is connected to the fluxmeter. If the field is uniform and of density $0.085wb/m^2$, calculate the fluxmeter deflection when the field direction is reversed.

(4 marks)

5. (a) With the aid of a schematic diagram, explain the operation of the Difference Amplifier type electronic voltmeter. (6 marks)

(b) With the aid of circuit and phasor diagrams, describe the operation of an electronical resonance frequency meter. (9 marks)

(c) With the aid of circuit and waveform diagrams, describe the operation of the sawtooth generator. (5 marks)

6. (a) With the aid of circuit and phasor diagrams derive the expression for total power measured in a three phase star connected balanced load circuit using the two wattmeter method. (9 marks)

(b) A wattmeter is used to measure power in a single phase circuit. The load voltage is 120V 50Hz and the load current is 15A at a lagging power factor of 0.12. The wattmeter voltage coil circuit has a resistance of 3.2KΩ and an inductance of 32mH. The current coil has resistance of 0.2Ω and negligible inductance.
Calculate the value of wattmeter reading when the pressure coil is connected on the load side. (11 marks)

7. (a) Draw a block diagram to show the components of a data recording instrumentation system. (3 marks)

(b) With the aid of circuit diagrams describe the operation of a linear variable differential transformer in the measurement of displacement. (8 marks)

(c) A semi-conductor strain gauge is bonded to a steel beam 0.25m long and has a cross-sectional area of 4.75cm^2. Young's modulus of steel is 200 GN/m^2. The strain gauge has an unstrained resistance of 200Ω and a gauge factor of 2.06. When a load is applied, the resistance of the gauge changes by 0.0125Ω.

Calculate:

(i) the change in length of the steel beam;
(ii) the amount of force applied. (4 marks)

(d) With the aid of a diagram describe measurement of pressure using the spiral type Bourdon tube. (5 marks)

8 (a) (i) State any two applications of optical recorders.

(ii) With aid of a labelled diagram explain the principle of operation of ultra violet recorder.
(9 marks)

(b) Figure 2 shows Wein bridge used for measurement of capacitance. If the bridge is balanced:

(i) derive expression for unknown capacitance C_1;

(ii) sketch the phasor diagram.
(11 marks)

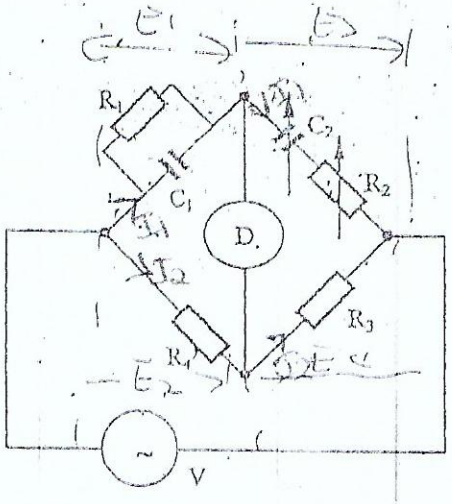


Figure 2

9 (a) (i) State four precautions that may be taken into consideration when using a multirange voltmeter.

(ii) With the aid of a circuit diagram describe the operation of a multirange ammeter.
(10 marks)

(b) A universal shunt has a total resistance of 6KΩ. Determine the multiplying power of a shunt for 1500Ω and 3000Ω tapping if a milliammeter has resistance of 26Ω.
(4 marks)

(c) With the aid of a diagram describe the calibration of an ammeter by the potentiometer method.
(6 marks)

1. (a) Define the following terms with reference to measurement systems:

(i) sensitivity;
(ii) resolution;
(iii) repeatability.

(3 marks)

(b) Derive the dimensional equations for the following electrical quantities using the e.m system of units:

(i) magnetising force; $\checkmark H = \frac{\text{force}}{\text{pole strength}}$
(ii) reluctance. $= \frac{B}{H} = \frac{\text{Flux}}{\text{Area}} = \frac{\text{current}}{\text{Area}}$.

(4 marks)

(c) The mean deflecting torque of the electro-dynanometer type wattmeter is given by the expression:

$$Td \propto V^p M^q Z^r$$

Where:

V = voltage applied
M = mutual inductance between fixed and moving coils.
Z = impedance of the load circuit.

Determine the values of p,q and r from the dimensions of the quantities.

(7 marks)

(d) With the aid of labelled diagrams, describe the Carey-Foster slide-wire bridge method for low resistance measurements.

(6 marks)

2. (a) State any **three** advantages of Magnetic Tape recorders. (3 marks)

(b) Explain the procedure for calibration of a d.c. voltmeter using the potentiometer method.

(4 marks)

(c) With the aid of labelled diagrams, describe the:

(i) potentiometric type digital voltmeter;
(ii) strain gauge circuit for dynamic measurement and recording of electrical quantities;
(iii) operation of the moving iron synchroscope.

(13 marks)

3. (a) Explain the ammeter/ voltmeter method of inductance measurements. (4 marks)

(b) Figure 1 shows the circuit diagram of the Modified Campbell bridge circuit. Derive the expression for the unknown capacitance C and the unknown inductance L.

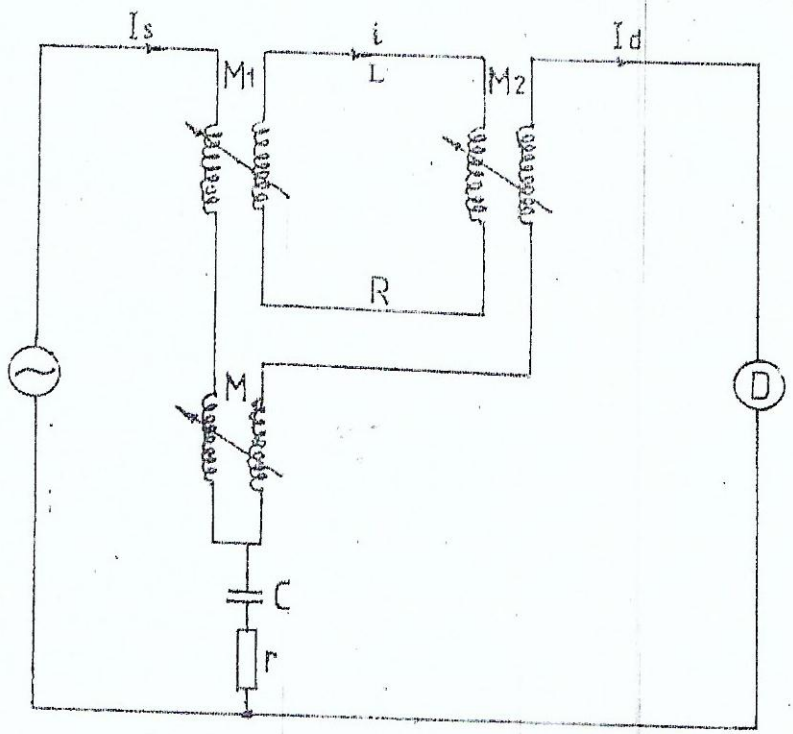


Fig. 1

C = pure capacitor representing an imperfect capacitor
r = series resistance
M, M1 and M2 are three variable mutual inductances.

(10 marks)

(c) The arms of a four arm bridge d e f a is supplied with ac voltage and gives the following values:

Arm d e: A resistance of 200 ohm in parallel with a capacitance of 1μF;
Arm e f: 400 ohm resistance
Arm f g: 1000 ohm resistance
Arm g d: A resistance R_2 in series with a 2 μF capacitance.

Determine the value of R_2 and the frequency at which the bridge will balance.

(6 marks)

(a) With the aid of labelled diagrams, describe the operation of single phase core type high voltage testing transformer. (7 marks)

(b) Figure 2 shows a two core cable AB of 96 m length with partial break between each core and earth at a point x km from A. The resistance between the cores at A with B open circuited is 1200 ohm. The resistance between core 1 and earth at A with B earthed is 300 ohm and the resistance between core 2 and earth at A with B earthed is 360 ohm. If the resistance of the cable is 5.75 ohm per km per core, determine the distance x.

(13 marks)

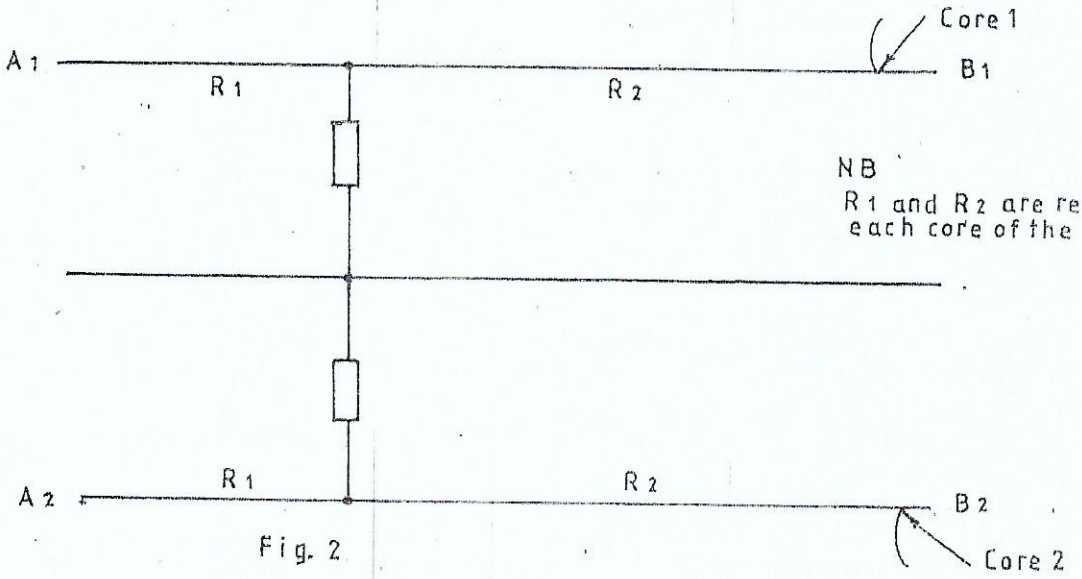


Fig. 2

5. (a) Explain the following terms with reference to measurement systems:

(i) true value;
(ii) static error;
(iii) observational error.

(6 marks)

(b) A voltmeter having a sensitivity of 1000 Ω/V reads 100 V on its 150 V scale when connected across an unknown resistor in series with a milliameter. When the milliammeter reads 5mA, determine the:

(i) apparent resistance of the unknown resistor;
(ii) actual resistance of the unknown resistor;
(iii) error due to the loading effects of the voltmeter.

(3 marks)

(c) (i) State any three advantages of instrument transformers.

(ii) A current transformer has a bar primary and 200 secondary winding turns. The secondary winding burden is an ammeter of resistance 1.2 ohm and reactance 0.5 ohm. The secondary winding has a resistance 0.2 ohm and reactance of 0.3 ohm. The core requires the equivalent of an mmf of 100 A for magnetization and 50 A for core losses. Determine the primary winding current and the "Ratio Error" when the ammeter in the secondary winding circuit indicates 5A.

(11 marks)

(c) An iron ring has a mean diameter of 0.1 m and a cross-section of 33.5 mm^2. It is wound with a magnetising winding of 320 turns and a secondary winding of 220 turns. On reversing a current of 100 A in the magnetising winding, a ballistic galvanometer gave a throw of 272 scale divisions while a Hibberts magnetic standard with 10 turns and a flux of 0.025×10^{-3} Wb gave a reading of 102 scale divisions.
Determine the relative permeability of the specimen. (10 marks)

9. (a) State any **three** factors that influence the choice of a transducer for measurement of physical quantity. (3 marks)

(b) (i) With the aid of a block diagram, describe the d.c. signal conditioning system.

(ii) Draw the strain gauge bridge circuit with IC operational amplifier.

(9 marks)

(c) A single strain gauge having resistance of 120 ohm is mounted on a steel cantilever beam at a distance of 0.15 m from the free end. The change in gauge resistance is found to be 0.152 ohm. The beam is 0.25 m long with a width of 20 mm and length of 3 mm. An unknown force 'F' applied at the free end of the beam produces a deflection of 12.7 mm at the free end. If the Young's Modulus of steel is 200 GN/M^2. Determine the gauge factor. (8 marks)

(i) temperature;

(ii) contact resistance. (2 marks)

(b) A test voltage is applied for several minutes between the conductors of a 500 metre length of cable and earth. A galvanometer connected in series with the cables reads 250 divisions with a shunt multiplier value of 2.5. If a standard resistance of 1 MΩ is inserted in the circuit the scale reads 350 divisions when the value of shunt multiplier is 1000. Calculate the insulation resistance of the cable. (5 marks)

(c) With the aid of a labelled diagram, explain the working principle of the Kelvins double bridge for the measurement of low resistance. (7 marks)

(d) In a test for a fault to earth by Murray loop test, the faulty cable has a length of 6.8 km. The faulty cable is looped with a sound cable of the same length and cross section. The resistance of ratio arms are 120 Ω and 60 Ω at balance.

(i) sketch the scheme of connection;

(ii) calculate the distance of the fault from the test end. (6 marks)

2. (a) State any **two** advantages of digital techniques in electrical measurement systems. (2 marks)

(b) Derive the dimensional equations of the following quantities in electrostatic system of units:

(i) charge;

(ii) current. (7 marks)

(c) In an experiment, the expression for eddy current produced in an iron former situated in the field of a permanent magnet was found to be:

$$I_e = k\frac{BlbA}{(2b+1)\rho}$$

where: B = flux density
l = length of iron former
b = width of iron former
A = area of iron former
ρ = resistivity of conducting iron former
k = constant of proportionality

Using the LMTI system of units, determine whether the expression is dimensionally correct. (11 marks)

The secondary winding supplies a current of 4A to a non-inductive burden of 2 Ω resistance. The flux in the core is set up by an mmf of 100 A. The supply frequency is 50 Hz. Calculate the:

(i) transformation ratio;

(ii) phase angle of the transformer. (10 marks)

5. (a) (i) Define "hysteresis" in magnetic circuits.

(ii) The hysteresis loop of a magnetic materials is drawn to the following scales: 1 cm = 200 AT/m and 1 cm = 0.2 wb/m^2. The area of the loop is 48 cm^2. If the density of the material is 7.8×10^3 kg/m^3, determine the hysteresis loss in watts/kg at frequency of 50 Hz. (8 marks)

(b) Table 1 shows data for a ferromagnetic material tested with the help of a permeameter provided with coil B wound over the specimen and another coil H wound near the surface. These two coils are connected to two separate ballistic galvanometers having a constant of 25×10^{-6} weber-turn per scale division. The testing is done by reversing the current of the magnetising winding wound over the specimen. The reading of the ballistic galvanometer to coil B is 120 divisions and that connected to coil H is 12 divisions. Determine for the specimen:

(i) flux density;

(ii) magentising force. (12 marks)

Table 1

Coil	Turns	Area
B	150	50×10^{-6} m^2
H	15,000	5×10^{-6} m^2

6. (a) With the aid of circuit and phasor diagrams, derive the expression for the power factor using the two wattmeter method for a three phase balanced load. (15 marks)

(b) A three phase 0.5 kV motor load has a power factor of 0.4. Two wattmeters connected to measure the input power indicate 40 kW. Determine the reading of each wattmeter. (5 marks)

7. (a) State any two adjustments carried out in energy meters so that they read correctly.
(2 marks)

(b) Draw a labelled diagram of a two element energy meter
(4 marks)

(c) With the aid of circuit and waveform diagrams describe the operation of a peak reading diode voltmeter.
(9 marks)

(d) A $4\frac{1}{2}$ digit voltmeter is used for voltage measurements:

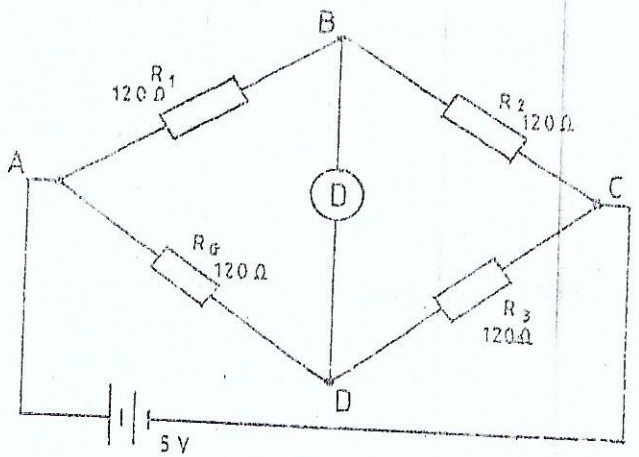
(i) Determine the voltmeter resolutions;

(ii) Explain how a reading of 0.6973 would be displayed on 1 V range. (5 marks)

8. (a) (i) Define the term "instrumentation" as applied in electrical engineering;

(ii) With the aid of a block diagram, describe the main elements of an instrumentation system.
(8 marks)

(b) The diagram of figure 2 shows a wheatstone bridge circuit used in the measurement of strain. Calculate the output voltage when the strain gauge resistance changes by 1.2 Ω.
(7 marks)



NB: R_G = resistance of strain gauge.

Fig. 2

(c) With the aid of a diagram, describe the operation of the pH cell in industrial process.
(5 marks)

9. (a) With the aid of a diagram, describe the crossed phase method of measuring reactive power in 3 phase 3 wire circuits. (6 marks)

(b) A temperature measuring system incorporates a platinum resistance thermometer, a wheatstone bridge, a voltage amplifier and a pen recorder. The sensitivities in the transducer, wheatstone bridge, amplifier gain and pen recorder are 0.35 ohm/°C, 0.01 V, 100 V/V and 0.1 cm/V respectively. Determine the:

(i) overall system sensitivity of the system;

(ii) temperature change corresponding to a pen recorder movement of 5 cm. (6 marks)

(c) (i) With the aid of a diagram, describe the elements of a magnetic tape recorder;

(ii) A magnetic tape has a number density of 8 numbers per millimeter and moves at a speed of 1.5 m/s. Determine the numbers received by the tape in one second. (8 marks)

1. (a) Define the following terms as applied in electrical measurements:

(i) Dimension;
(ii) Unit. (2 marks)

(b) State **three** disadvantages of the C.G.S. over the MKS system of units. (3 marks)

(c) Explain the following types of errors in measurements:

(i) gross errors;
(ii) systematic errors;
(iii) random errors. (6 marks)

(d) A 0 - 200 V voltmeter has a guaranteed accuracy of 0.8 % of full scale reading. The voltage measured by this instrument is 80 V. Determine the:

(i) relative error;
(ii) limits within which the value of measured voltage lies. (9 marks)

2. (a) Outline **three** features of international standards. (3 marks)

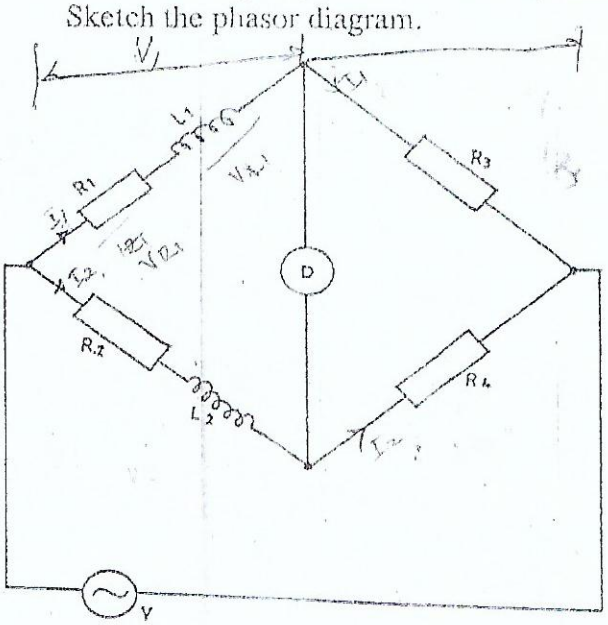
(b) Explain how the following types of errors occur in a.c. bridges and in each case state how they are minimized.

(i) stray conductance effects;
(ii) eddy current. (6 marks)

(c) (i) State the **three** types of detectors used in a.c. brides.

(ii) Figure 1 shows a balanced a.c. bridge:

I. Derive the expression for the unknown components L_1 and R_1.
II. Sketch the phasor diagram. (11 marks)



3. (a) State the **three** types of tests that are used for testing of magnetic materials. (3 marks)

(b) With the aid of a circuit diagram describe the step by step method of determining the B-H curve in magnetic measurements. (6 marks)

(c) A soft iron ring has a mean diameter of 0.12 m. It is wound with magnetising winding of 400 turns and secondary winding of 200 turns. On reversing a current of 12 A in the magnetising winding, a ballistic galvanometer gives a throw of 282 scale divisions, while a Hibbert magnetic standard with 12 turns and a flux of 0.3×10^{-3} Webers gives a reading of 120 scale divisions.
Determine the relative permeability of the specimen. (11 marks)

4. (a) State any **three** causes of errors in electrodynamometer wattmeters. (3 marks)

(b) With the aid of circuit and phasor diagrams derive the expression for power measured in a three phase balanced load using one wattmeter method. (11 marks)

(c) A 240 V single phase watt hour meter has a constant load current of 5 A flowing through it for 8 hours at unity power factor. The meter disc makes 2400 revolutions during this period. Determine the meter constant. (6 marks)

5. (a) Define the following terms in relation to potential transformers:

(i) nominal ratio;

(ii) turns ratio. (2 marks)

(b) With the aid of labelled equivalent circuit and phasor diagrams derive the expression for transformation ratio of a current transformer. (9 marks)

(c) A current transformer with a bar primary has 420 turns in its secondary winding. The resistance and reactance of secondary winding circuit are 2 Ω and 1.5 Ω respectively. When a current of 10 A flows in the secondary winding the magnetizing mmf is 100 A and the iron loss is 1.5 watts. Determine the ratio error. (9 marks)

6. (a) (i) State **two** applications of cathode ray oscilloscope.
(ii) Draw a labelled block diagram of a cathode ray oscilloscope. (8 marks)

(b) A beam of electrons leave the cathode of a cathode ray tube with zero velocity. The cathode-anode voltage is 1 KV. Determine the maximum velocity of the electron beam. (2 marks)

(c) (i) With the aid of a diagram, explain the capacitance potential divider method of high voltage measurement.
(ii) State **three** advantages of the method in (c)(i). (10 marks)

7. (a) Explain any **three** difficulties encountered in the measurement of high resistance. (6 marks)

(b) With the aid of a circuit diagram explain measurement of insulation resistance of a cable using the loss of charge method. (6 marks)

(c) Table 1 shows the result of a test on a cable by loss of charge method using a ballistic galvanometer. Use the results to determine the insulation resistance of the cable (8 marks)

	Galvanometer Deflection
Discharged immediately after electrification	220 divisions
Discharged after 36 seconds and after electrification	150 divisions
Discharged after 36 sec after electrification and in parallel with a resistance of 12 MΩ	120 divisions

8. (a) State any **three** advantages of digital voltmeters over analogue voltmeters. (3 marks)

(b) (i) Draw a labelled block diagram of a digital voltmeter.

(ii) A $4\frac{1}{2}$ digital voltmeter has an accuracy of $\pm 0.5\%$ of reading and $\pm$ 1 digit. Determine the resolution of the instrument for a 20 V range. (6 marks)

(c) With the aid of a diagram explain the operation of a helical bourdon tube used in pressure measurement. (6 marks)

(d) A resistance wire strain gauge with a gauge factor of 3 is bounded to a steel structural member subjected to a stress of 120 MN/m^2. The modulus of elasticity of steel is 200 GN/m^2. Determine percentage change in the value of the gauge resistance due to the applied stress. (5 marks)

9. (a) State **three** advantages of magnetic tape recorders. (3 marks)

(b) (i) Explain the functions of the following components of a tape recorder:
I. recording head;
II. tape transport mechanism;
III. conditioning devices.

(ii) The recorded wavelength by a tape recorder is 18.0 μm. The speed of the tape is 0.9 m/s. Determine the frequency for satisfactory recording. (9 marks)

(c) (i) Outline three conditions observed before a three phase alternator can be synchronized to a three phase busbar.

(ii) With the aid of a diagram describe the operation of a Weston type synchroscope. (8 marks)