Supplement

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The answers to the examination papers which are given in this Supplement are not claimed to be thoroughly exhaustive and complete. They are, however, accurate so far as they go and are such as might be given within the time allowed by any student capable of securing high marks in the examinations.

CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS, 1932

1.—MAGNETISM AND ELECTRICITY: QUESTIONS AND ANSWERS.

W. S. PROCTER, A.M.I.E.E.

Q. 1. Express by a formula the relationship between the electrical resistance of a wire and its dimensions.

A given length of wire has a resistance of 30 ohms. The wire is cut into three equal lengths and they are connected in parallel. What is the combined resistance of the three pieces?

A. 1. $R = \frac{\rho l}{a}$, where R = resistance of wire, in ohms,

l = length of wire, in cms,

a = cross-sectional area of wire, in sq. cms,

and ρ = resistivity of material from which wire is drawn, in ohms per cm. cube.

When the wire is cut into three equal lengths, the resistance of each piece is $\frac{30}{3} = 10$ ohms. When the three pieces are connected in parallel, their joint resistance is $10/3 = 3\frac{1}{3}$ ohms.

Q. 2. What power is lost in a resistance R through which a current is flowing, the potential difference between the ends of the resistance being E?

An electric lamp for a 240-volt supply is rated at 60 watts. What is its resistance? If used with a voltage of 210 volts what power would it take, assuming that its resistance remains constant?

A. 2. P = EI watts. $I = \frac{E}{R}$ $\therefore P = \frac{E^2}{R}$ watts.

where P = the power in watts,

E = the difference of potential, in volts,

I = the current, in amperes,

and R = the resistance in ohms.

The resistance of the lamp, R_1, is

$$R_1 = \frac{E^2}{P} = \frac{240 \times 240}{60} = 960 \text{ ohms.}$$

The power taken by the lamp when connected to a voltage of 210 volts is, assuming that the resistance of the lamp remains unaltered, $P = \frac{E^2}{R} = \frac{210 \times 210}{960} = 46$ watts, approx.

Q. 3. Give brief explanations or definitions of the following terms:—Astatic Needles, Magnetic Equator, Lines of Magnetic Force, Moment of a Magnet, Electric Density, Electrostatic Induction.

A. 3. *Astatic Needles.* A combination of magnetic needles, so arranged that the effect of the earth's magnetic field upon the system is zero or practically so.

Magnetic Equator. The line of zero dip which surrounds the earth in the neighbourhood of the geographical equator.

Lines of Magnetic Force. The imaginary paths along which a single N. pole would travel if free to move.

Moment of a Magnet. The product of the distance between the poles of a magnet and the strength of one pole.

Electric Density. The strength of the electric field at a point, *i.e.*, the force in dynes acting on a unit positive charge situated at that point.

Electrostatic Induction. The production of an electric charge on a body or bodies in the neighbourhood of a charged body.

Q. 4. Explain why the internal resistance of a Leclanché dry battery increases, when in constant use, from its value when new. 12 cells, each 1.5 volts and ½ ohm internal resistance, are connected in series with an external resistance of 18 ohms. What is the current in the circuit? If four of the cells are connected in opposition to the others, what current will flow in the circuit?

A. 4. The internal resistance of a Leclanché dry battery in constant use increases on account of the gradual evaporation of the moisture in the exciting and depolarizing pastes, and the disintegration of the zinc. In addition, an increase in resistance may be due to the gradual exhaustion of the depolarizer or to the inability of the depolarizer to absorb the hydrogen liberated by the passage of an excessive current.

$$I = \frac{E}{R} = \frac{12 \times 1.5}{6 + 18} = \frac{18}{24} = 0.75 \text{ ampere, or } 750 \text{ mAs.}$$

With four cells connected in opposition to the remaining eight, $I = \frac{E}{R} = \frac{6}{6 + 18} = \frac{6}{24} = 0.25$ ampere, or 250 mAs.

Q. 5. Two copper plates are immersed in a solution of copper sulphate and connected to a battery of cells. Describe what action takes place and explain, by formula or otherwise, how the effect depends on the strength of the current and the time the current flows. State a practical application of the effect.

A. 5. The combination forms a copper voltameter; the plate at which current enters is termed the anode, that at which the current leaves being known as the cathode. During the passage of the current, the copper sulphate ($CuSO_4$) is split up into copper (Cu) and a compound of sulphur and oxygen (SO_4). The copper is deposited on the cathode, whilst the

SO_4 passes to the anode where it combines with copper to form copper sulphate. The result is therefore that the anode loses an amount of copper which is gained by the cathode; further, the strength of the copper sulphate solution remains unchanged.

The amount of copper deposited on the cathode is $w = eIt$, where w = weight of copper deposited, in grams.

e = electro-chemical equivalent (E.C.E.) of copper.

I = current flowing, in amperes.

t = time for which current flows, in seconds.

The E.C.E. of a metal is the weight deposited by one coulomb of electricity (*i.e.*, one ampere flowing for one second) and is expressed in grams. The E.C.E. of copper is .000329 gram per coulomb.

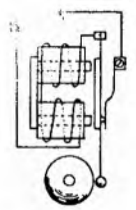
Among the practical applications of electrolysis are electroplating processes, electrolytic refining processes, and methods of determining polarity by the use of pole finding paper and similar means; the copper voltameter is also used in laboratories for the calibration of ammeters.

Q. 6. Explain briefly what is meant by Self-Induction.

Show, by means of a diagram, how a simple trembling bell operates and explain the effect of the self inductance of the coils.

A. 6. Self-induction is the name given to the production of a counter e.m.f. in a circuit by an alteration in the strength of the current flowing in that circuit. The counter e.m.f. is generated by variation in the flux set up around the conductor which causes the conductor to be cut by the changing lines of force; by Lenz's Law, the direction of the resulting e.m.f. is opposed to the e.m.f. applied to the circuit.

A diagram of a simple trembling bell is shown in the sketch.



With the armature at rest, the completion of the external circuit causes a current to flow through the coils of the electromagnet. The resulting flux causes the attraction of the armature, which, in turn, disconnects the circuit at the local contact. The magnetic field collapses and the armature is returned to normal by the restoring spring. The circuit is now completed by the local contact and the cycle of operations recurs. The armature therefore vibrates so long as the external circuit remains closed and the hammer carried on the armature extension piece strikes the gong at each vibration.

The effect of the self-inductance of the coils is to cause sparking to occur at the armature contacts at the moment of disconnexion; the collapse of the magnetic field generates an e.m.f. which is of sufficient magnitude to give rise to a spark across the contact gap the instant disconnexion occurs.

Q. 7. What is the relationship between the electrostatic charge on a condenser, the potential between its plates and its capacity?

A condenser of two microfarads capacity is connected in series with a second condenser and the capacity of the combination is 1.2 microfarads. What is the capacity of the second condenser?

A. 7. $C = \frac{Q}{V}$, where C = the capacity of the condenser,

Q = the charge on the condenser,

and V = the potential difference between its plates.

$\frac{1}{C_1} = \frac{1}{C_2} + \frac{1}{C_3}$, where C_2, C_3, are the capacities of the individual condensers and C_1 is their joint capacity when connected in series.

$$\frac{1}{1.2} = \frac{2}{1} + \frac{1}{C_3} \therefore \frac{1}{C_3} = \frac{1}{1.2} - \frac{1}{2} = \frac{2 - 1.2}{2.4} = \frac{0.8}{2.4}$$

$$\therefore C_3 = \frac{2.4}{0.8} = 3\ \mu F.$$

Q. 8. Express, by formula, the relationship between the force acting between two small electrified bodies, the quantity of charge, and the distance between them. How would you prove the formula experimentally?

A. 8. $f = \frac{q_1 q_2}{d^2}$, where f = the force, in dynes,

q_1, q_2 = the quantity of charge on the two bodies, in C.G.S. units.

and d = the distance between them, in cms.

The force is one of attraction if the formula gives a negative answer, and one of repulsion if the answer is positive.

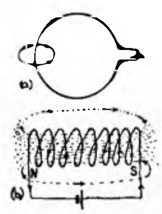
A torsion balance may be used to prove the formula experimentally. Essentially, the instrument consists of a light insulated arm supported within a cylindrical glass case by a fine silver wire; a pith ball is fixed to one end of the arm. The upper end of the wire is fixed to a screw carrying a pointer moving over a scale divided into degrees; by turning the screw, a greater or lesser amount of torsion can be given to the wire, the *force* of the torsion being directly proportional to the *angle* of torsion. A second pith ball, carried on the end of a glass rod, can be inserted into the case. A scale, engraved in degrees, is marked around the glass case at the level of the pith balls.

In the experiment, both pith balls are charged with like polarity and therefore repel one another. The amount of repulsion is read in degrees on the lower scale; suppose this to be 30°. The distance is reduced to 15° by turning the screw, so imparting torsion to the suspending wire, and the amount of movement of the screw required to do this is read from the upper scale; let this be 105°. In the first instance, the torsion in the wire is 30°, whilst in the second instance it is 105 + 15 = 120°. Thus, when the distance between the pith balls is reduced to one-half, the force between them is four times as great.

By successively imparting charges of different values to the two pith balls, and noting the amount of repulsion between them, it can be similarly demonstrated that the force between them at any given distance is proportional to the product of the two quantities of electricity on the pith balls.

Q. 9. Show clearly, by means of diagrams, the lines of magnetic force due to the current flowing (a) in a single circular loop of wire, (b) in a long solenoid.

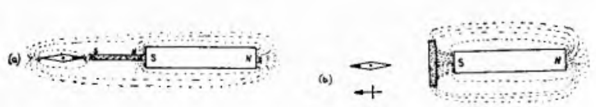
Indicate the direction of the current and the magnetic polarity. State a rule for determining the polarity.



A. 9. The polarity may be determined by Fleming's Right Hand Rule: if the fingers of the right hand be placed around the solenoid in such a position that the current flows in the direction from the wrist to the tips of the fingers, then the outstretched thumb points towards the North pole of the solenoid.

Q. 10. A bar magnet is placed horizontally in the magnetic meridian with its South pole towards the North. A compass needle is placed with its centre in line with the bar magnet, a short distance due north from it. Show, by drawing the lines of magnetic force, the action of the bar magnet on the compass needle when (a) a thin rod of soft iron is placed between them, along the line which joins their centres, (b) a plate of soft iron is placed across the space between them.

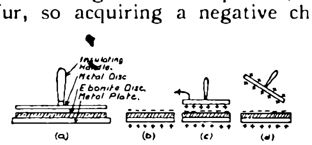
A. 10.



Q. 11. Describe the electrophorus and explain with sketches the method of charging it.

A. 11. The electrophorus consists essentially of a circular sheet of ebonite fixed to a metal sheet (see sketch (*a*)) and a brass plate, of slightly less diameter than the ebonite sheet, provided with an insulating handle.

To charge the electrophorus, the ebonite plate is rubbed with fur, so acquiring a negative charge (sketch (*b*)). The brass disc is then placed upon the ebonite sheet; actually it may be regarded as in contact with the ebonite at only a small number of points and, hence, its under surface is positively, and its upper surface negatively, electrified by induction. The disc is then earthed by touching it with the finger, when electrons are repelled through the body to earth, so leaving the disc positively charged (sketch (*c*)). The disc is lifted away by means of the insulating handle, and the positive charge utilised as required, (sketch (*d*)).



As the charge on the disc is obtained by induction, a number of charges may be obtained from the initial charging of the ebonite.

Q. 12. The soft iron keeper of a horse-shoe electromagnet is (a) fixed a short distance away from the poles of the magnet, and (b) allowed to rest on the poles. Compare the magnetic circuits in the two cases and explain what is meant by the reluctance and magneto-motive force. How is the latter measured?

A. 12. In (*a*), the reluctance of the air gaps is extremely high compared with the rest of the magnetic circuit, with the result that with a given magneto-motive force the flux will be considerably reduced. In (*b*), the air gap is reduced to very small dimensions and the reduction in the reluctance results in a considerable increase in the flux produced by a given magneto-motive force.

Reluctance (s) is the resistance offered by a substance to the passage of magnetic lines of force. It is directly proportional to the length (l) and inversely proportional to the product of the cross-sectional area (a) and the permeability (μ) of the substance. Thus, $s = \frac{l}{a\mu}$

Magneto-motive force is the power of a current flowing in a solenoid to set up a magnetic field; it is given by 1.257 NI, where N = the number of turns of wire and I = the current flowing in amperes.

The law of the magnetic circuit is—

$$\text{Flux} = \frac{\text{Magneto-motive force}}{\text{Reluctance}} = \frac{1.257\,NI}{\frac{l}{a\mu}}$$

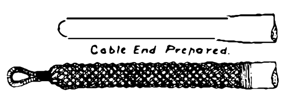
A measure of the magneto-motive force may be obtained by comparing the forces required to pull the keeper away from the poles with different values of current flowing in the coils. The pull exerted by a magnet is directly proportional to the square of the flux density which, in turn, is directly proportional to the magneto-motive force.

II.—TELEPHONY, PRELIMINARY: QUESTIONS AND ANSWERS

W. S. PROCTER, A.M.I.E.E.

Q. 1. Describe a cable grip and also the process of fitting and using it. (30 marks).

A. 1. A cable grip consists of a woven lattice of steel wire, circular in shape and having one end open; at the other end the wires forming the lattice are brought together and bound, and then formed into an eye (see sketch). In fitting the grip to a cable end, the sealing disc on the end of the cable is removed and, by means of a punch, the conductors are doubled back inside the sheath for about ¾ of an inch. The lead sheath is then dressed over the opening until it is reduced to slightly less than half the diameter of the cable. A cup-shaped lead disc is pushed into the opening and the cable end sealed by filling the recess with solder; the sealed end is moulded into a rounded form as shown in the sketch. The cable sheath is next dressed down on to the wires to consolidate the cable so that part of the stress is borne by the wires. The cable grip is compressed lengthwise and then pushed on to the prepared cable end. When the nose is hard up against the cable end, the mouth of the grip is pulled away from the nose so as to cause the lattice to grip the cable tightly. The mouth is then securely bound to the sheath by means of strong twine.



The drawing-in rope having previously been pulled into the duct, the eye of the grip is attached to the swivel, fixed to the end of the rope, by means of a keystone connecting link. Tension on the rope causes the grip to contract and grasp the cable sheath firmly, so ensuring that the cable follows the rope along the duct.

Q. 2. Compare sal-ammoniac and manganese chloride as excitants for primary cells. (30).

A. 2. The chemical action which takes place in a Leclanché cell charged with sal-ammoniac results in the generation of free ammonia gas. An account of the deleterious effect which this gas has upon metal work and upon the acid solution in any adjacent secondary cells, it is necessary to provide free ventilation in any battery compartment used for accommodating such primary cells. This, in turn, facilitates the evaporation of the sal-ammoniac solution.

With manganese chloride as the excitant, no free gases are evolved. The cells can, therefore, be sealed, thereby practically stopping evaporation and, at the same time, preventing the oxidation which takes place when manganese chloride, whether in crystal or solution form, is exposed to the atmosphere. If a cell containing manganese chloride is not sealed, the zinc rod becomes coated with an oxide, which has the effect of increasing the internal resistance.

Cells charged with manganese chloride give a slightly higher e.m.f. than those charged with sal-ammoniac, but, on the other hand, they are not so efficient for heavy rates of discharge.

Q. 3. Describe briefly a system of underground cable records. (30).

A. 3. In a typical system of underground cable records, ordnance map records, diagrams and card records are used. The *ordnance map record* shows the whole of an area, to a suitable scale, together with all details of the underground cable routes; symbols are used to denote D.Ps., manholes, joint boxes, etc. The *conduit diagram* shows the distance between each jointing point; the size and type of the duct; and the number of ways in use. In addition, a record of the location and depth of all buried boxes, couplings, etc., is kept by means of a series of small diagrammatic maps. The *cable diagram* shows the size and weight of conductor for each cable in the area whilst the *cable pair distribution diagram* records the method in which the wires are connected, all stumped pairs, jointing points and D.Ps.

being shown together with the main cable numbers of all the pairs led to the D.Ps. *Block wiring* and *P.B.X. distribution* details are recorded on small diagrams whilst records of *direct underground distribution* to subs' premises are contained on large scale maps.

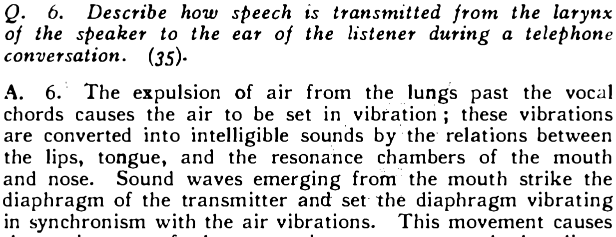
The card record consists of a card for each D.P. showing details of the D.P. pair numbers, the corresponding M.D.F. bar and pair numbers, the exchange number and name and address of the sub working on each pair; the calculated line resistance, and details of tied or interconnected pairs are also shown. A card record for each main cable shows the D.Ps. which it serves, the weight of conductor and the route length for each pair, and the position on the M.D.F. Finally, an index card correlating M.D.F. bar and pair numbers with D.P. pair numbers, together with a card record for all miscellaneous circuits completes the scheme.

Q. 4. Describe a 2 M.F. condenser as used in telephony. (30).

A. 4. A typical 2 μF condenser used in telephony consists of two strips of tinfoil paper and two strips of plain paper arranged alternately and rolled up together; about 21 sq. ft. of tinfoil surface are required for each plate. The tinfoil paper is prepared by pasting finely-divided tin upon one side of a thin body paper, the tinfoil surface being subjected to a calendering process during manufacture to make the tin coating practically continuous, so improving its electrical conductance. The purpose of the interleaving paper is to increase the dielectric strength and also to obtain high insulation. Connexion to the plates is effected through strips of thin metal foil laid between the foiled surfaces and the interleaving paper. The roll of tinfoil and interleaving paper with the metal foil lugs is desiccated and then treated with hot paraffin wax; when cold, the roll is compressed to the required size. The condenser is placed in a protective metal case and the metal foil strips are connected to soldering tags projecting from one end of the case.

Q. 5. Draw one *of the following circuits:—*
(a) A subscribers' multiple C.B.S. exchange termination.
(b) A subscribers' multiple C.B. exchange termination.
(c) An operators' C.B. head set circuit. (35).

A. 6. See sketches (*a*), (*b*) or (*c*) respectively.



Q. 6. Describe how speech is transmitted from the larynx of the speaker to the ear of the listener during a telephone conversation. (35).

A. 6. The expulsion of air from the lungs past the vocal chords causes the air to be set in vibration; these vibrations are converted into intelligible sounds by the relations between the lips, tongue, and the resonance chambers of the mouth and nose. Sound waves emerging from the mouth strike the diaphragm of the transmitter and set the diaphragm vibrating in synchronism with the air vibrations. This movement causes the resistance of the transmitter to vary and the direct current flowing through the transmitter is thereby varied in strength.

In a local battery telephone, the primary winding of an induction coil is included in the transmitter circuit and the variations in the strength of the direct current cause an alternating e.m.f. to be generated in the secondary winding. The resulting alternating current has a wave form closely approximating to that of the original sound wave in the air.

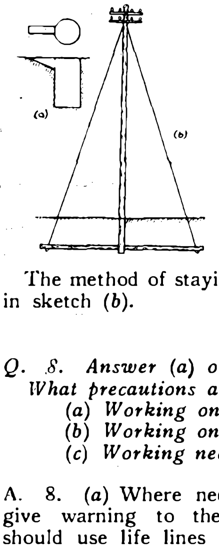
The current is transmitted over the circuit connecting the two telephones and at the receiving end flows through the coils of a polarized electromagnet termed a receiver. The receiver diaphragm is normally held towards the poles; when the magnetic field set up by the alternating current assists the permanent field, the diaphragm is drawn still further towards the poles; whilst when the magnetic field opposes the permanent field, the diaphragm moves away from the poles. The diaphragm is thereby made to vibrate and its vibrations closely follow those of the incoming alternating current.

The receiver is held to the ear and, on account of the small volume of air between the diaphragm and the ear drum, a minute movement of the diaphragm is rendered audible by causing the ear drum to move and thereby stimulate the nerves of the ear, so causing the sensation of sound to be recorded by the brain.

Q. 7. Describe the method of erecting a pole, using the "bar and spoon." Compare this system with the stepped hole method.
How is a pole stayed in marshy ground? (35).

A. 7. A circular hole, some 6″ larger in diameter than the butt of the pole, is excavated by pick and shovel to a depth of about 18″. The hole is deepened by loosening the earth by means of the digging bar and scooping the loose earth out with the spoon. When the desired depth is reached, the bottom of the hole is well punned to ensure that the pole stands on firm soil.

A small channel is cut outward from the edge of the hole to facilitate erection of the pole (sketch (*a*)) and the butt is placed in position in the channel. The digging bar is placed in the hole to act as a slide for the butt, and the pole is raised by means of pole lifters. The hole is filled in and the earth consolidated by using the punner end of the digging bar. Finally, any turf which has been removed is carefully replaced.



Compared with the stepped hole method, a minimum amount of earth is removed and, in addition, solid earth surrounds the pole on all sides.

The method of staying a pole in marshy ground is illustrated in sketch (*b*).

Q. 8. Answer (a) or (b) or (c).
What precautions are necessary when:—
(a) Working on roofs?
(b) Working on railways?
(c) Working near power circuits? (35).

A. 8. (*a*) Where necessary, watchmen should be posted to give warning to the public. On sloping roofs, workmen should use life lines and safety belts. The life lines should be of 2″ prepared hemp rope and must be in thoroughly sound condition; they should be fixed to a roof pole or to a stable part of the building and should be so disposed that there is no liability of chafing. Duckboards or ladders provided on roofs should always be used, any additional ladders being securely fastened before being used. Lifting ropes used for raising material to the roof should be sufficiently strong for the work and workmen on the ground level should not stand immediately below. Tools not in use should be kept in tool baskets. During frosty or snowy weather, slippery roofs should be sprinkled with sand or ashes. In moving about on roofs, skylights should be avoided and movements should be made cautiously and carefully to avoid dislodging slates or tiles.

(*b*). In walking along a railway line, it is preferable to keep to the right and have both sets of metals on the left; walking between the rails or in the 6-foot way should be avoided as far as possible, but, if unavoidable, a workman should walk between the rails of the right-hand line and turn off to the right on the approach of a train. In tunnels, on viaducts and wherever ladders have to be used near the rails, a watchman should be stationed on the line to give warning of the approach of trains by a whistle or horn. On the approach of a train, ladders should be removed from the track to a distance at least 4′ 6″ from the rail. In tunnels, the nearest signalman should be informed of the work in progress; note should be made of the manhole nearest to the location of the work and, if the manhole cannot be reached on the approach of a train, the workmen should stand between the rails of the other line. Should a train approach on this line also, workmen should lie down in the six-foot way. In curved tunnels or any other circumstances where the approach of a second train is not visible, workmen should lie down in the 6-foot way even though only one train is approaching and should stay there until the train or trains have left the tunnel. A trolley should not be placed upon the railway line without the written permission of the railway authorities.

(c). Indiarubber gloves should invariably be worn, and, where wires have to be erected over or under aerial power circuits, the endless sashline method should be used. Span wires, anchor wires and other attachments supporting trolley wires should never be handled as, although they are normally insulated from the trolley wire, any defect in the insulators might result in a serious shock being obtained.

For work near high tension circuits, however, indiarubber gloves afford no protection; the only safe rule is to keep well clear of such circuits. Ladders, ropes, etc., should be at least 4′ away from high tension wires. In all cases, safety belts should be used.

Q. 9. A subscribers' circuit on a C.B.S. exchange is disconnected on the A line. The test clerk places a loop across the line side of the exchange fuses. Comment on this operation. (40).

A. 9. In the C.B.S. No. 1 system, the procedure gives rise to a false test in the event of the disconnexion on the A-wire being inside the exchange. The loop across the lines causes the earthed bell at the subscriber's telephone to be connected to the B-wire, so operating the calling signal (see sketch (*a*) in the Answer to Q. 5); the test is thus inconclusive. The correct procedure is to withdraw the fuses, loop the exchange side and, if the calling signal is operated by so doing, to test each fuse individually.

In the C.B.S. Nos. 2 and 3 systems, the withdrawal of the fuses is not necessary because the subscriber's bell circuit is condensered.

Q. 10. What is an ampere-turn? If 400 ampere-turns are to be provided on a relay having 1,500 ohms resistance and designed for use on a 50 v. exchange, how many turns will be needed? (40).

A. 10. An ampere-turn is a current of one ampere flowing in one turn of wire, or its numerical equivalent. The number of ampere-turns is the product of the current (I) in amperes and the number of turns (N), *i.e.*, NI.

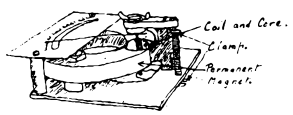
$$I = \frac{E}{R} = \frac{50}{1500} = \frac{1}{30} \text{ ampere.}$$

$$NI = 400 = N \times \frac{1}{30}$$

$$\therefore \quad N = 30 \times 400 = 12{,}000 \text{ turns.}$$

Q. 11. Sketch and describe the horizontal type of D'Arsonval Galvanometer used with a Wheatstone Bridge. What are its outstanding advantages? How could it be used as a voltmeter and as an ammeter? (40).

A. 11. The Paul unipivot galvanometer consists of a powerful permanent magnet, circular in shape and having a coil of wire suspended parallel to the lines of force in the air gap. A core of soft iron, spherical in shape, is suspended within the coil to ensure a radial magnetic field. The coil thus moves in a narrow air gap (see sketch). The pointer is fixed to the coil and moves over a graduated scale.



The force tending to turn the coil is proportional to the current, the number of turns on the coil, and the intensity of the magnetic field. The galvanometer is independent of the earth's magnetic field and remains unaffected by any magnets in the neighbourhood. The coil is wound on a light copper frame to damp the vibration of the coil and so render the instrument practically dead-beat.

Since the deflection of the instrument is directly proportional to the current flowing in the coil, the instrument could be used as an ammeter by shunting it with a suitable resistance and as a voltmeter by including in series with the coil a resistance sufficiently high.

Q. 12. Two condensers of 10 M.F. and 2 M.F. capacity respectively are joined in series; one end of the series is earthed and the other end joined to a 50 v. exchange battery. What will be the charge held by each condenser? The larger condenser is then shunted by 1,000 ohms and the smaller by 2,000 ohms: will the charges be altered and, if so, what will now be the charge on each? (40).

A. 12. The difference in potential is divided between the two condensers inversely in proportion to their capacities, since the quantities of electricity displaced out of and into their respective plates are necessarily the same. Hence, $Q = VC = V_1C_1 = V_2C_2$ where Q is the charge, V the p.d. across the series, V_1V_2 the p.d. across each condenser, C their joint capacity and C_1C_2 their respective capacities.

$$\text{Now } \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{10} + \frac{1}{2} = \frac{10+2}{20}$$

$$C = \frac{20}{12} = 1\tfrac{2}{3}\ \mu\text{F.}$$

$$\therefore \quad Q = 50 \times 1\tfrac{2}{3} \times 10^{-6} \text{ coulombs}$$
$$= 83.3 \times 10^{-6} \text{ coulomb.}$$

When the condensers are shunted, the p.d. across them changes and becomes—

$$\frac{1000}{3000} \times 50 = 16\tfrac{2}{3} \text{ V across the } 10\ \mu\text{F condenser,}$$

and $$\frac{2000}{3000} \times 50 = 33\tfrac{1}{3} \text{ V across the } 2\ \mu\text{F condenser.}$$

The charge on each condenser is therefore—

$$Q_1 = C_1V_1 = 10 \times 16\tfrac{2}{3} \times 10^{-6} = 166\tfrac{2}{3} \times 10^{-6} \text{ coulomb,}$$

and $$Q_2 = C_2V_2 = 2 \times 33\tfrac{1}{3} \times 10^{-6} = 66\tfrac{2}{3} \times 10^{-6} \text{ coulomb.}$$

III.—TELEGRAPHY, GRADE I: QUESTIONS AND ANSWERS

W. S. PROCTER, A.M.I.E.E.

Q. 1. Sketch and describe the jointing of open line wires (a) using jointing sleeves, (b) by Britannia joints. Why is it important that the jointing sleeves should be of the same material as the line wire? (30 marks).

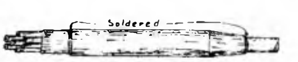
A. 1. (*a*) The ends of the wires are first cleaned and then placed side by side in a sleeve of the same material as the line wire. The ends of the sleeve are then gripped in jointing clamps and one of the clamps is turned until four turns have been given to the joint for conductors up to 100 lb. per mile, and five turns joint is black varnished to prevent for 150 lb. conductors. The sleeve the ingress of moisture.

(*b*) The Britannia joint is used for conductors in conductors larger than 150 lb. per mile. Tinned copper wire, of 50 lb. gauge, is lapped around the ends of the two wires after the cleaning process, and the joint is soldered and black varnished. For conductors of 600 lb. gauge, a length of thinner wire is laid in the groove between the ends of the line wire to make the joint more solid.

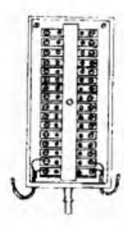
The jointing sleeve must be of the same material as the line wire to prevent electrolytic action at the joint. The black varnish is applied to the joint as a further prevention.

Q. 2. Sketch and describe the termination of a seven-pair lead-covered paper core underground cable on a terminal pole (a) by means of cable distribution plugs, (b) by means of cable terminal blocks. State which you consider to be the better method, giving your reasons. (40).

A. 2. (*a*) The cable distribution plug consists of a solid casting of lead through which pass seven 2-wire lead-covered enamel and cotton insulated cables of 10 lb. gauge; the cores of these cables are served with a coating of insulating compound to make them airtight. A lead sleeve is passed over the cable and the cable pairs are jointed to the seven 2-pair cables, the enamel being removed with emery paper and the joints insulated with paraffined paper sleeves. On completion of the joint, the lead sleeve is slipped over the joint and the larger end soldered to the plug whilst the cable end is soldered to the cable (see sketch). The 2-pair cables of 7-pair plugs are each 6 ft. long.



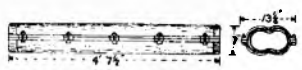
(*b*) The cable is sealed at the back of the box with insulating compound and the pairs are terminated on connexion tags. The 2-wire lead-covered cables are connected to the screw tags as and when required. The front of the box is provided with a captive cover which is secured in position by a screw.



The cable terminal block is the better method of termination since it permits of greater flexibility when changes have to be made. For spare pairs, there is no need to provide lengths of 1-pair cable as is required with C.D. plugs, thus obviating an unsightly appearance on a pole where only a few pairs are in use.

Q. 3. Make a neat dimensioned sketch of a split coupling suitable for use at a jointing point on a route of two-way self-aligning ducts.

Under what conditions should a split coupling be used in preference to a jointing chamber? (35).

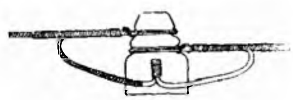


A. 3. Split couplings are used in preference to jointing chambers where jointing positions occur under inexpensive pavings such as gravel, macadam or grass margin.

Q. 4. Describe types of covered wires used (a) for open telegraph lines crossing low or medium pressure power circuits, (b) in districts where the life of bare wires is short due to chemical corrosion. Sketch and describe the method of terminating these covered wires on an insulator. Define the expression " Medium Pressure Power Circuit." (35).

A. 4. (*a*) The conductor is insulated with a layer of impregnated paper and a spiral layer of cotton. A braid of cotton, impregnated with a weatherproof composition consisting of red lead, linseed oil and paraffin wax, is applied overall.

(*b*) The conductor is covered with a cotton braid impregnated with a weatherproof composition similar to that described in (*a*).

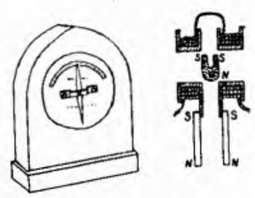


The sketch shows the method of terminating these covered wires on an insulator.

A medium pressure power circuit is one in which the supply voltage lies between 250 and 650 volts.

Q. 5. Describe with the aid of sketches the construction of a differential galvanometer used on duplex telegraph circuits. What deflections would be obtained when a current of 10 milliamperes (a) is passed through one coil, (b) divides equally through both coils connected differentially? (35).

A. 5. The galvanometer consists of two differentially-wound coils and a U-shaped soft iron needle which is suspended upon an axle well below the centre of the coils. The coils have a resistance of 50 ohms and each is shunted by a resistance of 300 ohms, giving a joint resistance of nearly 43 ohms. The needle is magnetized by induction from a pair of comparatively large bar magnets fixed upon each coil (see sketch); these magnets have their S poles upwards in order to assist the magnetic effect of the Earth's field upon the needle. The axle also carries the pointer which moves over a centre-zero scale graduated in degrees. The coils, needle, and magnets are enclosed in a wooden case; the coils are terminated upon four connexion screws fitted on the back of the case. A circular glass cover protects the pointer and scale from damage.

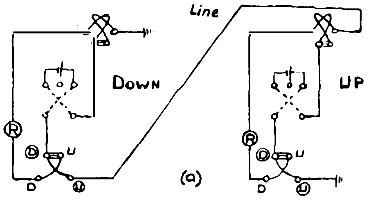


(*a*) The deflection would be about 25°.

(*b*) No deflection would be obtained.

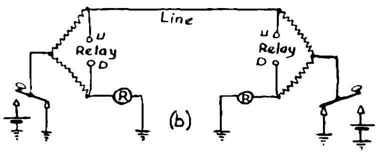
Q. 6. Explain with the aid of simple diagrams the principles of bridge duplex and of differential duplex working. Describe in detail the operation of obtaining a resistance balance on a double current duplex circuit. (40).

A. 6. Sketch (*a*) shows the connexions of a double current differential duplex circuit. One coil of the differentially-wound relay is connected in the line circuit whilst the other forms part of the compensation circuit. With both keys at rest or both depressed, the current flowing in the line circuit is twice that flowing in the compensation circuit, since the batteries at each station are connected in series through the line and the resistance of the compensation circuit, R, is equal to that of the line and the line coils of the distant galvanometer and relay. The magnetic effect of the line coil of the relay therefore preponderates and either a space or a mark, respectively, is recorded.



When one key is depressed while the other is at rest, the reversal of the battery causes the line current to fall to zero, because the batteries at each end now oppose one another through the line. The effect of the current in the compensation circuit is to record a space at one end and a mark at the other.

The diagram in sketch (*b*) shows the principle of bridge duplex working. The current from the key divides between two equal resistances having the receiving apparatus connected across their ends. The resistance of the compensation circuit, R, is equal to that of the line plus the distant apparatus. So long as the ends of the two resistance arms are at the same potential, the receiving apparatus remains unaffected. With one key depressed and the other at rest, the potential difference across the distant relay causes the relay to mark. With both keys depressed, no current flows in the line circuit; the current from the home battery, flowing through the relay in the direction U—D, causes a mark to be recorded at each end.



To obtain a resistance balance on a double current duplex circuit, the 40-ohm arm of the rheostat is reduced to zero and the 400-ohm arm set to any value in excess of the resistance of the circuit. The key is then depressed and the galvanometer deflection observed. The 400-ohm arm is reduced step by step until the depression of the key gives a deflection in the opposite direction to that previously observed. The 40-ohm arm is then increased step by step until balance is obtained.

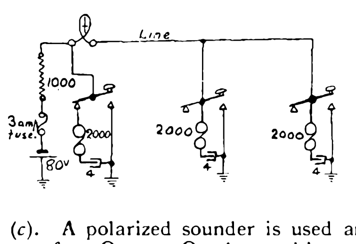
Q. 7. Draw a diagram of a central battery simplex telegraph circuit with two out offices.

Explain the essential differences in the types of sounder used—

(a) On a central battery simplex circuit.
(b) For secondary cell working.
(c) On a direct sounder circuit employing primary cells. (40).

A. 7. The sketch shows a diagram of a central battery simplex telegraph circuit with two out offices.

(*a*). The sounders on this type of circuit are of the polarized type in order to enable the circuit to be operated by the charge and discharge of the 4 μF condensers. The coils have a resistance of 2,000 ohms.



(*b*). The coils of sounders used for secondary cell working are of 1,000 ohms resistance and are shunted by 9,000 ohms, giving a joint resistance of 900 ohms. They are operated from the 24-volt battery and have a figure of merit of 11 mA.

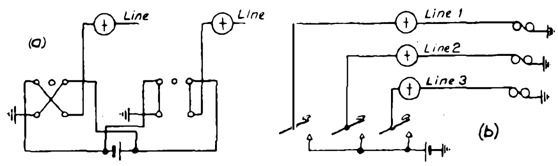
(*c*). A polarized sounder is used and its coils have a resistance of $100\Omega + 100\Omega$; the working current required is 23 mA. Formerly, a non-polarized sounder of 20 ohms resistance (coils 21Ω, shunt 420Ω) was employed and the working current required was 100 mA.

Q. 8. Explain the principle of universal battery working, showing why separate batteries must be used for positive and negative currents and why the battery should have a low internal resistance.

If 50 circuits each of 500 ohms resistance are connected to a battery with E.M.F. of 24 volts and internal resistance of 20 ohms, calculate the current flowing in one circuit—

(a) When the key on this circuit only is depressed.
(b) When the keys on all 50 circuits are depressed simultaneously. (30).

A. 8. Sketch (*a*) shows the reason why separate batteries are necessary in universal battery working. Two double current circuits are shown connected to the same battery; one is marking and the other spacing, with the result that no current is sent to line in either circuit because both poles of the battery are earthed through the keys. To avoid short-circuiting the battery in this way, separate positive and negative batteries are necessary.



Sketch (*b*) shows the elements of universal battery working. The number of circuits connected to the battery varies from instant to instant according to the positions of the keys of the various circuits connected to the battery. For satisfactory working, it is essential that the current flowing in any circuit must be approximately the same (i) when it alone is taking current and (ii) when all the circuits connected to the battery are taking current. This condition is only satisfied when the internal resistance of the battery is small in comparison with the joint resistance of the circuits connected to it, and when the battery is of sufficient capacity to supply the maximum demand made upon it.

$$(a)\quad I = \frac{E}{R + R_1} = \frac{24}{20 + 500} = \frac{24}{520} = 46 \text{ mA.}$$

$$(b)\quad I = \frac{E}{R + R_1} = \frac{24}{20 + \frac{500}{50}} = \frac{24}{30} = 800 \text{ mA.}$$

$$\text{Current in each circuit} = \frac{800}{50} = 16 \text{ mA.}$$

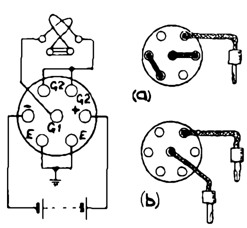
Q. 9. Draw a diagram of a test tablet 7 hole, showing the connexions to the testing battery, galvanometer and earth.

Draw diagrams showing the positions of "U" links and cords—

(a) To send positive current to a single-wire line.
(b) To receive a current from a "loop" circuit.

Explain in detail how you would make a sectional localization of an earth fault on a single-wire telegraph circuit. (30).

A. 9. The connexions of a test tablet 7 hole are shown in the sketch, whilst sketches (*a*) and (*b*) show the positions of "U" links and cords.



To make a sectional localization of an earth fault on a single-wire telegraph circuit, the furthest testing point, at which the circuit is led in for testing, is asked to disconnect the circuit. The line is then tested and, if proved clear, the testing point is asked to restore the circuit and the penultimate testing point is asked to disconnect the circuit. Proceeding in this way, the two testing points between which the fault exists are located.

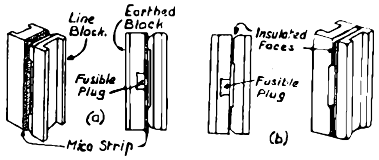
Q. 10. Sketch and describe the construction of two types of carbon lightning protectors suitable for fitting on main distribution frames—

(a) A type employing a mica separator.

(b) A more recent type in which the carbons are separated by means of insulating varnish.

State the approximate dimensions of the air gaps and break down voltages for the two types. Why is the latter type considered to be an improved design? (35).

A. 10. The 3-unit carbon protector (sketch *a*) consists of two blocks of moulded carbon, $1\frac{1}{4}$ in. long by $\frac{3}{8}$ in. wide, separated by a mica strip 3 to 5 mils thick and having three circular holes to form the air gaps. The earthed block carries a circular plug of metal, consisting of 8 parts of bismuth, 5 of tin, and 3 of lead, having a fusing point of 200°F—210°F. The line block is chamfered to minimize leakage due to dust bridging the gaps. Both blocks are slotted to receive the connecting springs or guides which serve to maintain the protector in position. The break down voltage is about 350 volts D.C.



The 2-unit protector (sketch *b*) consists of two blocks of moulded carbon having flat active surfaces which are sprayed with a fusible gum varnish. The carbon blocks are coated at each end with a thin layer of insulating varnish which dries nail hard and is non-hygroscopic. The air gap is 3 to 6 mils and the break down voltage 500 to 750 volts D.C.

With the 3-unit protector, the mica strip is liable to become displaced so earthing the line. Further the grinding of a 3—5 mil recess has the effect of exposing the soft carbon which is readily disintegrated by line discharges, giving rise to earth faults. These disadvantages are overcome in the new 2-unit protector.

Q. 11. Explain the meaning of the terms—

"The electromotive force of a cell."

"The internal resistance of a cell."

How would you measure the E.M.F. and the internal resistance of a Leclanché cell? (30).

A. 11. The electromotive force of a cell is the electrical pressure set up between the poles of the cell consequent upon the chemical action taking place in the cell, and is measured in volts.

The internal resistance of a cell is the resistance offered to the passage of an electric current from one pole through the cell to the other pole.

The e.m.f. of a Leclanché cell may be measured by connecting the cell to the 5-volt terminals of a Detector No. 2 or No. 4. The internal resistance of the cell may be measured by the voltmeter-shunt method; the e.m.f. of the cell on open circuit (V_1) and the difference of potential between its terminals (V_2) when connected to a resistance of R ohms are noted. The internal resistance of the cell (r) is given by—

$$r = R\,\frac{V_1 - V_2}{V_2}\ \text{ohms.}$$

Q. 12. Define or explain the following terms:—

(a) "Differential" as applied to a galvanometer.

(b) "Multiple Twin" as applied to a cable.

(c) "Pilot Hole" as applied to underground construction.

(d) "Polarization" as applied to a cell.

(e) "Polarized" as applied to a relay.

(f) "Rating Current" as applied to a fuse.

(g) "Regulation" as applied to open wires.

(h) "Skinner" as applied to "cable forms." (40).

A. 12. (*a*). A galvanometer is said to be differential when it has two coils equal in resistance, length and position with respect to the needle. The same deflection would therefore be produced by a given current when passing through either coil. When the current flows through both coils in sequence, the deflection is doubled; whilst when the current passes through the two coils in such a direction that the magnetic effect of one coil opposes that of the other, no deflection results.

(*b*). A multiple twin cable is one in which the quads are built up by first twinning two paper-insulated conductors to form a twisted pair and then twinning two pairs together to form a quad.

(*c*). A pilot hole is an excavation made on the line of a projected duct route in order to ascertain the nature of the obstructions likely to be encountered and the nature of the sub-soil in which the duct track is to be laid.

(*d*). In a primary cell, polarization is the production of an e.m.f. in opposition to the prime e.m.f. of the cell; it is due to the accumulation of hydrogen around the carbon element, the hydrogen being liberated by the chemical action producing the prime e.m.f. of the cell. This effect also increases the internal resistance of the cell by reducing the area in contact with the electrolyte. The effects of polarization are overcome by surrounding the carbon element with manganese dioxide which, by combining with the hydrogen to form water and manganese sesquioxide, effectively depolarizes the cell.

(*e*). A polarized relay is one in which the direction of the movement of the tongue depends upon the direction of the current. This effect is obtained by giving the magnetic circuit of the relay a permanent flux derived either from a permanent magnet or from a polarizing coil of the relay.

(*f*). The rating current of a fuse is the recognized safe carrying current of the wire, and is half the fusing current.

(*g*). The regulation of overhead wires is the operation of adjusting the tension on each wire of a span so that the amount of the dip is the same in each case.

(*h*). A skinner is the length of insulated wire between a laced cable form and the connecting point.

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