SUPPLEMENT

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TEC & CGLI:

GUIDANCE FOR STUDENTS

Contents

TECHNICIAN EDUCATION COUNCIL

Certificate Programme in Telecommunications

Sets of model questions and answers for TEC units are given below. They have been designed following analysis of assessment test papers actually set during the 1978–79 session by a number of colleges all over the country. The model questions and answers reflect the types and standard of question set and answer expected, and include the styles of both in-course and end-of-unit assessments.

The model questions and answers therefore illustrate the assessment procedures that students will encounter, and are useful as practice material for the skills learned during the course.

The use of calculators is permitted except where otherwise indicated.

Representative time limits or proportion of marks are shown for each question (or group of questions), and care has been taken to give model answers that reflect these limits. Where additional text is given for educational purposes, it is shown within square brackets [ ] to distinguish it from the information expected of students under examination conditions.

We would like to emphasize that, because the model questions are based on work at a number of colleges, they are not representative of questions set by any particular college.

As a general rule, questions are given in italic type and answers in upright type. Answers are sometimes shown in bold upright type; this is because, for some objective questions, it is convenient to place the questions and answers side by side, and bold type enhances the distinction in such cases. Where possible, answers have been positioned such that they may be covered up if desired.

TELECOMMUNICATIONS SYSTEMS 1 1978–79

Students are advised to read the notes above

Q1 Name the 2 transducers used in a telephone instrument, and give a simple explanation of their function. What are the standard types of transducer used? (2 min)

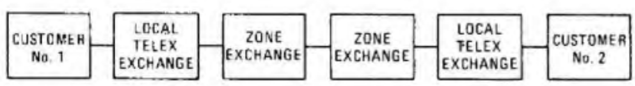
A1 The **microphone**, which converts sound-energy waves into electrical signals. The standard type used in the telephone is the carbon-granule transmitter.

The receiver, which converts the alternating electrical-speech signal into sound-energy waves. The standard type used is the rocking-armature receiver.

Q2 What sort of Telex exchange is fully interconnected and why are all Telex exchanges connected to London? Draw a block diagram showing 2 Telex customers connected over the maximum number of links. Label each type of exchange. (5 min)

A2 Zone exchanges in the Telex network are fully interconnected. All Telex exchanges are connected to London because the Telex network is almost exclusively used by business customers. This means that the majority of Telex calls originating outside London are made to London, the principal business centre for the country.

The block diagram is shown in the sketch.



Q3 Name all the possible types of exchanges that a DSC may be connected to. For what is DSC an abbreviation? List the types of exchange, in order, if a telephone call is routed through 7 exchanges. (5 min)

A3 DSCs may be connected to

(*a*) other DSCs,
(*b*) main switching centres,
(*c*) group switching centres, and
(*d*) international exchanges.

DSC is an abbreviation of *district switching centre*.

The exchanges, in order, are

(*a*) local exchange,
(*b*) group switching centre,
(*c*) district switching centre,
(*d*) main switching centre,
(*e*) district switching centre,
(*f*) group switching centre, and
(*g*) local exchange.

Q4 What is an auxiliary route? (4 min)

A4 An auxiliary route is a connexion between 2 exchanges that would not normally be planned. For example, a direct connexion between 2 local exchanges when normally the routing would be via a group switching centre.

Such a route is provided when there is sufficient demand (traffic) between the 2 exchanges and, on provision, it makes equipment spare at the group switching centre.

Q5 Name the 2 types of exchanges that form the transit switching network. What is the expected proportion of traffic that this network will carry?

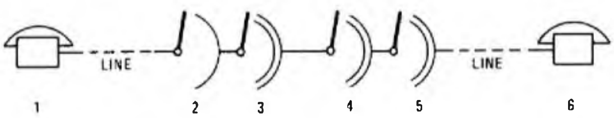
Give 2 reasons why this network was introduced. (5 min)

A5 The 2 types of exchange are *main switching centres* and *district switching centres*.

It is expected that the transit network will carry 5% of the STD traffic.

To have fully introduced STD over the existing network would have meant possible routes involving more than 2 group-switching-centre-to-group-switching-centre links. This would have involved excessive transmission loss and a large number of routing digits which would have caused excessive post-dialling delay.

Q6 Consider the simple trunking diagram and complete the following statements.



(*a*) *The second group selector is item number...............*

(*b*) *The final selector is item number...............*

(*c*) *The called subscriber is item number...............*

(*d*) *The calling subscriber is item number...............*

(*e*) *The first selector is item number...............*

(*f*) *The subscriber's line circuit is item number...............* (*1 min*)

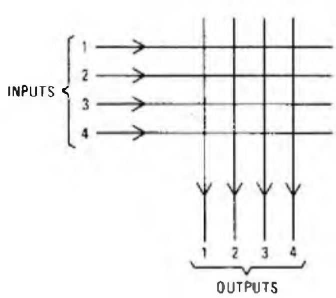
A6 (*a*) 4 (*b*) 5 (*c*) 6 (*d*) 1 (*e*) 3 (*f*) 2

Q7 Why is it impracticable to connect directly all telephone customers to each other? (*5 min*)

A7 To interconnect directly thousands of customers, a very large cable distribution network would be needed to give each customer direct access to all others. A large switching complex would also be needed at each customer's premises to enable signalling to the required customer, and give privacy to the conversation.

Q8 What type of switch is used in modern telephone exchanges? Draw a typical diagram of such a switch. (*3 min*)

A8 A matrix switch. A typical diagram is shown in the sketch.



Q9 A step-by-step (Strowger) telephone exchange has first, second and final switching stages. What is the range of customer numbers that can be provided, allowing only numbers starting with digits 2 to 7? (*2 min*)

A9 From 2000 to 7999.

Q10 Name the flexibility points available in the local distribution network. (*2 min*)

A10 The flexibility points available are

(*a*) the distribution point,

(*b*) the primary cross-connexion point (cabinet), and

(*c*) the secondary cross-connexion point (pillar).

Q11 What is the difference between ringing current and ringing tone? (*5 min*)

A11 Ringing current is connected by the final selector to the called customer's line in order to ring his telephone bell. It has a frequency of 17 Hz.

Ringing tone is connected by the final selector to the calling customer's line via the complete switched network, to indicate that the called customer's line is having ringing current applied to it. It has a frequency of 400 Hz.

Q12 State the speed of light. Given that a signal travels at the speed of light, what other property is required to enable you to state the signal's frequency? State the relationship between these 3 variables. (*3 min*)

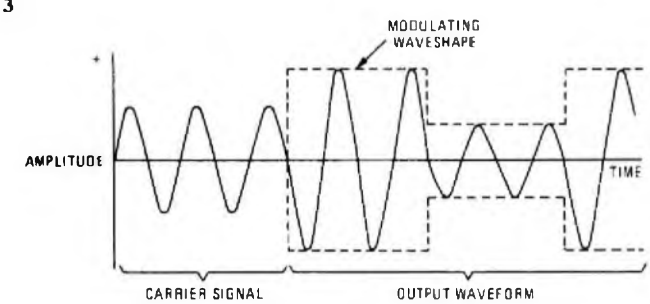
A12 3×10^8 m/s.

Its wavelength (metres).

$$\text{Frequency in hertz} = \frac{\text{velocity in metres per second}}{\text{wavelength in metres}}.$$

Q13 Draw a typical example of the output waveform from a double-sideband amplitude modulator if the modulating signal is a square wave. (*4 min*)

A13



Q14 Given the modulating signal shown in Fig. 1, draw a typical output waveform from a pulse-amplitude modulator. (*4 min*)

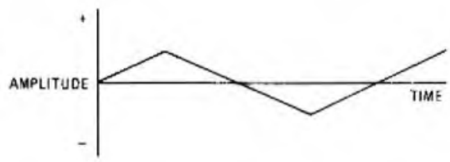
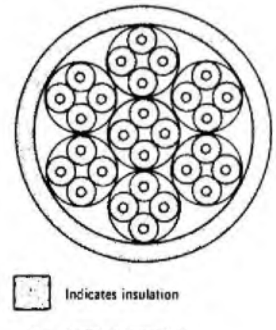


Fig. 1

A14

Q15 A cable has 28 wires arranged in quad form. Draw a cross-sectional diagram showing the wires and the insulation. (*4 min*)

A15



Q16 Complete the following statement.
A square wave is made up of the (a)..........................and all the (b)..............harmonics. *(2 min)*

A16 (*a*) fundamental
(*b*) odd

Q17 A double-sideband amplitude modulator has a carrier of 64 kHz. If the output waveband is from 61 kHz to 67 kHz what is the waveband of the modulating signal? *(4 min)*

A17 The output waveband of a double-sideband modulator is calculated from the formula

carrier frequency ± the maximum modulating frequency.

Hence, the maximum modulating frequency is the carrier frequency minus the lower transmitted frequency, or the upper transmitted frequency minus the carrier frequency.

Therefore the maximum modulating frequency is

$$64 - 61 = 3 \text{ kHz}.$$

The waveband is 0–3 kHz.

Q18 The third harmonic of a signal is 60 kHz. What is the frequency of the second and fourth harmonics? *(3 min)*

A18 The third harmonic is the fundamental frequency × 3.
Therefore, the fundamental = third harmonic ÷ 3 = 60/3 = 20 kHz.
Therefore the second harmonic is 20 × 2 = 40 kHz, and
the fourth harmonic is 20 × 4 = 80 kHz.

Q19 Complete the following statements.
(*a*) *A pure AC signal is called a ....wave.*
(*b*) *The carrier spacing on a Post Office telephony channel is ....Hz.*
(*c*) *The output of a frequency modulator is...............amplitude.*
(*d*) *The carrier of the demodulating circuit is the.......................... as the carrier at the modulator.* *(3 min)*

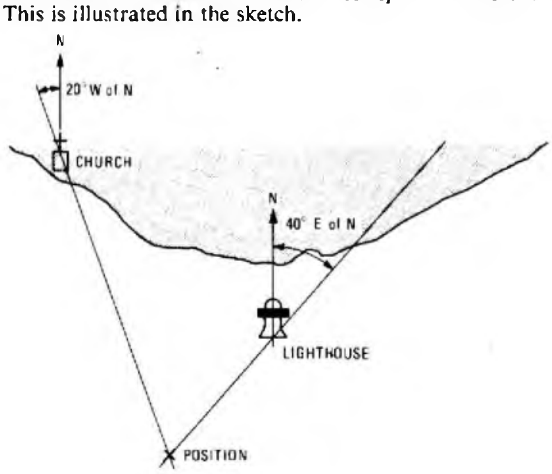
A19 (*a*) sine
(*b*) 4000
(*c*) a constant
(*d*) same frequency

Q20 List in frequency order (highest first) the following waves.
(*a*) *Infra red.*
(*b*) *Audio.*
(*c*) *Radio.*
(*d*) *Cosmic.*
(*e*) *Light.*
(2 min)

A20 (*d*), (*e*), (*a*), (*c*), (*b*).

Q21 A boat has no radar. Describe a method which may be used to mark its position on a chart when in sight of land on a clear day. *(10 min)*

A21 The direction relative to north is found, using a compass, of an identifiable landmark; for example, a church steeple. A line can then be drawn on the chart representing this bearing and passing through the position of the landmark on the chart. This procedure is repeated with another landmark. Where the 2 lines cross represents the boat's position. This is illustrated in the sketch.



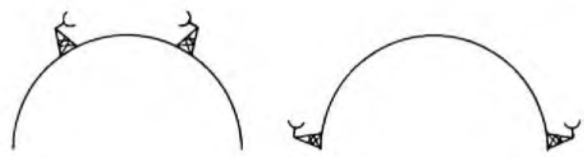
Q22 Which of the following statements is true?
(*a*) *PPI stands for pulse primary indication, or*
(*b*) *PPI stands for plan position indicator.* *(1 min)*

A22 (*b*).

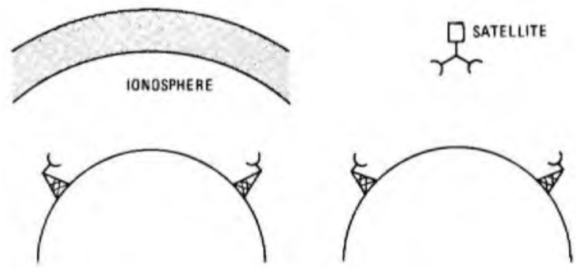
Q23 State 2 uses each of digital and analogue computers. *(4 min)*

A23 (*a*) Digital computers:
(*i*) the keeping of bank accounts, and
(*ii*) the calculations for the payment of wages.
(*b*) Analogue computers:
(*i*) a flight simulator, and
(*ii*) for the calculation of stress effect (for example, in a bridge).

Q24 On the diagrams, show and name the most likely radio paths, and give the frequency range in each case. *(5 min)*

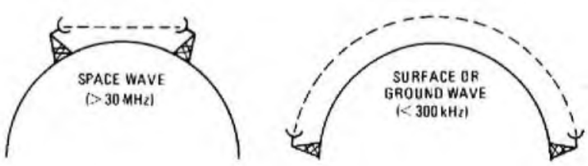


(*a*) (*b*)

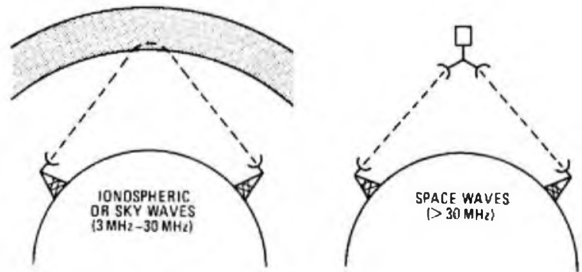


(*c*) (*d*)

A24



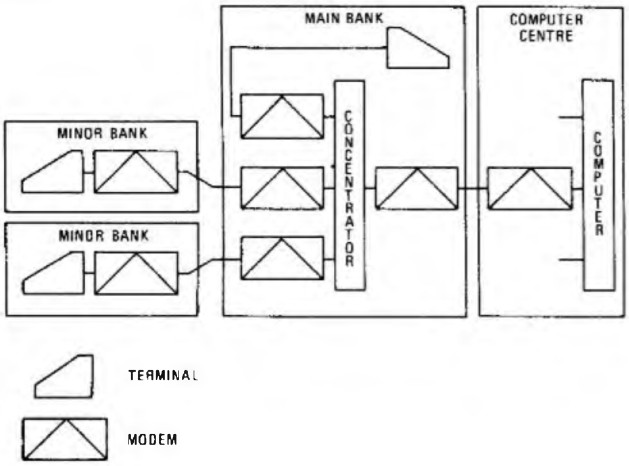
(*a*) (*b*)



(*c*) (*d*)

Q25 A data system consists of the following elements:
2 minor banks; 1 major bank; a concentrator; a central computer; and all the necessary modems and terminals.
Draw a block diagram of the system. *(8 min)*

A25



Q26 What is the function of a modem? *(6 min)*

A26 A modem acts as an interface between telecommunications equipment and a data terminal or computer. It is a 2-way device. In one direction it changes binary information from the terminal or computer to analogue signals that are capable of being transmitted over the telecommunications network. In the other direction, on receipt of analogue signals from the telecommunications network, it converts signals into digital form, suitable to operate a terminal or computer. The term *modem* is a contraction of *mod*ulator/*dem*odulator.

Q27 How is the aspect ratio of a television picture calculated and state the normal figure for British television. *(2 min)*

A27 The aspect ratio is calculated by the ratio of the width to the height of a television picture. In Britain the ratio is 4: 3.

PHYSICAL SCIENCE 1 1978–79

Students are advised to read the notes on p. 65

TYPICAL TIME LIMIT FOR Q1–9: 8 min

Q1 Select from the following list the correct units for density

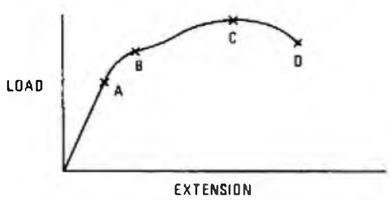
(*a*) *kg/m*^{2} (*b*) *g/m*^{2}
(*c*) *kg/m*^{3} (*d*) *it is a ratio and does not have units.*

A1 (*c*) kg/m^3.

Q2 Explain what is meant by the elastic limit of a ductile material.

A2 The elastic limit is the stress below which the material exhibits elasticity; that is, it will return to its original shape when the deforming force is removed.

Q3 The sketch shows a graph of load plotted against extension for a ductile material. Name the points A, B, C and D.



A3 A is the elastic limit; B is the yield point; C is the maximum load; D is the breaking strain.

Q4 Calculate the maximum stress which can be withstood by a brittle material if the maximum load on a specimen of 100 mm^2 *cross-sectional area is 20 kN.*

A4 $$\text{Stress} = \frac{\text{applied load}}{\text{cross-sectional area}} = \frac{20 \times 10^3}{100 \times 10^{-6}} = \underline{200\ \text{MN/m}^2}.$$

Q5 Which of the following energy conversions occur when an electric filament lamp is lit?

(*a*) *electrical to chemical* (*b*) *mechanical to electrical*
(*c*) *thermal to radiant* (*d*) *atomic to thermal*
(*e*) *electrical to thermal*

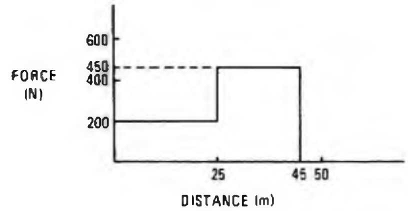
A5 (*e*) electrical to thermal and (*c*) thermal to radiant.

Q6 A force of 200 N moves a body through a horizontal distance of 25 m. The force is then increased by 250 N to move the body through a further 20 m. Draw a force/distance graph from the given data.

Does the area under the graph represent

(*a*) *power* (*b*) *work done*
(*c*) *potential energy* (*d*) *pressure applied*

A6



The area under the graph represents the work done.

Q7 A 100 W electric motor produces a force of 1 kN. Assuming there are no losses, how far could a body be moved by that force if the motor is switched on for 1 min?

A7 Energy expended by 100 W in 1 min = 100 × 60 = 6 kJ.

Distance moved by a force of 1 kN in expending 6 kJ $= \dfrac{6000}{1000} = \underline{6\ \text{m}}.$

Q8 The definition of the efficiency of a machine is

(*a*) $\dfrac{\textit{energy losses}}{\textit{energy input}}$ (*b*) $\dfrac{\textit{energy input}}{\textit{energy output}}$

(*c*) $\dfrac{\textit{energy losses}}{\textit{energy output}}$ (*d*) $\dfrac{\textit{energy output}}{\textit{energy input}}$.

A8 (*d*) $\dfrac{\text{energy output}}{\text{energy input}}$.

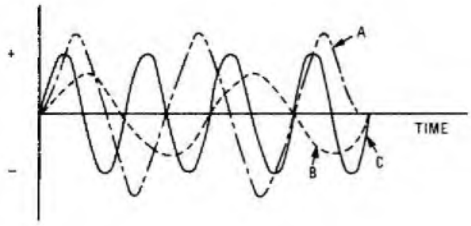
Q9 How much heat energy is lost when the temperature of a copper bar of 20 kg mass falls from 65°C to 40°C? The specific heat capacity of copper is 385 J/(kg°C).

A9 [Heat energy lost = mass of copper in kilograms × specific heat capacity × fall in temperature]

Heat energy lost = 20 × 385 × 25 = 192·5 kJ.

TYPICAL TIME LIMIT FOR Q10–13: 10 min

Q10 *The sketch shows 3 waveforms, A, B and C. Which has*
(a) the highest frequency *(b) the longest wavelength*
(c) the greatest amplitude?



A10 (*a*) C (*b*) B (*c*) A

Q11 *If the wavelength of an electrical signal through a given medium is 500 m and its frequency is 10 kHz, its velocity of propagation is*
(a) 20 m/s *(b) 5×10^6 m/s*
(c) 5×10^3 m/s *(d) 2×10^6 m/s*

A11 (*b*) 5×10^6 m/s

Q12 *A 10 MHz radio signal transmitted into space has a propagation velocity of 3×10^8 m/s. What is the wavelength of a 50 MHz radio signal which is also transmitted into space?*

A12 [The velocity of all radio signals in space is equal to the speed of light (3×10^8 m/s). Wavelength $(\lambda) = \frac{v}{f}$ where v is the velocity of propagation and f is the frequency.]

The wavelength $= \frac{3 \times 10^8}{50 \times 10^6} = 6$ m.

Q13 *If the 50 MHz signal of Q12 were transmitted in a copper conductor, would its wavelength be*
(a) the same *(b) longer* *(c) shorter?*

A13 (*c*) shorter.

TYPICAL TIME LIMIT FOR Q14–20: 25 min

Q14 *State the preferred units of the following*
(a) electrical current *(b) electro-motive force*
(c) potential difference *(d) resistance*

A14 (*a*) ampere (*b*) volt
(*c*) volt (*d*) ohm

Q15 *Using I, V and R to represent current, voltage and resistance respectively, write down 3 different formulae each representing Ohm's law, assuming the physical conditions remain constant.*

A15 $I = \frac{V}{R}$ $V = IR$ $R = \frac{V}{I}$

Q16 *Three resistors of different values are connected in series in an electric circuit. When current flows in the circuit, which of the following statements is/are true?*
(a) A different value of current flows in each resistor.
(b) The same potential difference exists across each resistor.
(c) The same current flows in all 3 resistors.
(d) A different potential difference exists across each resistor.
(e) The current in the lowest valued resistor is highest.
(f) The potential difference across the highest valued resistor is lowest.

A16 (*c*) The same current flows in all 3 resistors.
(*d*) A different potential difference exists across each resistor.

Q17 *Two 4 Ω resistors and a 2 Ω resistor are all connected in parallel. The effective resistance of the arrangement is*
(a) 10 Ω *(b) 4 Ω* *(c) 2 Ω* *(d) 1 Ω*

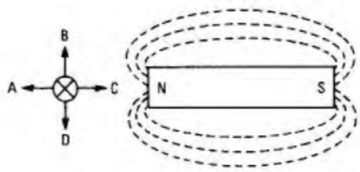
A17 (*d*) 1 Ω

Q18 *Calculate the current that flows when a 10 W, 50 V soldering iron is switched on.*

A18 [$I = \frac{P}{V}$, where I is the current, P is the power and V is the voltage.]

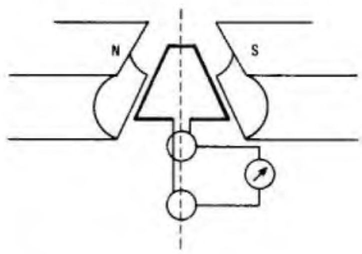
Current flowing $= \frac{10}{50} = 0{\cdot}2$ A = 200 mA.

Q19 *The sketch shows a conductor, in the magnetic field of a bar magnet, carrying current away from the observer. State in which direction (A, B, C or D) the conductor will experience a force.*

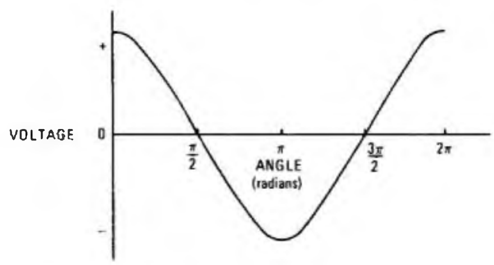


A19 B [By use of Fleming's left-hand rule.]

Q20 *The sketch shows the coil of an AC generator positioned between the pole faces of a permanent magnet. By means of a graph, show the variation of generated voltage when the coil is rotated through one complete revolution at constant velocity, starting with the coil in the position shown.*

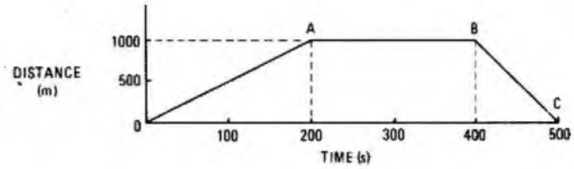


A20



TYPICAL TIME LIMIT FOR Q21–23: 20 min

Q21 *The sketch shows a distance/time graph of the movement of a body. From the graph, calculate the slope of section OA; what does this represent? What is happening to the body during the periods AB and BC?*



A21 The slope of section OA $= \frac{1000}{200} = \underline{5}.$

This represents the speed of the body; that is, 5 m/s.

During period AB the body is stationary and during period BC it is returning to its starting point.

Q22 A vehicle accelerates at 2 m/s² and reaches a velocity of 30 m/s after 10 s. State the formula used to calculate the initial velocity of the vehicle. Calculate that initial velocity.

A22 $$v = u + at,$$

where v is the final velocity, u is the initial velocity, a is the acceleration and t is the time from the start of the observation.

$$\therefore \quad 30 = u + 2 \times 10.$$

$$\therefore \quad u = 30 - 20 = \underline{10\text{ m/s}}.$$

Q23 If a hot-air balloon has a total mass of 800 kg, including passengers, calculate the rate of acceleration from the ground if the hot air produces an uplifting force of 8000 N. Acceleration due to gravity = 9·81 m/s².

A23 [Force (in newtons) = mass (in kilograms) × acceleration (in metres/second²).]

The downward force due to gravity = 800 × 9·81 = 7·848 kN.

Upward force = 8000 N (given).

∴ the net force on the balloon = 8000 − 7848,
= 152 N upwards.

∴ the acceleration from the ground $= \frac{152}{800} = \underline{0{\cdot}19\text{ m/s}^2}.$

TYPICAL TIME LIMIT FOR Q24: 1 min

Q24 Select the vector quantities from the following list

(a) mass (b) force (c) velocity

(d) speed (e) power (f) energy

A24 (*b*) force (*c*) velocity

TYPICAL TIME LIMIT FOR Q25–26: 1 min

Q25 Which of the following liquids is most suitable for use as the electrolyte of a simple cell

(a) tap water (b) distilled water

(c) dilute sulphuric acid (d) concentrated hydrochloric acid

A25 (*c*) dilute sulphuric acid.

Q26 The following metals appear in the electrochemical series in the order given

(a) aluminium (b) zinc (c) lead (d) copper

If any 2 of these metals are to be used for the electrodes of a simple cell, which pair will produce the highest EMF?

A26 (*a*) aluminium and (*d*) copper.

TYPICAL TIME LIMIT FOR Q27–30: 30 min

Q27 During an experiment, the resistance of a specimen of conducting material was noted to be 150 Ω at 0°C and 165 Ω at 20°C. Calculate the temperature coefficient of resistance of the material.

A27 [The resistance at a given temperature is given by

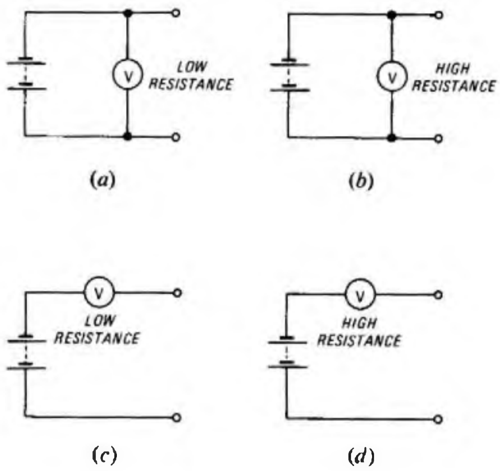
$$R_T = R_0(1 + \alpha T),$$

where R_0 is the resistance at 0°C, α is the temperature coefficient of resistance, R_T is the resistance at temperature T°C.

Thus, $\alpha = \frac{R_T/R_0 - 1}{T}.$]

The temperature coefficient of resistance $= \frac{165/150 - 1}{20} = \underline{0{\cdot}005/°\text{C}}.$

Q28 Which of the following circuits is most suitable for measuring the EMF of a battery?



A28 Circuit (*b*).

Q29 A battery has an EMF of 10 V. If the terminal voltage falls to 9·8 V when a load of 100 Ω is connected, what is the internal resistance of the battery?

A29 As the terminal voltage falls to 9·8 V when the load is connected, the potential difference across the internal resistance = 10 − 9·8 = 0·2 V.

Let the internal resistance be r, the load be R and the current flowing be I.

Then $Ir = 0{\cdot}2$ V.

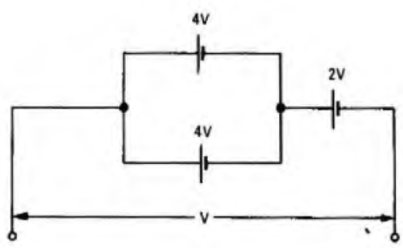
But $IR = 9{\cdot}8$ V.

$$\therefore \quad \frac{r}{R} = \frac{0{\cdot}2}{9{\cdot}8}.$$

$$\therefore \quad r = \frac{0{\cdot}2}{9{\cdot}8} \times 100 = \underline{2{\cdot}04\ \Omega}.$$

Q30 The terminal voltage of the battery arrangement shown in the sketch is

(a) 4 V (b) 10 V (c) 6 V (d) 1·6 V.



A30 (*c*) 6 V.

Students are advised to read the notes on p. 65

Q1 A shelf of 10 selectors was observed at one-minute intervals and the occupancy of each selector was as shown by the ticks in the table below. Calculate the amount of traffic carried during the observed period. Include in your answer the unit of measurement. *(4 min)*

Selector	*Intervals*									
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
First		✓	✓	✓	✓			✓	✓	✓
Second	✓		✓	✓	✓	✓	✓			✓
Third	✓	✓	✓	✓				✓	✓	✓
Fourth	✓	✓		✓	✓	✓	✓	✓		
Fifth				✓	✓	✓	✓		✓	✓
Sixth	✓	✓	✓					✓	✓	✓
Seventh				✓	✓	✓	✓	✓		
Eighth				✓	✓	✓				
Ninth	✓	✓								
Tenth										

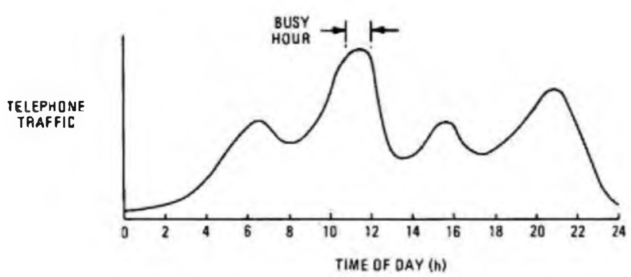
A1 Traffic carried = the average number of simultaneous calls,

$$= \frac{\text{total number of observed calls}}{\text{the number of observations}},$$

$$= \frac{50}{10} = \underline{5 \text{ erlangs.}}$$

Q2 Draw a graph showing how telephone traffic varies over a 24 h period for an exchange in a town which has a busy fishing port and also has a large number of holidaymakers. Give reasons for the shape of your graph and indicate the busy hour. *(10 min)*

A2 The graph is shown in the sketch.



The 24 h graph shows 4 peaks in telephone traffic. The first peak, occurring early in the morning, would be caused by traffic generated during the period the fish catch is landed and sold. The second peak occurs during mid-morning and would be due to business activities; this would drop during lunchtime and rise again during the afternoon. The last peak of the day would be due mainly to visitors and residents, beginning when the cheap-rate charging became available at 18.00 hours for inland calls and 20.00 hours for international calls.
[Although the relative size of the peaks may vary, the graph should have included 4 peaks, with the busy hour labelled on the highest peak.]

Q3 The total traffic which can be successfully carried by a certain junction route during the busy hour is 1500 calls and the total number of calls receiving equipment-engaged tone due to congestion on this route was 10. What grade of service is offered by this junction route? Express your answer as a decimal correct to 3 places. *(4 min)*

A3 Grade of service $= \dfrac{\text{number of calls lost}}{\text{number of calls offered}}$,

$$= \frac{10}{1500 + 10} = 0{\cdot}0067,$$

$$= \underline{0{\cdot}007 \text{ correct to 3 decimal places.}}$$

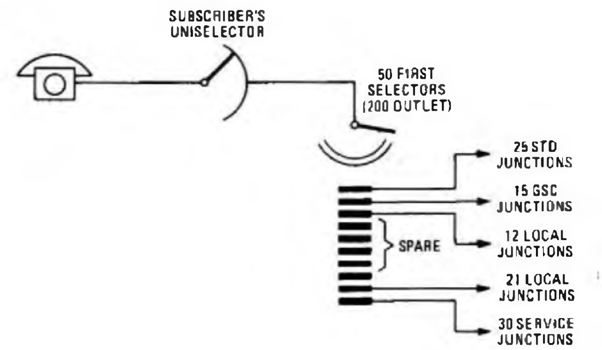
Q4 Which of the following grades of service would give the best quality of service to a calling subscriber? (Tick the correct answer) *(2 min)*

(*a*) $\frac{1}{20}$ (*b*) *0·02*

(*c*) $\frac{1}{200}$ (*d*) *0·002*

A4 (*d*) 0·002 ✓

Q5 From the information given in the sketch, determine which selector levels have full availability and which have limited availability. Also state the type of availability from the subscriber's uniselector. *(4 min)*



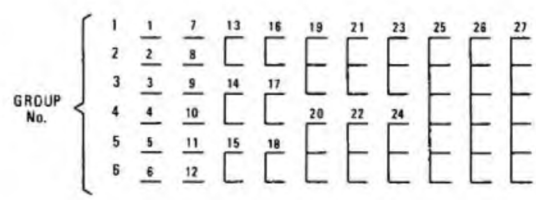
A5

Level 0: limited availability
Level 9: full availability
Level 8: full availability
Levels 7–3: spare
Level 2: full availability
Level 1: limited availability
Subscriber's uniselector: limited availability

Q6 (*a*) *Draw a typical grading chart for a 6-group grading having 27 trunks and an availability of 10.*

(*b*) *When is it necessary to employ such a grading system?* *(6 min)*

A6 (*a*) The grading chart is shown in the sketch.



(*b*) Grading of trunks is employed when the number of trunks required in a group is greater than the number of outlets available. It also increases the efficiency of use of each trunk.

Q7 The maximum number of routing digits that may be obtained from a Strowger director is . . . (Tick correct answer) *(2 min)*

(*a*) *3* (*b*) *6* (*c*) *7* (*d*) *10*

A7 (*b*) 6 ✓

Q8 Which piece of equipment is held for the shortest period of time during a local call in a director area? (Tick correct answer) *(2 min)*

(*a*) *final selector*

(*b*) *first code-selector*

(*c*) *tandem selector*

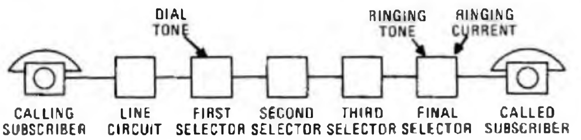
(*d*) *A-digit selector*

A8 (*d*) A-digit selector √

Q9 (*a*) *Draw a block diagram of a 5-digit non-director Strowger telephone exchange depicting an own-exchange call.*

(*b*) *Label your diagram with the source of signalling tones required to complete a successful call.*

A9



[Alternatively, a correctly drawn trunking diagram would have been acceptable.]

Q10 (*a*) *List all the items of equipment that would be particularly involved in setting up an own-exchange call in a Strowger director exchange. Label those items that could operate as either a "hunter" or "finder".*

(*b*) *State which items distribute the signalling tones.* *(6 min)*

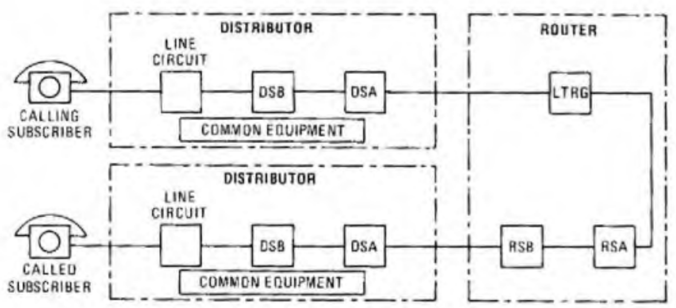
A10 (*a*) (*i*) calling subscriber's equipment
(*ii*) first code-selector
(*iii*) A-digit hunter
(*iv*) A-digit selector
(*v*) local director
(*vi*) first numerical selector
(*vii*) second numerical selector
(*viii*) final selector

Item (*i*) could be hunter or finder type; item (*iii*) is a hunter type.

(*b*) Dial tone originates via the A-digit selector; ringing tone and ringing current both originate via the final selector.

Q11 Describe, with the aid of a block diagram, how a call progresses through a local crossbar telephone exchange during an own-exchange call. *(20 min)*

A11 The routing of such a call is shown in the sketch.



When the calling subscriber's handset is lifted, his own line circuit operates at the exchange. This alerts the distributor common equipment to find a free path through a DSB switch and a DSA switch to a LTRG which has access to a free register. When the free register has been found, the call path is switched through from the line circuit to the register, which then returns dial tone to the calling subscriber.

At the completion of dialling, all the dialled digits are stored in the register. The stored digits are transferred to a free router-control, which then checks that the called line is free.

A free path has then to be established back through the called subscriber's DSB and DSA switches and the RSB and RSA switches. When the free path has been determined, the call path is switched from the called subscriber's line circuit through to the LTRG. All other common equipment is then freed for use by other calls and the LTRG sends ringing tone to the calling subscriber and ringing current to the called subscriber. The LTRG monitors the call for the called-subscriber-answered condition and controls the call for its duration. [Abbrevations used: DSA distributor switch A; RSA router switch A; LTRG line transmission relay group.]

Q12 How many electromechanical switching points are there in the call path of an own-exchange telephone call in a crossbar exchange? (Tick the correct answer) *(2 min)*

(*a*) *0*

(*b*) *6*

(*c*) *the same as the number of digits dialled*

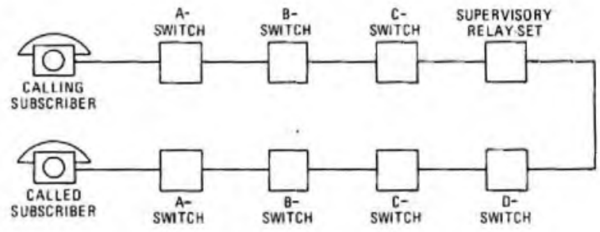
(*d*) *one less than the number of digits dialled*

A12 (*b*) 6 √

Q13 (*a*) *Draw a block diagram of a completed own-exchange telephone call in a TXE2-type exchange. Suitably label all your boxes.*

(*b*) *State the name of the piece of equipment which controls the call and list all its functions.* *(20 min)*

A13 (*a*) The diagram is shown in the sketch.



(*b*) A completed connexion is under the control of the supervisory relay-set, the functions of which are:

(*i*) to provide holding conditions for the A–C switches,
(*ii*) to provide holding conditions necessary for the A–D switches,
(*iii*) to provide ringing tone to the calling subscriber,
(*iv*) to provide ringing current to the called subscriber,
(*v*) to recognize when the called subscriber answers,
(*vi*) to provide a transmission bridge,
(*vii*) to provide meter pulses, and
(*viii*) to recognize when the subscribers clear down.

Q14 In a TXE2 exchange, dial tone is returned from . . . (Tick the correct answer) *(2 min)*

(*a*) *the A-switch*

(*b*) *the supervisory relay-set*

(*c*) *the register*

(*d*) *the call-control.*

A14 (*c*) the register √

Q15 In a TXE2 exchange, the dialled digits are initially stored in the . . . (Tick the correct answer) *(2 min)*

(*a*) *the register*

(*b*) *the call-control*

(*c*) *the supervisory relay-set*

(*d*) *the decoder*

A15 (*a*) the register √

Q16 In order to operate a crosspoint in a crossbar switch, how many magnets must be operated? (Tick the correct answer) *(2 min)*

(*a*) *1* (*b*) *2* (*c*) *3* (*d*) *4*

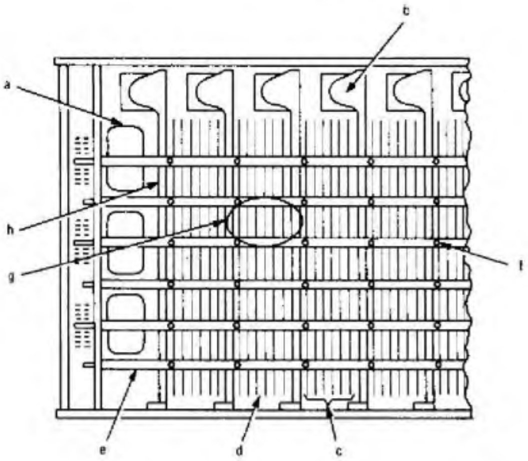
A16 (*b*) 2 √

Q17 In order to maintain a crosspoint operated in a crossbar switch, how many magnets must be operated? (Tick the correct answer) *(2 min)*

(*a*) *1* (*b*) *2* (*c*) *3* (*d*) *4*

A17 (*a*) 1 √

Q18 *The sketch shows a section of a crossbar switch. Label the parts arrowed.* *(6 min)*



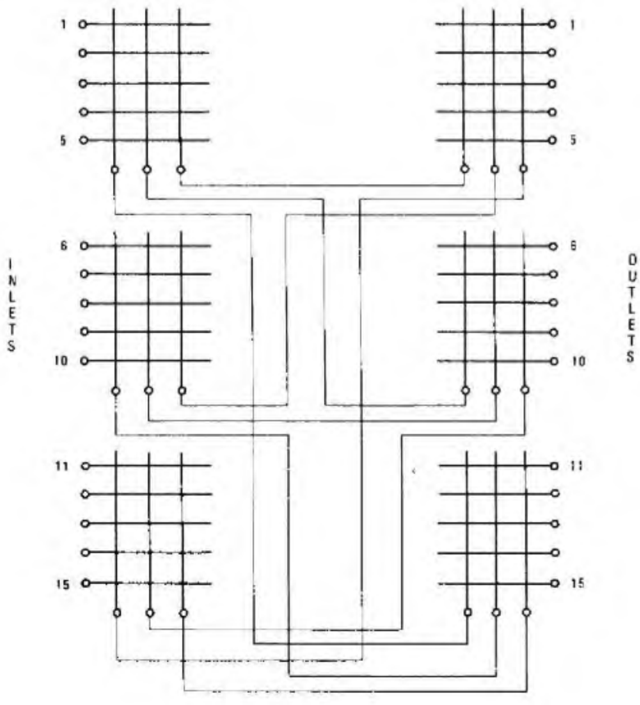
A18 (*a*) select-bar magnet and armature
(*b*) bridge-bar magnet and armature
(*c*) bridge assembly
(*d*) spring contacts
(*e*) select bar
(*f*) flexible steel finger
(*g*) crosspoint
(*h*) bridge bar

Q19 (*a*) *Draw a matrix switch having 15 inlets and 15 outlets employing link trunking to reduce the number of crosspoints to 90 but retaining full access.*

(*b*) *From your drawing determine any major disadvantages this arrangement may have over a full 15 × 15 matrix employing 225 crosspoints. Give an example.*

(*c*) *State what method may be employed to minimize this disadvantage.* *(20 min)*

A19 (*a*) The drawing of the matrix switch is shown in the sketch.



(*b*) With only 9 link trunks it is only possible for the switch to establish 9 simultaneous calls, the tenth call being blocked. Additionally, because there is only one trunk between the first 5 inlets and the first 5 outlets, once a call has been established in this section of the switch the remaining 4 inlets would be blocked from access to the remaining 4 outlets. This applies to each of the 3 sections of the switch and is known as *internal blocking*.

(c) Blocking may be reduced, but not entirely eliminated, by either of the following methods:

(*i*) the provision of an additional switching stage between the inlet switches and the outlet switches, or
(*ii*) certain outlets from some of the inlet switches being permanently wired to extra inlets on succeeding inlet switches.

Each of these methods requires the provision of additional crosspoints and basically seek to provide an alternative path where blocking would otherwise occur.

Q20 *Which of the following signalling systems operate at 10 pulses/s? Give your answer by ticking the correct system(s).* *(2 min)*

(*a*) *single-current*
(*b*) *single-frequency*
(*c*) *multi-frequency*
(*d*) *double-current*

A20 (*a*) single-current √
(*b*) single-frequency √
(*d*) double-current √

Q21 *How many different signals may be obtained by combining any 2 signalling frequencies from a total of 4 different signalling frequencies? (Tick the correct answer)* *(2 min)*

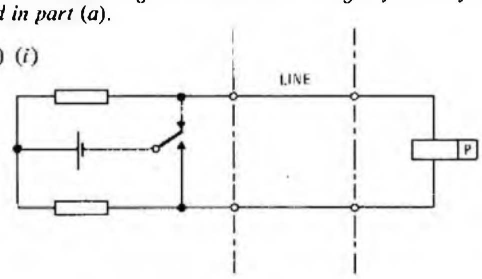
(*a*) 2 (*b*) 4 (*c*) 6 (*d*) 8

A21 (*c*) 6 √

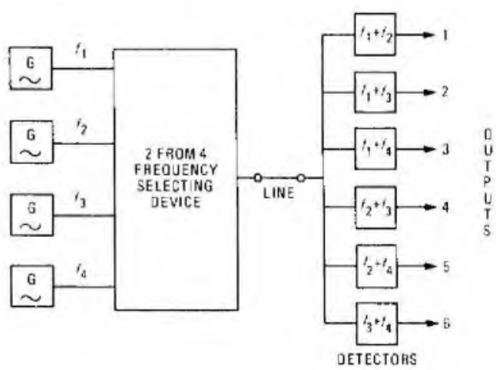
Q22 (*a*) *Sketch a simple telephone signalling circuit employing each of the following systems*
(*i*) *double-current signalling, and*
(*ii*) *multi-frequency signalling.*

(*b*) *Give one advantage and one disadvantage of each of the systems described in part* (*a*). *(15 min)*

A22 (*a*) (*i*)



(*ii*)



(*b*) (*i*) *Advantage:* Double-current signals are not so susceptible to line distortion as single-current signals, and may therefore be used on longer lines.

Disadvantage: Such a system is more expensive than a single-current system.

(*ii*) *Advantage:* Multi-frequency signals may be transmitted very much faster than other systems which are limited to 10 pulses/s.

Disadvantage: Such systems are more expensive than other systems.

Q23 Which of the following best describes the function of the telephone-instrument regulator? (Tick the correct answer) *(2 min)*

(*a*) *It smooths out the DC line current*

(*b*) *It standardizes the transmitter output and the input to the receiver*

(*c*) *It prevents high voltages damaging the instrument*

(*d*) *It prevents transmitter current being fed to its own receiver*

A23 (*b*) It standardizes the transmitter output and the input to the receiver.

Q24 The dial signals from a normal telephone instrument are . . . (Tick the correct answer) *(2 min)*

(*a*) *33% break, 66% make loop-disconnect*

(*b*) *66% break, 33% make earth-loop-disconnect*

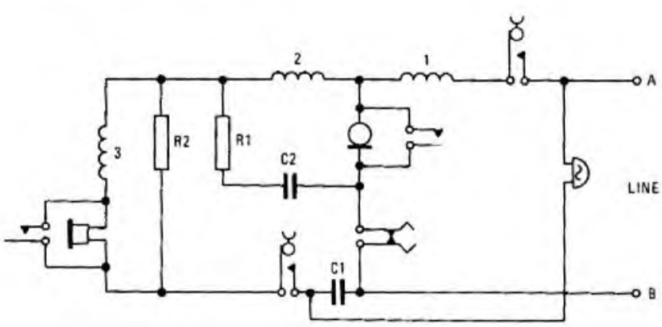
(*c*) *66% break, 33% make loop-disconnect*

(*d*) *33% break, 66% make earth-loop-disconnect*

A24 (*c*) 66% break, 33% make loop-disconnect √

Q25 (*a*) *List all the signals that would be required between a telephone instrument and the telephone-exchange equipment to establish a successful call.*

(*b*) *List the components of the telephone instrument shown in the sketch to provide each of the signals given in part* (*a*) *(10 min)*



A25 (*a*) (*i*) Calling the exchange
(*ii*) dial pulses
(*iii*) ringing indication
(*iv*) called-subscriber answered
(*v*) cleardown

(*b*) The components involved in each of the signals listed in part (*a*) are:

(*i*) gravity switch in the A-leg, coil No. 1, telephone transmitter, dial impulse springset, B-leg;
(*ii*) gravity switch in the A-leg, coil No. 1, dial pulsing springs, dial off-normal spring across the transmitter;
(*iii*) AC bell, capacitor C1;
(*iv*) as for part (*i*);
(*v*) gravity switch in the A-leg, gravity switch in the B-leg.

Q26 (*a*) *Explain the meaning of the term sidetone.*

(*b*) *Give 3 disadvantages of excessive sidetone.*

(*c*) *Give one disadvantage of too little sidetone.*

(*d*) *Give a suitable sketch and explain how sidetone may be reduced to an acceptable level.* *(10 min)*

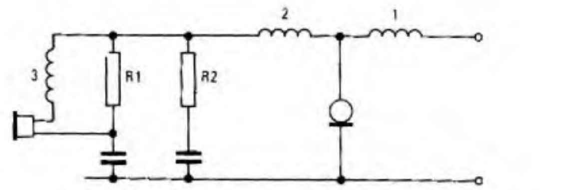
A26 (*a*) Sidetone is the reproduction of sounds in the receiver from the transmitter of the same instrument.

(*b*) Three disadvantages of excessive sidetone are:

(*i*) The speaker tends to lower his voice as he appears to himself to be shouting. This reduction then causes the speaker to appear to be faint to the listener.
(*ii*) The ear of the speaker adjusts to the high-level energy and thus the incoming signal appears faint.
(*iii*) Interference from background room-noise becomes more significant and possibly intolerable.

(*c*) Little or no sidetone gives the speaker the impression that the telephone is "dead" which is disconcerting.

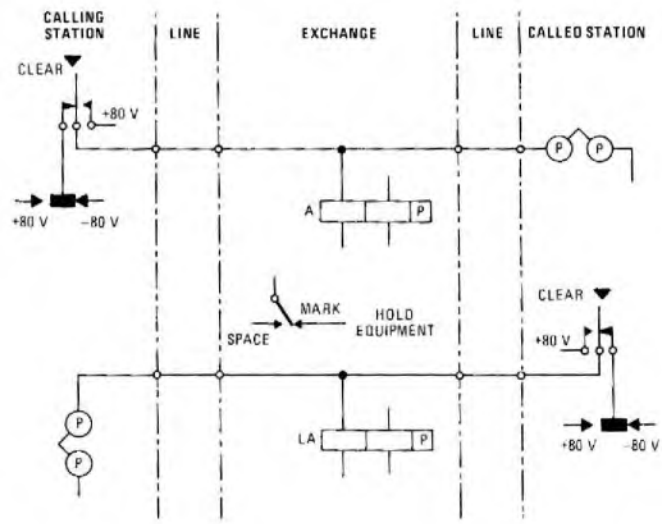
(*d*) A circuit to reduce the amount of sidetone is shown in the sketch.



Voltages generated by the transmitter cause a current to flow through the receiver. This current also flows through winding No. 2 which, in turn, induces a voltage in winding No. 3 such as to cause a current to flow in the opposite direction to that caused directly by in the transmitter. By careful selection of component values, the 2 currents may be adjusted to give the desired amount of sidetone.

Q27 Explain briefly, with the aid of a circuit-element diagram, how cleardown of an own-exchange Telex call is achieved. *(15 min)*

A27 When the call is finished, to achieve cleardown each subscriber should press the CLEAR key for a minimum time of 325 ms. The operation of the CLEAR key extends a +80 V SPACE condition to the exchange, which operates the polarized relay A to the SPACE position. The cleardown of the equipment is then initiated and both lines revert to their working free condition. Cleardown is under the control of either subscriber, unlike a telephone circuit where only the calling subscriber can clear the call. If the CLEAR key is pressed at the called station, the polarized relay LA is released, which in turn releases relay A.



Q28 When a Telex operator calls the exchange, the calling condition to the line is. . . . . (Tick the correct answer.) *(2 min)*

(*a*) *a pulsing +80 V*

(*b*) *a pulsing −80 V*

(*c*) *a steady +80 V*

(*d*) *a steady −80 V*

A28 (*d*) a steady −80 V √

Q29 A Telex operator is advised that he may proceed to dial by what condition? (Tick the correct answer.) *(2 min)*

(*a*) *printed supervisory*

(*b*) *a glowing lamp*

(*c*) *the sound of the motor running*

(*d*) *a standard 10 s delay*

A29 (*b*) a glowing lamp √
[The lamp is usually green which lights only when the motor has reached its working speed.]

Students are advised to read the notes on p. 65

TYPICAL TIME LIMIT FOR Q1–5: 12 min

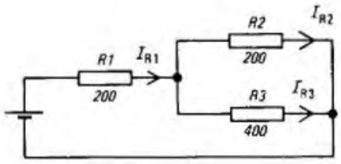
Q1 *Match the units in the second column to the quantities in the first.*

(1) Potential difference	*(a) ohms*	**1d**
(2) Current	*(b) joules*	**2h**
(3) Resistance	*(c) farads*	**3a**
(4) Charge	*(d) volts*	**4g**
(5) Force	*(e) newtons*	**5e**
(6) Energy	*(f) watts*	**6b**
(7) Power	*(g) coulombs*	**7f**
	(h) amperes	

Q2 *Find the current (I) in a resistance (R) of 2 MΩ connected to a supply voltage (V) of 400 mV.*

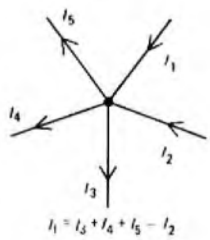
A2 $I = \frac{V}{R} = \frac{400 \times 10^{-3}}{2 \times 10^6} = 200 \times 10^{-9}$ A = 200 nA.

Q3 *In the sketch, if I_{R2} = 40 mA, find the supply voltage.*



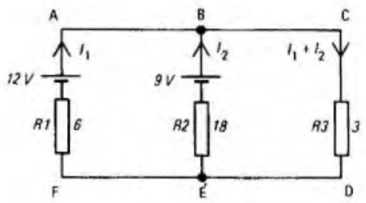
A3 Voltage across R2 (V_{R2}) = $40 \times 10^{-3} \times 200$ = 8 V.
Voltage across R3 (V_{R3}) = V_{R2} = 8 V.
Current in R3 (I_{R3}) = 8/400 A = 20 mA.
Current in R1 (I_{R1}) = $I_{R2} + I_{R3}$ = 60 mA.
Voltage across R1 (V_{R1}) = $60 \times 10^{-3} \times 200$ = 12 V.
Supply voltage = $V_{R1} + V_{R2//R3}$ = 12 + 8 = 20 V.

Q4 *Identify and state the law applicable to the situation shown in the sketch.*



A4 Kirchhoff's first law: the algebraic sum of the currents at a junction is zero.

Q5 *Use Kirchhoff's second law to find the current flowing in R3.*



A5 The nodes of the circuit are labelled as shown, and the currents I_1 and I_2 are assumed, giving the current in R3 as $I_1 + I_2$.

Loop ABCDEF: $3(I_1 + I_2) + 6I_1 = 12$.

$\therefore \quad 9I_1 + 3I_2 = 12.$ .... (1)

Loop BCDE: $3(I_1 + I_2) + 18I_2 = 9$.

$\therefore \quad 3I_1 + 21I_2 = 9.$ .... (2)

Multiplying equation (2) by 3, and subtracting equation (1) gives

$60I_2 = 15$, whence $I_2 = 0{\cdot}25$ A.

Substituting for I_2 in equation (1) gives

$9I_1 = 12 - 0{\cdot}75$, whence $I_1 = 1{\cdot}25$ A.

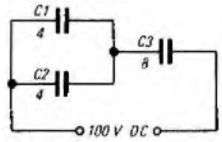
Hence, the current in R3

$= 0{\cdot}25 + 1{\cdot}25 = 1{\cdot}5$ A.

TYPICAL TIME LIMIT FOR Q6–8: 5 min

Q6 *The insulating medium separating two charged surfaces is known as a* .... **dielectric**

Q7 *For the circuit shown, determine the energy stored in the capacitors.*



A7 The capacitance, $C_{1//2}$, of capacitors C1 and C2 in parallel is given by

$$C_{1//2} = C_1 + C_2 = 8\ \mu F.$$

The total capacitance, C, of the circuit is $C_{1//2}$ in series with C3, and is given by

$$C = 1/\{(1/C_{1//2}) + (1/C_3)\} = 1/(1/8 + 1/8) = 4\ \mu F.$$

The energy stored in a capacitor is $\frac{1}{2}CV^2$, where V is the voltage. The total energy stored in the circuit is therefore

$$\tfrac{1}{2} \times 4 \times 10^{-6} \times 100^2 \text{ J} = 20 \text{ mJ}.$$

Q8 *Select from the list below the correct value of field strength between the plates of a parallel-plate capacitor charged to 60 V if the distance between the plates is 2 mm.*

(a) 30 kV/m — **a. 30 kV/m**
(b) 120 mV/m
(c) 120 mJ — $[E = V/d = 60/(2 \times 10^{-3})$ V/m]
(d) 30 kC
(e) 15 kV/m²

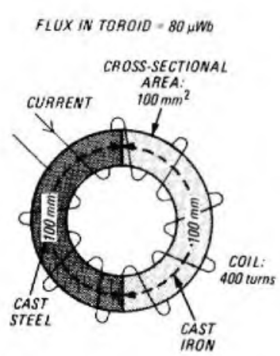
TYPICAL TIME LIMIT FOR Q9–12: 10 min

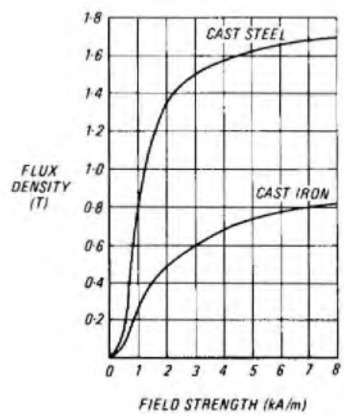
Q9 *Permeability is the ratio of* .... **flux density**
to .... **field strength.**

Q10 *State the units of the following quantities:*

(a) absolute permeability	**henrys/metre**
(b) magnetomotive force	**amperes**
(c) reluctance	**amperes/weber**

Q11 *Using the magnetizing curves given, find for the toroid shown, (a) the flux density, (b) the field strength in each of the iron and steel parts, (c) the total magnetomotive force required, (d) the current in the coil, and (e) the reluctance of the iron and of the steel. Neglect leakage.*





A11 (*a*) $B = \Phi/A = 80 \times 10^{-6}/100 \times 10^{-6}$ T = $\underline{800 \text{ mT}}$.

(*b*) From the curves, for B = 800 mT, $\underline{H_{iron} = 7 \text{ kA/m}}$,
and $\underline{H_{steel} = 1 \text{ kA/m}}$.

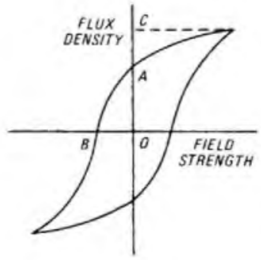
(*c*) $MMF_{iron} = H_{iron}\, l_{iron} = 7 \times 10^3 \times 100 \times 10^{-3} = 700$ A.
$MMF_{steel} = H_{steel}\, l_{steel} = 1 \times 10^3 \times 100 \times 10^{-3} = 100$ A.
$MMF_{total} = MMF_{iron} + MMF_{steel} = \underline{800 \text{ A}}$.

(*d*) $I = MMF/N = 800/400 = \underline{2 \text{ A}}$.

(*e*) $S_{iron} = MMF_{iron}/\Phi = 700/80 \times 10^{-6}$ A/Wb $= \underline{8{\cdot}75 \text{ MA/Wb}}$.
$S_{steel} = MMF_{steel}/\Phi = 100/80 \times 10^{-6}$ A/Wb $= \underline{1{\cdot}25 \text{ MA/Wb}}$.

B	: flux density	MMF	: magnetomotive force
H	: field strength	l	: length
Φ	: flux	I	: current
A	: cross-sectional area	S	: reluctance
N	: turns on coil		

Q12 In the hysteresis loop shown, what is represented by:



(*i*) *OA*	**Remanence**
(*ii*) *OB*	**Coercivity**
(*iii*) *point C*	**Saturation**

TYPICAL TIME LIMIT FOR Q13–15: 4 min

Q13 The force on a conductor in a magnetic field is related to the flux density of the field, the current in the conductor, and the length of the conductor in the field. Assuming that the other two factors remain constant, what happens to the force if the current doubles?

A13 It doubles also.

Q14 What is the effect called whereby a change in current in one circuit causes an EMF to be induced in another?

A14 Mutual inductance.

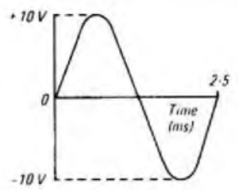
Q15 A 20 mH inductor has a resistance of 8 Ω. Calculate the energy stored in its magnetic field when it is connected to a 28 V supply.

A15 Current in inductor $= \dfrac{\text{voltage}}{\text{resistance}} = \dfrac{28}{8} = 3{\cdot}5$ A.

Energy stored = 0·5 × inductance × square of current,
$= 0{\cdot}5 \times 20 \times 10^{-3} \times 3{\cdot}5^2$ J $= \underline{122{\cdot}5 \text{ mJ}}$.

TYPICAL TIME LIMIT FOR Q16–20: 12 min

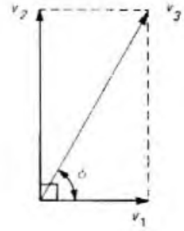
Q16 For the sinusoidal waveform given, state:



(*a*) *the peak amplitude*	**10 V**
(*b*) *the period*	**2·5 ms**
(*c*) *the frequency*	**400 Hz**
(*d*) *the RMS amplitude*	**7·07 V**
(*e*) *the instantaneous amplitude at 1·25 ms*	**zero**

Q17 Two sine waves are defined by the expressions $v_1 = 5{\cdot}2 \sin \omega t$ volts and $v_2 = 9 \sin (\omega t + \pi/2)$ volts. Find by phasor addition an expression for v_3, where $v_3 = v_1 + v_2$.

A17 The phasor diagram is shown in the sketch. Phasor v_1 is the reference phasor, and has an amplitude of 5·2 V. Phasor v_2, having an amplitude of 9 V, leads phasor v_1 by $\pi/2$ rad (90°).



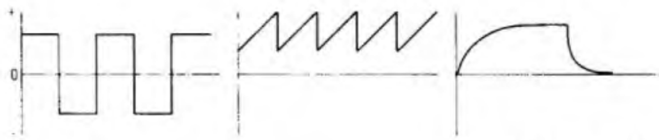
The amplitude of phasor $v_3 = \sqrt{(5{\cdot}2^2 + 9^2)} = 10{\cdot}34$ V.

The phase angle (ϕ) = $\tan^{-1} 9/5{\cdot}2 = 60°$, which is $\pi/3$ rad. Phasor v_3 leads phasor v_1, so that the phase angle is $+\pi/3$ rad.

Therefore, $\underline{v_3 = 10{\cdot}34 \sin (\omega t + \pi/3) \text{ volts}}$.

Q18 State whether each of the following waveforms is alternating or unidirectional.

Alternating	**Unidirectional**	**Unidirectional**

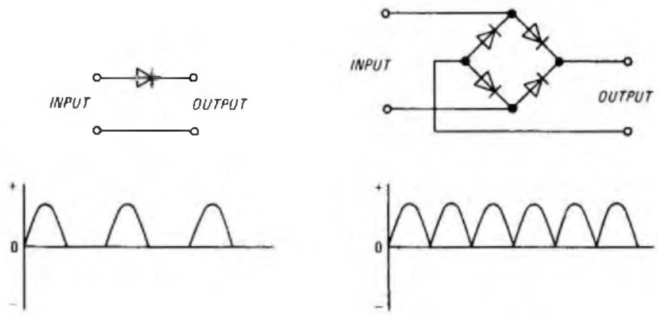


Alternating	**Unidirectional**	**Unidirectional**

Q19 What RMS current flows when a sinusoidal voltage of peak amplitude 8·5 V is applied to a 300 Ω resistor? What is the power in the circuit?

A19 RMS voltage = 0·707 × 8·5 = 6 V.
RMS current = 6/300 A = $\underline{20 \text{ mA}}$.
Power = $20^2 \times 10^{-6} \times 300$ W = $\underline{120 \text{ mW}}$.

Q20 Assuming a sinusoidal input, sketch several cycles of the output waveform for each of the circuits shown.



TYPICAL TIME LIMIT FOR Q21–29: 30 min

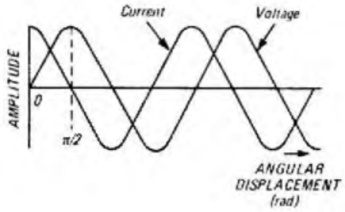
Q21 Find the current flowing in a 40 mH pure inductance connected across a 12 V 318 Hz supply.

A21 Inductive reactance, X_L, is given by $2\pi fL$ ohms, where f is the frequency (hertz), and L is the inductance (henrys).

$\therefore \quad X_L = 2\pi \times 318 \times 40 \times 10^{-3} = 80\ \Omega$.

Current = voltage/reactance = 12/80 A = $\underline{150 \text{ mA}}$.

Q22 The two waveforms shown refer to a circuit containing a pure reactance. Is the reactance capacitive or inductive?



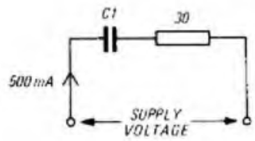
A22 Capacitive

Q23 What is the reactance of a 4 μF capacitor at 1 kHz?

A23 Capacitive reactance, X_C is given by $1/2\pi fC$ ohms, where f is the frequency (hertz), and C is the capacitance (farads).

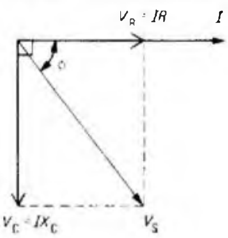
$\therefore \quad X_C = 1/2\pi \times 1 \times 10^3 \times 4 \times 10^{-6} = \underline{39{\cdot}8\ \Omega}.$

Q24 Draw a phasor diagram showing the current and voltages in the circuit given. Determine the supply voltage and its phase angle.



Capacitive reactance 40 Ω

A24 [*Tutorial Note:* Phasor I (the current) is the reference phasor. Phasor V_R (the voltage across the resistor) is in phase with the current, and has a magnitude IR, where R is the resistance. Phasor V_C (the voltage across the capacitor) lags the current by 90°, and has a magnitude IX_C, where X_C is the capacitive reactance. The supply voltage, V_S, is the resultant of V_R and V_C, and ϕ is the phase angle between the supply voltage and the current.]



$V_R = 0{\cdot}5 \times 30 = 15$ V.
$V_C = 0{\cdot}5 \times 40 = 20$ V.
$V_S = \sqrt{(15^2 + 20^2)} = \underline{25\ \text{V}}.$
$\phi = \tan^{-1} 20/15$
$= \underline{53{\cdot}13° \text{ (lagging)}}.$

Q25 A circuit consists of a 35 mH inductance in series with a 12 Ω resistor. If the circuit is operated at a frequency of 50 Hz, determine (a) the magnitude of the impedance, and (b) its phase angle.

A25 (*a*) $X_L = 2\pi fL = 2\pi \times 50 \times 35 \times 10^{-3} = 11\ \Omega.$
$|Z| = \sqrt{(R^2 + X_L^2)} = \sqrt{(12^2 + 11^2)} = \underline{16{\cdot}3\ \Omega}.$

(*b*) $\phi = \tan^{-1} X_L/R = \tan^{-1} 11/12 = \underline{42{\cdot}5°}.$

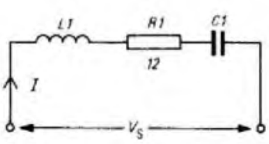
(In an inductive circuit, the voltage leads the current.)

X : Reactance
f : Frequency
L : Inductance
$|Z|$: Magnitude of impedance
R : Resistance
ϕ : Phase angle

Q26 Find the power dissipated in a 450 μH inductor connected to a 3 kHz supply. The current in the circuit is 5 μA, and the resistance of the inductor is 0·5 Ω.

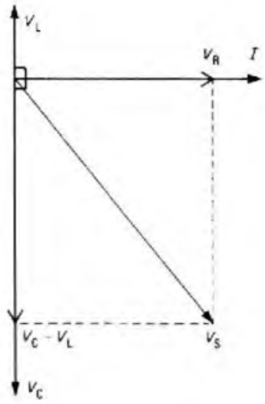
A26 Power = current² × resistance
$= 5^2 \times 10^{-12} \times 0{\cdot}5\ \text{W} = \underline{12{\cdot}5\ \text{pW}}.$

Q27 For the circuit shown, find
(a) the current, I,
(b) the voltage (V_L) across L1,
(c) the voltage (V_C) across C1,
(d) the supply voltage (V_S),
(e) the impedance (Z), and
(f) the power dissipated (P).



Reactance (X_L) of L1 = 5 Ω
Reactance (X_C) of C1 = 20 Ω
Voltage (V_R) across R1 = 96 V

A27 [*Tutorial Note:* Constructing a phasor diagram assists in the solution of this problem. I is the reference phasor. V_R is in phase with I, and has a magnitude IR_1 (so that $I = V_R/R_1$). V_C lags I by 90°, and has a magnitude IX_C. V_L leads I by 90°, and has a magnitude IX_L. The effective reactive voltage in the circuit is given by $V_C - V_L$, and V_S is the resultant of $(V_C - V_L)$ and V_R.]



(*a*) $I = 96/12 = \underline{8\ \text{A}}.$
(*b*) $V_L = 8 \times 5 = \underline{40\ \text{V}}.$
(*c*) $V_C = 8 \times 20 = \underline{160\ \text{V}}.$
(*d*) $V_C - V_L = 120$ V.
$V_S = \sqrt{\{(V_C - V_L)^2 + V_R^2\}}$
$= \sqrt{(120^2 + 96^2)} = \underline{154\ \text{V}}.$
(*e*) $Z = V/I = 154/8 = \underline{19{\cdot}25\ \Omega}.$
(*f*) $P = I^2 R_1 = 8^2 \times 12 = \underline{768\ \text{W}}.$

Q28 Define series resonance.

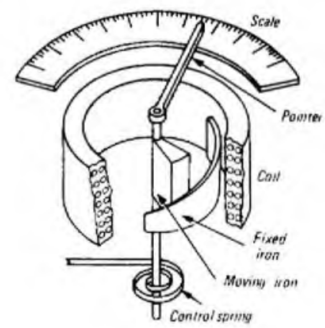
A28 Series resonance occurs when the supply voltage and current are in phase.

Q29 Indicate which of the following statements are true and which are false for a circuit in series resonance, (V_S is the supply voltage, V_L is the voltage across the inductance, and V_C is the voltage across the capacitance.)

(*a*) $V_L = V_C$	**False**
(*b*) $V_L = -V_C$	**True**
(*c*) V_L *exceeds* V_C	**False**
(*d*) V_C *and* $V_L = 0$	**False**
(*e*) V_C *can exceed* V_S	**True**

TYPICAL TIME LIMIT FOR Q30–33: 10 min

Q30 The diagram shows the basic construction of a moving-iron instrument. The current to be measured is passed through the coil.



(*a*) *What is set up by this current?*	**A magnetic field**
(*b*) *What state does this produce in the fixed and moving irons?*	**It magnetizes them**
(*c*) *What type of force results between the fixed and moving irons?*	**A force of repulsion**
(*d*) *What is the effect of this force on the moving iron, and why?*	**The moving iron moves towards the smaller end of the fixed iron, where the repulsion is less**
(*e*) *How is this effect translated into a scale reading?*	**The movement rotates the pointer over the scale**
(*f*) *What eventually neutralizes the effect?*	**The control spring**

Q31 Briefly explain how one major source of error in measurement is eliminated by using a DC potentiometer rather than a standard moving-coil voltmeter.

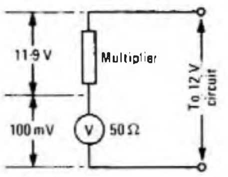
A31 Under balance conditions, a potentiometer takes no current from the circuit under test, and so does not disturb the circuit conditions. A moving-coil instrument requires a driving current, and so would alter the conditions in the circuit.

Q32 What is the effect of using a moving-coil rectifier instrument to measure a non-sinusoidal waveform?

A32 The scale of a moving-coil rectifier instrument is normally calibrated to indicate the RMS value of a sinusoidal input. The instrument is therefore subject to error when used with non-sinusoidal inputs.

Q33 A moving-coil instrument has a resistance of 50 Ω and gives full-scale deflexion with a voltage of 100 mV across the coil. The instrument is to be used as a voltmeter with a 0–12 V scale. Draw a sketch showing the circuit elements necessary to achieve this. Give values for any components you specify.

A33 [*Tutorial Note:* At full-scale deflexion, the instrument requires a potential difference of 100 mV across it. If 12 V are to be measured, 11·9 V must be dropped across a resistor in series with the meter. This resistor is known as a *multiplier.*]



If the voltage across the meter is 100 mV and its resistance is 50 Ω, the current in the circuit is $100 \times 10^{-3}/50 = 2$ mA. Thus, the value of the multiplier

$= 11{\cdot}9/2 \times 10^{-3} = \underline{5{\cdot}95\ \text{k}\Omega}.$

CITY AND GUILDS OF LONDON INSTITUTE

Questions and Answers

Answers are occasionally omitted or reference is made to earlier Supplements in which questions of substantially the same form, together with the answers, have been published. Some answers contain more detail than would be expected from candidates under examination conditions.

MATHEMATICS A 1979

Students were expected to answer any 6 questions

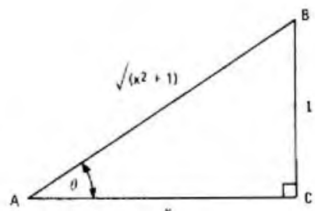
Q1 (a) (i) Convert 1·46 rad to degrees and minutes.
(ii) Express 127° 33′ in radians correct to 2 decimal places.

(b) If $\tan\theta = \frac{1}{x}$, *find expressions for* $\sin\theta$ *and* $\cos\theta$ *in terms of x.*

(c) Three phasors i_1, i_2 *and* i_3 *amperes are given by*

$$i_1 = 12\sin\omega t,$$
$$i_2 = 8\sin\left(\omega t - \frac{\pi}{4}\right), \text{ and}$$
$$i_3 = 6\sin\left(\omega t + \frac{2\pi}{3}\right).$$

Calculate their resultant and express the result in the form $i = I\sin(\omega t + \alpha)$, *where* α *is in radians and t is in seconds.*



(*a*)

A1 (*a*) (*i*)

$$\pi \text{ rad} = 180°$$
$$\therefore\quad 1{\cdot}46 \text{ rad} = \frac{180}{\pi} \times 1{\cdot}46°,$$
$$= 83{\cdot}6518°,$$
$$= \underline{83°\ 39'}.$$

(*ii*)

$$127°\ 33' = \frac{\pi}{180} \times 127{\cdot}55 \text{ rad},$$
$$= \underline{2{\cdot}23 \text{ rad}} \text{ correct to 2 decimal places.}$$

(*b*)

$$\tan\theta = \frac{1}{x}.$$

Sketch (*a*) shows triangle ABC in which BC = 1 and AC = *x*, so that $\tan\theta = \tan\angle BAC = \frac{1}{x}$.

By Pythagoras's theorem,

$$AB^2 = AC^2 + BC^2,$$
$$= x^2 + 1.$$
$$\therefore\quad AB = \sqrt{(x^2 + 1)}.$$

Hence,

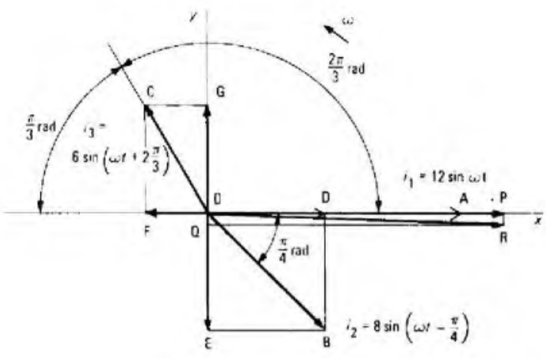
$$\sin\theta = \frac{BC}{AB} = \underline{\frac{1}{\sqrt{(x^2+1)}}}, \text{ and}$$
$$\cos\theta = \frac{AC}{AB} = \underline{\frac{x}{\sqrt{(x^2+1)}}}.$$

(*c*)

$$i_1 = 12\sin\omega t \text{ amperes},$$
$$i_2 = 8\sin\left(\omega t - \frac{\pi}{4}\right) \text{ amperes},$$
$$i_3 = 6\sin\left(\omega t + \frac{2\pi}{3}\right) \text{ amperes}.$$

Sketch (*b*) shows the 3 current phasors, drawn on rectangular axes O*x* and O*y* and using the conventional counter-clockwise rotation of vectors to represent phase difference.

OA represents the phasor i_1 along the *x*-axis, OB represents the phasor i_2 lagging i_1 by $\frac{\pi}{4}$ rad (that is, an angle of $-\frac{\pi}{4}$ rad) and OC represents i_3 leading i_1 by $\frac{2\pi}{3}$ rad.



(*b*)

Resolving i_2 into components along the *x*-axis and the *y*-axis,

$$OD = OB\cos\left(-\frac{\pi}{4}\right) = 8 \times 0{\cdot}7071 = 5{\cdot}6568\ A.$$

$$OE = OB\sin\left(-\frac{\pi}{4}\right) = 8 \times -0{\cdot}7071 = -5{\cdot}6568\ A.$$

Resolving i_3 into components along the *x*-axis and the *y*-axis,

$$OF = OC\cos\frac{2\pi}{3} = 6 \times -0{\cdot}5 = -3\ A.$$

$$OG = OC\sin\frac{2\pi}{3} = 6 \times 0{\cdot}866 = 5{\cdot}196\ A.$$

The net component along the *x*-axis is

$$OA + OD + OF,$$
$$= 12 + 5{\cdot}6568 - 3 = 14{\cdot}6568\ A.$$

The net component along the *y*-axis is

$$OE + OG,$$
$$= -5{\cdot}6568 + 5{\cdot}196 = -0{\cdot}4608\ A.$$

These components are shown as OP and OQ along the *x*-axis and the *y*-axis respectively.

The resultant of the 3 phasors is therefore represented by the diagonal of the rectangle OPRQ, shown as OR.

$$OR^2 = OP^2 + PR^2 = OP^2 + OQ^2,$$
$$= 14{\cdot}6568^2 + (-0{\cdot}4608)^2,$$
$$= 214{\cdot}822 + 0{\cdot}212 = 215{\cdot}034.$$
$$\therefore \quad OR = 14{\cdot}664\ A.$$
$$\tan\angle POR = \frac{PR}{OP} = \frac{OQ}{OP},$$
$$= \frac{-0{\cdot}4608}{14{\cdot}6568} = -0{\cdot}03144.$$
$$\therefore \quad \angle POR = -0{\cdot}03143\ \text{rad}.$$

Hence, the resultant, i, is expressed as

$$i = 14{\cdot}664\sin(\omega t - 0{\cdot}0314).$$

Q2 *(a) Solve each of the following equations for values of A such that $0° \leqslant A \leqslant 360°$.*

(i) $\sin A = 0{\cdot}9511$,
(ii) $\cos A = 0{\cdot}8387$, and
(iii) $\tan A = 1{\cdot}8040$.

(b) Compile a table of values for $y_1 = 3\sin(2\theta + 30°)$ and $y_2 = 4\cos(3\theta - 60°)$ at intervals of 10° between $\theta = 0°$ and $\theta = 50°$ giving all the results correct to 2 places of decimals.

(c) Draw accurately on the same axes the graphs of $y_1 = 3\sin(2\theta + 30°)$ and $y_2 = 4\cos(3\theta - 60°)$.

(d) Using the graphs in part (c), solve the equation

$$3\sin(2\theta + 30°) = 4\cos(3\theta - 60°).$$

A2 (*a*) (*i*)

$$\sin A = 0{\cdot}9511.$$
$$\therefore \quad A = 72° \text{ or } (180° - 72°),$$
$$= 72° \text{ or } 108°.$$

(*ii*)

$$\cos A = 0{\cdot}8387.$$
$$\therefore \quad A = 33° \text{ or } (360° - 33°),$$
$$= 33° \text{ or } 327°.$$

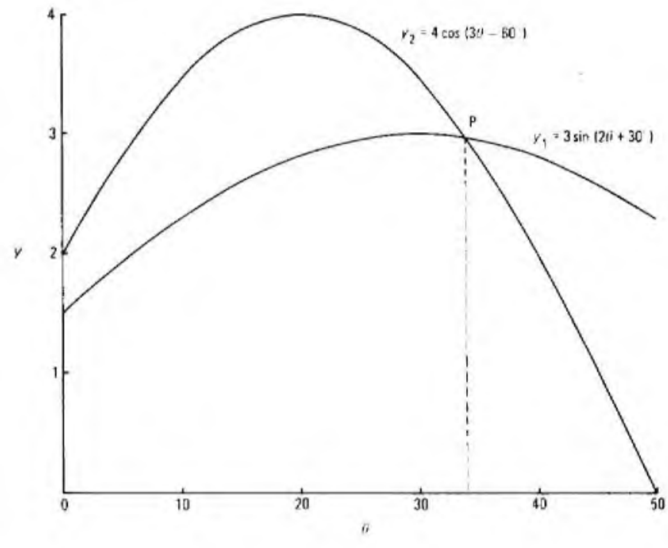
(*iii*)

$$\tan A = 1{\cdot}8040.$$
$$\therefore \quad A = 61° \text{ or } 61° + 180°),$$
$$= 61° \text{ or } 241°.$$

(*b*)

$\theta°$	0	10	20	30	40	50
$2\theta° + 30°$	30	50	70	90	110	130
$\sin(2\theta + 30)°$	0·5	0·766	0·940	1·0	0·940	0·766
$3\theta° - 60°$	−60	−30	0	30	60	90
$\cos(3\theta - 60)°$	0·5	0·866	1·0	0·866	0·5	0
y_1	1·50	2·30	2·82	3·00	2·82	2·30
y_2	2·00	3·46	4·00	3·46	2·00	0·00

(*c*) The graphs of y_1 and y_2 are shown in the sketch.



(*d*) From the sketch, the graphs intersect at the one point, P, within the range of θ from 0° to 50° and at point P, $y_1 = y_2$.

The solution, from the sketch, is $\theta = 34°$.

Q3 *A periodic waveform is of the form $i = 20\sin(200\pi t + 0{\cdot}4)$, where i is in amperes, t in seconds and the angle in radians.*

(a) State the amplitude, frequency and period.

(b) Calculate the value of i when $t = 0$.

(c) Calculate the 2 values of t between 0 and 0·01 when $i = 15$.

(d) Sketch the graph of this waveform between $t = 0$ and $t = 0{\cdot}01$. Indicate on the graph the results obtained in parts (b) and (c).

A3 (*a*) Amplitude = 20 A.
Frequency = 100 Hz.
Period = 0·01 s.

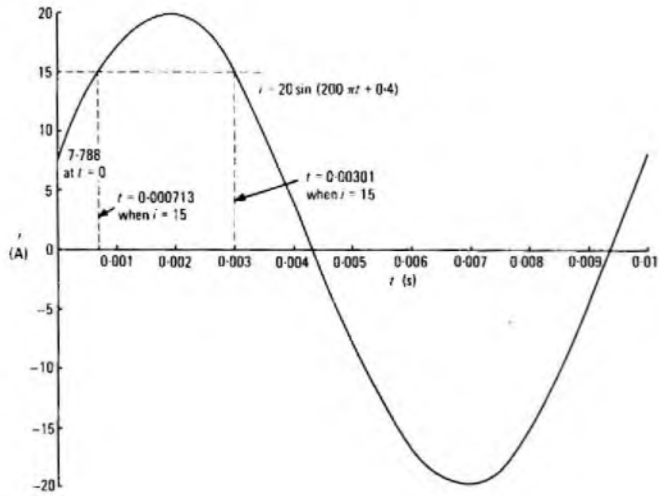
(*b*) When $t = 0$, $i = 20\sin 0{\cdot}4$,
$= 20 \times 0{\cdot}3894$,
$= 7{\cdot}788$ A.

(*c*) When $i = 15$,

$$20\sin(200\pi t + 0{\cdot}4) = 15.$$
$$\therefore \sin(200\pi t + 0{\cdot}4) = 0{\cdot}75.$$
$$\therefore \quad 200\pi t + 0{\cdot}4 = 0{\cdot}8481 \text{ or } \pi - 0{\cdot}8481 \text{ or } 2\pi + 0{\cdot}8481 \text{ rad}.$$
$$\therefore \quad 200\pi t = 0{\cdot}4481 \text{ or } 1{\cdot}8935 \text{ or } 7{\cdot}1313.$$
$$\therefore \quad t = 0{\cdot}000713 \text{ or } 0{\cdot}00301 \text{ or } 0{\cdot}0113.$$

The final value given is outside the required range and therefore the required values are 0·000713 s and 0·00301 s.

(*d*) The graph is shown in the sketch with the results of parts (*b*) and (*c*) indicated.



Q4 (*a*) *Using the identity* $\sin^2\alpha + \cos^2\alpha = 1$, *obtain the numerical values for*

(*i*) $\dfrac{1}{1+\tan^2\alpha} \times \dfrac{1}{\cos^2\alpha}$, *and*

(*ii*) $\dfrac{\sin\alpha}{\cos^2\alpha - 1} \times \dfrac{\sin\alpha\cos\alpha}{\sqrt{(1-\sin^2\alpha)}}$.

(*b*) *If θ is an acute angle measured in radians, express* EACH *of the following in terms of* sin θ, cos θ *or* tan θ *with the appropriate plus or minus sign:*

(*i*) $\sin(\theta - \pi)$,
(*ii*) $\tan(1{\cdot}5\pi + \theta)$, *and*
(*iii*) $\cos(\theta + 0{\cdot}5\pi)$.

(*c*) *A coastguard station first observes a ship at a distance of 5·0 km. Half an hour later the ship is at a distance of 10·0 km. If the distances are recorded at sea level and the cosine of the angle between the two directions is −0·44, calculate the speed of the ship in kilometres per hour, assuming that it moves in a straight line.*

A4 (*a*) (*i*)

$$\frac{1}{1+\tan^2\alpha} \times \frac{1}{\cos^2\alpha}$$

$$= \frac{1}{1+\dfrac{\sin^2\alpha}{\cos^2\alpha}} \times \frac{1}{\cos^2\alpha},$$

$$= \frac{\cos^2\alpha}{\cos^2\alpha + \sin^2\alpha} \times \frac{1}{\cos^2\alpha} = \underline{1.}$$

(*ii*)

$$\frac{\sin\alpha}{\cos^2\alpha - 1} \times \frac{\sin\alpha\cos\alpha}{\sqrt{(1-\sin^2\alpha)}}$$

$$= \frac{\sin^2\alpha\cos\alpha}{-\sin^2\alpha\sqrt{\cos^2\alpha}} \text{ (since } \cos^2\alpha - 1 = -\sin^2\alpha\text{)},$$

$$= \underline{-1.}$$

(*b*) (*i*) $\sin(\theta - \pi) = \underline{-\sin\theta.}$

(*ii*) $$\tan(1{\cdot}5\pi + \theta) = \frac{\tan 1{\cdot}5\pi + \tan\theta}{1 - \tan 1{\cdot}5\pi\tan\theta}.$$

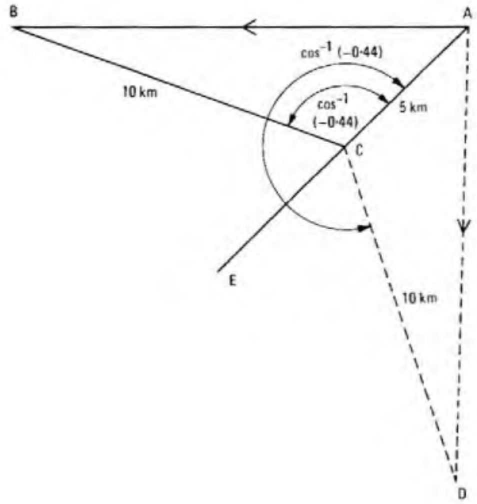
But, $\tan 1{\cdot}5\pi = \tan 270° = \infty$.
Dividing the numerator and the denominator by $\tan 1{\cdot}5\pi$ gives

$$\tan(1{\cdot}5\pi + \theta) = \frac{1 + \dfrac{\tan\theta}{\infty}}{\dfrac{1}{\infty} - \tan\theta},$$

$$= \frac{1}{-\tan\theta} = -\underline{\frac{1}{\tan\theta}}.$$

(*iii*) $$\cos(\theta + 0{\cdot}5\pi) = \cos\theta\cos 0{\cdot}5\pi - \sin\theta\sin 0{\cdot}5\pi,$$
$$= \cos\theta \times 0 - \sin\theta \times 1,$$
$$= \underline{-\sin\theta.}$$

(*c*) In the sketch, C represents the coastguard station and A the initial position of the ship, so that AC = 5 km. If B represents the second position of the ship after half an hour, then BC = 10 km and ∠ ACB = $\cos^{-1}(-0{\cdot}44)$.



Note: $\cos^{-1}(-0{\cdot}44) = 180° + 63° 54'$ and hence an alternative direction of travel of the ship would be in the direction AD, as shown by the dotted line in the sketch. It is clear that triangles ABC and ACD are congruent and hence both solutions will yield the same distance and hence the same speed.

In triangle ABC, AB is a straight line. Using the cosine rule

$$AB^2 = AC^2 + CB^2 - 2 \times AC \times CB \times \cos\angle ACB,$$
$$= 5^2 + 10^2 - 2 \times 5 \times 10 \times (-0{\cdot}44),$$
$$= 25 + 100 + 44,$$
$$= 169.$$

∴ $AB = \sqrt{169} = 13$ km.

∴ the speed of the ship $= \dfrac{13}{\frac{1}{2}} = \underline{26 \text{ km/h.}}$

Q5 (*a*) *State formulae for the curved surface area of*

(*i*) *a cylinder with radius r and height h, and*
(*ii*) *a sphere of radius R.*

(*b*) *A cylinder of radius r fits exactly into a sphere of radius R. Using the results of part* (*a*),

(*i*) *show that the curved surface area of the cylinder,* S_1 *is given by* $S_1 = 4\pi r\sqrt{(R^2 - r^2)}$, *and*

(*ii*) *find the ratio* $S_1 : S_2$ *if the ratio of their radii, r:R, is 4:5 and the surface area of the sphere is* S_2.

(*c*) *A length of wire has a resistance R, mass M, length l and diameter d. Write formulae to illustrate the following, using constant* k_1 *in part* (*i*) *and constant* k_2 *in part* (*ii*).

(*i*) *R varies directly as l and inversely as* d^2.
(*ii*) *M varies directly as l and* d^2.
(*iii*) *Express R in terms of M, d,* k_1 *and* k_2 *only.*

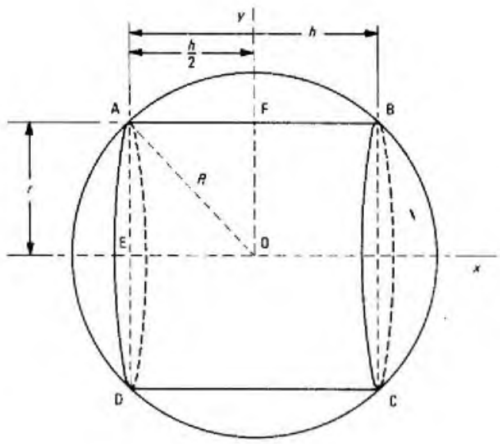
A5 (*a*) (*i*) Curved surface area of a cylinder = $\underline{2\pi rh.}$
(*ii*) Curved surface area of a sphere = $\underline{4\pi R^2.}$

(*b*) (*i*) The cylinder and sphere are shown in the sketch. Since the cylinder fits exactly into the sphere, with centre O, its circular end faces, BC and AD, coincide with the circular cross-sections of the sphere so that the extremity A of the diameter AD will be at the distance R from O. Also, from the symmetrical disposition of the cylinder about axes Ox and Oy, the axis Oy of the sphere will bisect AB at F.

Hence, in triangle AEO

$$AO^2 = AE^2 + EO^2,$$

or $$R^2 = r^2 + \left(\frac{h}{2}\right)^2.$$



$$\therefore \quad h^2 = 4(R^2 - r^2).$$
$$\therefore \quad h = 2\sqrt{(R^2 - r^2)}$$
$$\therefore \quad S_1 = 2\pi rh,$$
$$= 2\pi r \times 2\sqrt{(R^2 - r^2)},$$
$$= \underline{4\pi r\sqrt{(R^2 - r^2)}}.$$

(*ii*) $r:R = 4:5$ or $\frac{r}{R} = \frac{4}{5}$.

$$\therefore \quad R = \frac{5r}{4}.$$
$$\frac{S_2}{S_1} = \frac{4\pi R^2}{2\pi rh},$$
$$= \frac{4\pi(5r/4)^2}{2\pi r \times 2\sqrt{(R^2 - r^2)}},$$
$$= \frac{25r^2}{16r\sqrt{\{(5r/4)^2 - r^2\}}},$$
$$= \frac{25r}{16\sqrt{\{(25r^2 - 16r^2)/16\}}},$$
$$= \frac{25r \times 4}{16r\sqrt{9}} = \underline{\frac{25}{12}}.$$

(*c*) (*i*) $\underline{R = \frac{k_1 l}{d^2}}$.

(*ii*) $\underline{M = k_2 l d^2}$.

(*iii*) From part (*ii*), $l = \frac{M}{k_2 d^2}$.

Substituting for l in the expression given in part (*i*) gives

$$R = \frac{k_1 M}{k_2 d^2 \times d^2},$$
$$= \underline{\frac{k_1 M}{k_2 d^4}}.$$

Q6 (*a*) *The instantaneous values of a current i amperes at stated times t milliseconds over one complete cycle are given in the table below.*

t	0	4	9	15	20	26
i	4·0	5·2	6·3	7·0	7·2	6·7

t	31	35	39	44	51	57	60
i	5·6	4·6	3·8	3·0	2·6	3·2	4·0

(*i*) *Plot the graph of i against t for the range stated.*
(*ii*) *Apply the mid-ordinate rule, using 6 intervals of 10 ms, to determine the average value of the current.*

(*b*) *A voltage v volts has a periodic waveform shown in Fig. 1. Calculate the average value of v.*

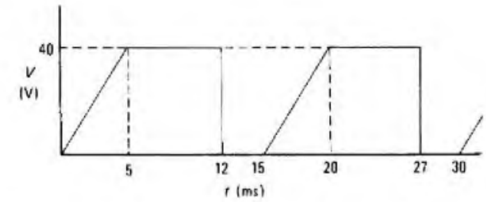
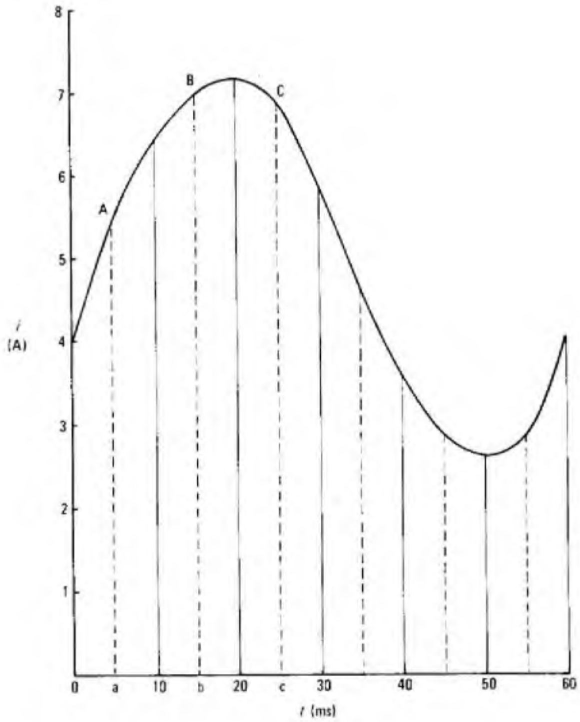


Fig. 1



(*a*)

A6 (*a*) (*i*) The graph of i against t is shown in sketch (*a*).
(*ii*) In the sketch, ordinates are erected at the 10 ms intervals and the mid-ordinates at 5, 15, 25 ms, etc. are shown by the dotted lines Aa, Bb, Cc, etc.
By the mid-ordinate rule,
area under the graph = length of one interval × sum of mid-ordinates.
The length of each interval is 10 ms and the lengths of the mid-ordinates are read from the graph and are shown in the table.

t	5	15	25	35	45	55
mid-ordinate	5·45	7·0	6·87	4·6	2·88	2·9

Hence, the area under the graph
$$= 10(5{\cdot}45 + 7{\cdot}0 + 6{\cdot}87 + 4{\cdot}6 + 2{\cdot}88 + 2{\cdot}9),$$
$$= 10 \times 29{\cdot}7 = 297 \text{ units.}$$
∴ the average value of current
$$= \text{area under graph} \div 60,$$
$$= 297/60 = \underline{4{\cdot}95 \text{ A.}}$$

(*b*) For the solution to a similar question see A6(*b*), Mathematics A 1977, *Supplement*, Vol. 71, p. 12, Apr. 1978.

Q7 (*a*) *Simplify the following, giving results without negative indices:*
(*i*) $10^{-6} \div 10^{-2} \times 10^3$.
(*ii*) $[16a^4b^{-6}]^{-3/2}$.
(*b*) *Rearrange the following formulae:*
(*i*) $Z = \sqrt{\{R^2 + (X_1 - X_2)^2\}}$ *to make* X_1 *the subject, and*
(*ii*) $Z_3 = \frac{Z_1 Z_2}{Z_1 + Z_2}$ *to make* Z_1 *the subject.*

(c) *If* $f = \dfrac{1}{2\pi}\sqrt{\left(\dfrac{1}{LC} - \dfrac{R^2}{L^2}\right)}$, *calculate the value of R when* $f = 350$, $L = 0{\cdot}02$, $C = 8 \times 10^{-6}$ and $\pi = 3{\cdot}142$.

A7 (*a*) (*i*)

$$10^{-6} \div 10^{-2} \times 10^3,$$
$$= \frac{10^{-6}}{10^{-2}} \times 10^3,$$
$$= \frac{10^2 \times 10^3}{10^6} = \frac{10^5}{10^6} = \underline{\frac{1}{10}}.$$

(*ii*)

$$[16a^4b^{-6}]^{-3/2} = \frac{1}{[16a^4b^{-6}]^{3/2}},$$
$$= \frac{1}{16^{3/2}a^6b^{-9}} = \underline{\frac{b^9}{64a^6}}.$$

(*b*) (*i*)

$$Z = \sqrt{\{R^2 + (X_1 - X_2)^2\}}.$$
$$\therefore \quad Z^2 = R^2 + (X_1 - X_2)^2.$$
$$\therefore \quad (X_1 - X_2)^2 = Z^2 - R^2.$$
$$\therefore \quad X_1 - X_2 = \sqrt{(Z^2 - R^2)}.$$
$$\therefore \quad X_1 = \underline{X_2 + \sqrt{(Z^2 - R^2)}}.$$

(*ii*)

$$Z_3 = \frac{Z_1Z_2}{Z_1 + Z_2}$$
$$\therefore \quad Z_3(Z_1 + Z_2) = Z_1Z_2.$$
$$\therefore \quad Z_1Z_3 + Z_2Z_3 = Z_1Z_2.$$
$$\therefore \quad Z_1(Z_3 - Z_2) = -Z_2Z_3.$$
$$\therefore \quad Z_1 = \underline{\frac{Z_2Z_3}{Z_2 - Z_3}}.$$

(*c*)

$$f = \frac{1}{2\pi}\sqrt{\left(\frac{1}{LC} - \frac{R^2}{L^2}\right)}.$$
$$\therefore \quad f^2 = \frac{1}{4\pi^2}\left(\frac{1}{LC} - \frac{R^2}{L^2}\right).$$
$$\therefore \quad 4\pi^2 f^2 = \frac{1}{LC} - \frac{R^2}{L^2}.$$
$$\therefore \quad \frac{R^2}{L^2} = \frac{1}{LC} - 4\pi^2 f^2.$$
$$\therefore \quad R^2 = \frac{L}{C} - 4\pi^2 f^2 L^2.$$

Substituting the given values.

$$R^2 = \frac{0{\cdot}02}{8 \times 10^{-6}} - 4 \times 3{\cdot}142^2 \times 350^2 \times 0{\cdot}02^2,$$
$$= 2500 - 1935 = 565.$$
$$\therefore \quad R = \sqrt{565} = \underline{23{\cdot}77.}$$

Q8 *(a) The output voltage, V volts, of a rectifier unit is related to the load current, I amperes, by the law* $V = aI + b$, *where a and b are constants. When* $I = 234$, $V = 586$ *and when* $I = 306$, $V = 526$.

Calculate

(i) the values of a and b, and
(ii) the value of I when $V = 556$.

(b) Supplies of 6 V DC and 12 V DC are connected to the network shown in Fig. 2. Currents I_1, I_2 *and* $(I_1 + I_2)$ *amperes flow in the parts of the circuit indicated.*

(i) Form 2 simultaneous equations relating I_1 *and* I_2.
(ii) Solve the equations to find the values of I_1 *and* I_2.

A8 (*a*) (*i*) Substituting the 2 sets of values given.

$$586 = 234a + b \qquad \ldots\ldots (1)$$
$$526 = 306a + b \qquad \ldots\ldots (2)$$

Subtracting equation (1) from equation (2) gives

$$-60 = 72a.$$
$$\therefore \quad a = -\frac{5}{6}.$$

Substituting for a in equation (1) gives

$$586 = -\frac{5}{6} \times 234 + b.$$

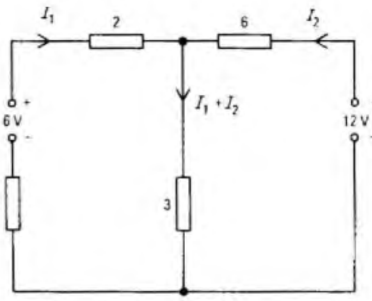


Fig. 2

$$\therefore \quad b = 586 + 195 = 781.$$

Thus, $\underline{a = -\frac{5}{6}}$ and $\underline{b = 781}$.

(*ii*) When V = 556 V and using the values of a and b determined in part (*i*),

$$-\frac{5}{6}I = 556 - 781.$$
$$\therefore \quad I = \frac{6}{5} \times 225 = \underline{270\text{ A.}}$$

(*b*) (*i*) Applying Kirchhoff's second law to the left-hand closed circuit of Fig. 2, the following equation results

$$6 = 2I_1 + 3(I_1 + I_2). \qquad \ldots\ldots (3)$$

Applying the same law to the right-hand closed circuit gives

$$12 = 6I_2 + 3(I_1 + I_2). \qquad \ldots\ldots (4)$$

The 2 required equations are equations (3) and (4).

(*ii*) From equation 3

$$6 = 2I_1 + 3I_1 + 3I_2,$$
$$= 5I_1 + 3I_2. \qquad \ldots\ldots (5)$$

From equation (4)

$$12 = 6I_2 + 3I_1 + 3I_2,$$
$$= 3I_1 + 9I_2. \qquad \ldots\ldots (6)$$

Multiplying equation (5) by 3 gives

$$18 = 15I_1 + 9I_2. \qquad \ldots\ldots (7)$$

Subtracting equation (6) from equation (7) gives

$$6 = 12I_1.$$
$$\therefore \quad I_1 = \tfrac{1}{2}\text{ A}.$$

Substituting for I_1 in equation (5) gives

$$3I_2 = 6 - 5 \times \tfrac{1}{2} = 3\tfrac{1}{2}.$$
$$\therefore \quad I_2 = 1\tfrac{1}{6}\text{ A}.$$

Thus, $\underline{I_1 = \tfrac{1}{2}\text{ A and } I_2 = 1\tfrac{1}{6}\text{ A.}}$

Q9 *(a) Form the equation whose roots are* $x = 3$ *and* $x = -5$, *expressing the result in the form* $x^2 + px + q = 0$.

(b) Factorize EACH *of the following into 2 linear factors:*

(i) $16x^2 - 25$,
(ii) $y^2 - 9y + 14$, and
(iii) $3w^2 - 2w - 5$.

(c) Solve the equations

(i) $4x^2 + 7x = 0$,
(ii) $(5t - 4)^2 = 36$, *and*
(iii) $2x^2 + x - 12 = 0$.

(d) A rectangular aluminium plate is 30 mm longer than it is wide. A square of side 10 mm is cut from each corner and the resulting sides turned up to form a tray. The base of the tray has an area of 2800 mm^2. *Calculate the dimensions of the original plate.*

A9 (*a*) $(x - 3)\{x - (-5)\} = 0.$

$\therefore\quad x^2 - 3x + 5x - 15 = 0.$

$\therefore\quad \underline{x^2 + 2x - 15 = 0.}$

(*b*) (*i*) $16x^2 - 25 = \underline{(4x - 5)(4x + 5).}$

(*ii*) $y^2 - 9y + 14 = \underline{(y - 2)(y - 7).}$

(*iii*) $3w^2 - 2w - 5 = \underline{(3w - 5)(w + 1).}$

(*c*) (*i*) $4x^2 + 7x = 0 = x(4x + 7).$

To satisfy this condition, either $x = 0$ or $4x + 7 = 0$.

$$\therefore\quad \underline{x = 0 \text{ or } x = -\frac{7}{4}.}$$

(*ii*) $(5t - 4)^2 = 36.$

$\therefore\quad 5t - 4 = \pm 6.$

$\therefore\quad 5t = 10 \text{ or } -2.$

$$\therefore\quad \underline{t = 2 \text{ or } -\frac{2}{5}.}$$

(*iii*) The general solution of a quadratic equation of the form $ax^2 + bx + c$ is $x = \dfrac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$.

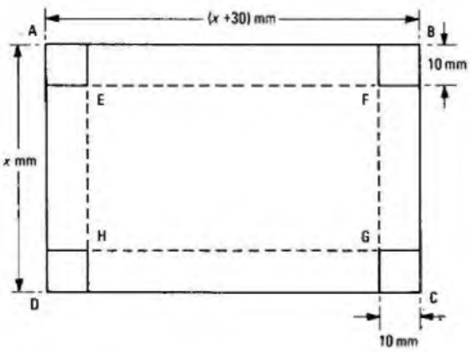
Therefore, for the equation $2x^2 + x - 12 = 0$,

$$x = \frac{-1 \pm \sqrt{(1 + 96)}}{4} = \frac{-1 \pm \sqrt{97}}{4},$$

$$= \frac{-1 \pm 9{\cdot}849}{4},$$

$$= \underline{2{\cdot}212 \text{ or } -2{\cdot}712.}$$

(*d*) The plate is shown as the rectangle ABCD in the sketch.



Let the width AD or BC be x mm. Then the long sides AB and DC are $(x + 30)$ mm in length. When the 10 mm side squares are cut from the corners, and the resulting sides turned up, the base of the tray will be the rectangle EFGH, shown in the sketch by the dotted lines.

$$\text{EF} = \text{AB} - 2 \times 10$$

$$= x + 30 - 20 = x + 10 \text{ mm}.$$

$$\text{EH} = x - 2 \times 10 = x - 20 \text{ mm}.$$

$\therefore\quad (x + 10)(x - 20) = 2800$

$\therefore\quad x^2 - 10x - 200 = 2800$

$\therefore\quad x^2 - 10x - 3000 = 0$

$\therefore\quad (x + 50)(x - 60) = 0$

$\therefore\quad x = -50 \text{ or } +60 \text{ mm}.$

The first of these values is clearly not permissible, and therefore the original dimensions of the plate are $\underline{60 \times 90 \text{ mm.}}$

Q10 (*a*) *The result of the calculation* $\dfrac{38{\cdot}4 \times \sqrt{65{\cdot}4} \times \sin 31^\circ 20'}{11{\cdot}36 \times 4{\cdot}85^2}$ *contains the significant figures 6044. By suitable approximation, determine an approximate value of the expression and hence insert the decimal point in its correct position in the result.*

(*b*) *Evaluate*

(*i*) $\log_3 81$,
(*ii*) $\log_5 \sqrt{125}$, *and*
(*iii*) $\log_2 (1/32)$.

(*c*) *If* $t = \dfrac{L}{R} \log_e \left(\dfrac{E}{E - iR}\right)$, *calculate the value of t when* $E = 240$, $R = 5$, $L = 6$ *and* $i = 7$.

(*d*) *Express*

(*i*) *the denary number 109 in binary form, and*
(*ii*) *the binary number 101 011 in denary form.*

(*e*) *Working throughout in binary notation, determine the results of the following. Do not convert the numbers to denary form.*

(*i*) *10 101 + 1101,*
(*ii*) *11 010 − 1101,*
(*iii*) *1101 × 101,* and
(*iv*) *110 111 ÷ 101.*

A10 (*a*)
$$\frac{38{\cdot}4 \times \sqrt{65{\cdot}4} \times \sin 31^\circ 20'}{11{\cdot}36 \times 4{\cdot}85^2},$$

$$\approx \frac{40 \times \sqrt{64} \times \sin 30^\circ}{10 \times 5^2},$$

$$= \frac{40 \times 8 \times \frac{1}{2}}{250},$$

$$= 0{\cdot}64.$$

Hence, the value of the expression must be $\underline{0{\cdot}6044.}$

(*b*) (*i*) $\log_3 81 = \underline{4.}$

(*ii*) $\log_5 \sqrt{125} = \log_5 5^{3/2} = \underline{\frac{3}{2}.}$

(*iii*) $\log_2 (1/32) = \log_2 (1/2^5) = \log_2 2^{-5} = \underline{-5.}$

(*c*)
$$t = \frac{L}{R} \log_e \left(\frac{E}{E - iR}\right),$$

$$= \frac{6}{5} \log_e \left(\frac{240}{240 - 7 \times 5}\right),$$

$$= 1{\cdot}2 \log_e \frac{240}{205},$$

$$= 1{\cdot}2 \log_e \frac{4{\cdot}8}{4{\cdot}1},$$

$$= 1{\cdot}2\,(1{\cdot}5686 - 1{\cdot}4110),$$

$$= 1{\cdot}2 \times 0{\cdot}1576,$$

$$= \underline{0{\cdot}1891.}$$

(*d*) (*i*)

		Remainder
2)	109	1
2)	54	0
2)	27	1
2)	13	1
2)	6	0
2)	3	1
2)	1	1

$$\therefore\quad 109_{10} = \underline{1\,101\,101_2.}$$

(*ii*) $101\,011_2 = 2^5 + 2^3 + 2^1 + 2^0,$

$= 32 + 8 + 2 + 1,$

$= \underline{43.}$

(*e*) (*i*)

```
 10 101
  1 101 +
--------
100 010
```

(*ii*)

```
 11 010
  1 101 -
--------
  1 101
```

(*iii*)

```
    1 101
      101 ×
    -----
    1 101
  110 100 +
---------
1 000 001
```

(*iv*)

```
      1 011
101)110 111
    101
    ---
        111
        101
        ---
        101
        101
        ---
        000
```

Answer $= \underline{1\,011.}$

Students were expected to answer any 6 questions

Q1 (*a*) *For an auto-to-auto relay-set associated with a junction between local exchanges,*

(*i*) *sketch the circuit elements concerned in guarding the P-wire when a caller clears, and*

(*ii*) *show, by means of a common timing chart, the sequence of operations at both ends of the junction when a caller clears.*

(*b*) *For a PABX exchange-line relay-set,*

(*i*) *explain why an extended guard is necessary when an extension clears after a call via the public exchange, and*

(*ii*) *outline the method used to provide an extended guard.*

Q2 (*a*) (*i*) *Sketch battery-testing circuit elements of the marginal-operate and marginal-hold types, using values 20 Ω, 140 Ω and 800 Ω, as appropriate, for the resistors and relay windings.*

(*ii*) *Illustrate the marginal-operate and marginal-hold features by calculating the current values. Assume an exchange battery of 48 V.*

(*b*) *Which method gives the greatest freedom from dual connexions, and why?*

Q3 *For a subscriber-dialled trunk call from a coin-box connected to a non-director satellite exchange,*

(*a*) *draw a trunking diagram to show the routing as far as the trunk first selector,*

(*b*) *state*

(*i*) *where the charge-rate information is determined, and*

(*ii*) *where it is stored, and*

(*c*) *explain briefly how the stored charge-rate information is used for controlling the equipment which periodically demands additional coins and give an outline of the signals used.*

A3 See A2, Telephony B 1974, *Supplement*, Vol. 68, p. 37, July 1975.

Q4 (*a*) *For a 200-line ordinary final selector,*

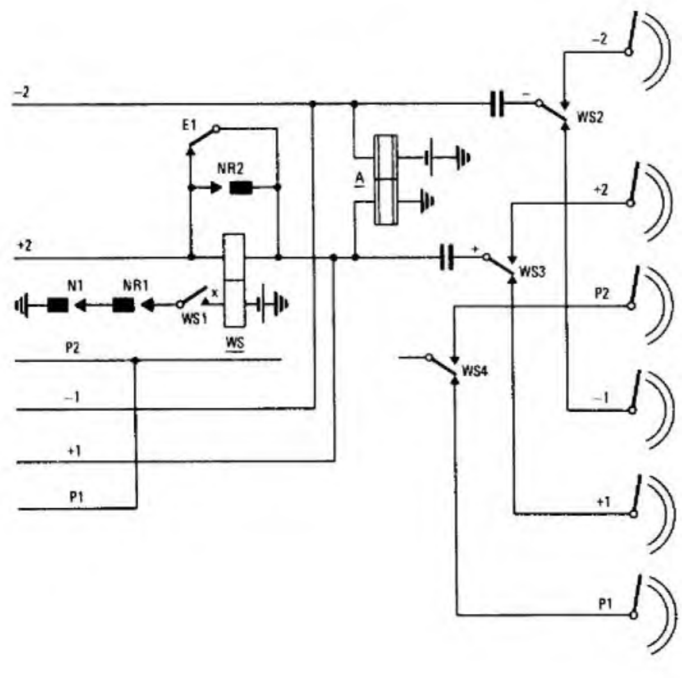
(*i*) *sketch the circuit element that discriminates between the 2 groups of subscribers,*

(*ii*) *explain how the discrimination is effected, and*

(*iii*) *what economy does the use of this selector offer and how does the economy arise?*

(*b*) *Explain why the same discriminating facility is not used in an 11-and-over PBX final selector.*

A4 (*a*) (*i*) The circuit element is shown in the sketch.



(*ii*) Relay WS (normal) connects the transmission path of the selector to the −1, +1 and P1 wipers to access the first 100 lines; relay WS (operated) connects the transmission path to the −2, +2 and P2 wipers to access the second 100 lines. When the selector is seized via the incoming −1, +1 and P1 wires, relay WS remains normal throughout the call and the call is routed to the appropriate line in the first group of 100 lines. When the selector is seized via the incoming −2, +2 and P2 wires, relay A operates in the normal way with relay WS short-circuited to ensure that relay A is fully energized. At the conclusion of vertical stepping, relay E operates, the short-circuit across relay WS is removed and relay WS operates. On the first rotary step, relay WS is short-circuited by contact NR2 but an alternative holding path is established via contacts N1 (operated), NR1 (operated) and WS1 (operated) until the selector is released. The transmission path is thus switched to the second group of 100 lines.

(*iii*) Small groups of circuits are inefficient. By combining the traffic from 2 penultimate selector levels to access a single group of final selectors, the efficiency is improved and the number of final selectors is significantly reduced.

(*b*) The 11-and-over PBX final selector has a single path of entry and is designed to provide access to large groups of PBX lines (up to 200) by searching for a free line over one or more levels. Each level provides access to 20 lines and testing over a level is somewhat similar to the testing method used in the 200-line outgoing group selector. The discriminating facility is therefore not appropriate.

Q5 (*a*) (*ii*) *With the aid of sketches of the circuit elements concerned, explain how the exchange alarm system is activated by the rupturing of a fuse in the battery supply to a rack shelf.*

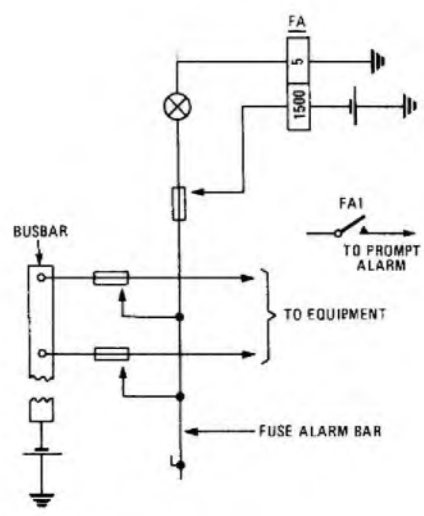
(*ii*) *How does the alarm indicating system guide the maintenance officer to the ruptured fuse?*

(*b*) *Explain*

(*i*) *why a two-motion selector release alarm includes a time delay, and*

(*ii*) *how the delay is provided.*

A5 (*a*) (*i*) Sketch (*a*) shows the principle of a rack fuse-alarm circuit. Alarm-type fuses are connected between the battery bus bar and the rack equipment to feed current to the selectors or relay-sets. Running beneath the fuses is the fuse alarm bar, normally not in contact with the fuses. When a fuse ruptures, the feed to the equipment is disconnected and a metal strip makes contact with the alarm bar, thus making a connexion between the bus bar and the fuse-alarm circuit. At the same time, an indicator projects from the surface of the ruptured fuse to enable it to be quickly located by the maintenance officer. The circuit operates as follows: relay FA operates over its 55 Ω coil in series with the rack lamp, which glows. Contact FA1 completes the prompt-alarm circuit, thus causing the floor lantern to light and the alarm to sound. The circuit for relay FA is disconnected when the faulty fuse is removed. Should the fuse-alarm fuse rupture, relay FA operates over both coils in series. Under these circumstances, however, the rack lamp does not glow.



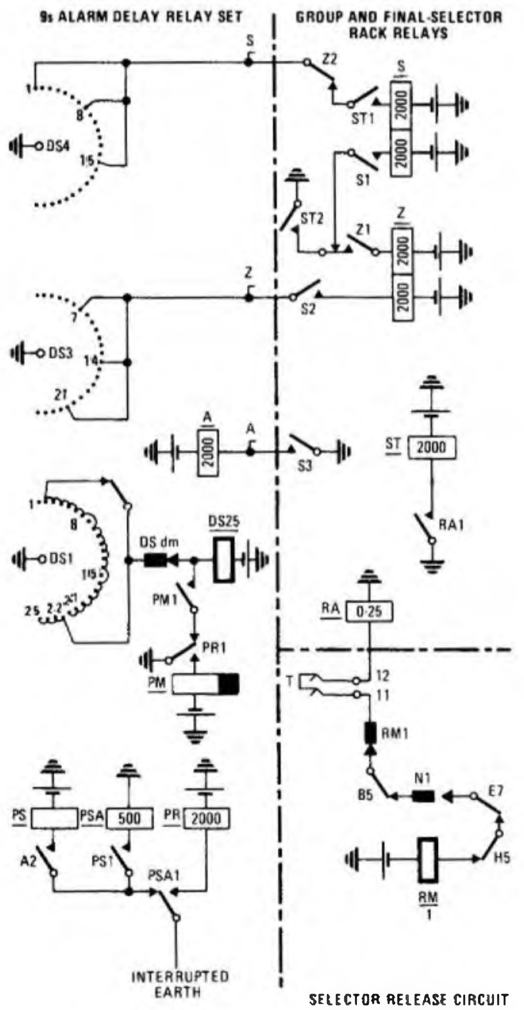
(*a*)

(*ii*) The alarm lantern on each floor indicates the floor on which the alarm has originated or, if the fault is on that particular floor, the section of the floor which is involved. Each section is divided into sub-sections with indicating lamps mounted at the end of each suite within each section. Having identified the sub-section, the particular rack is identified by the operation of the rack alarm lamp. As mentioned in part (*i*), the particular fuse is identified by an indicator projecting from the surface of the fuse.

(*b*) (*i*) A time delay is included in the circuit of a two-motion-selector alarm because otherwise every normal release of the selector would give a momentary alarm condition.

(*ii*) The circuit elements involved are shown in sketch (*b*). Note that the relay designated 'A' in the alarm-delay relay-set is normally designated 'ST' but has been redesignated here to avoid confusion with the ST relay in the selector rack.

The completion of a selector-release circuit operates an RA relay (of which there is one per 20 selectors) on the rack. Contact RA1 operates relay ST. Contact ST1 operates relay S from an earth via selector DS4. Contact S3 operates relay A, the start relay in the alarm-delay set. This set is fed with interrupted earth pulses (0·75 s on, 0·75 s off). The first earth pulse after contact A2 has made, operates relay PS. Contact PS1 prepares an operate path for relay PSA in series with relay PS, but the earth pulse maintains a short-circuit on relay PSA, which does not operate until the earth pulse is removed. Contact PSA1 then connects relay PR to the interrupted-earth lead, and further earth pulses operate and release this relay. The first operation of relay PR operates relay PM via contact PR1. Contact PM1 prepares a circuit for uniselector DS OPERATE magnet. When relay PR restores, the DS OPERATE magnet is energized during the slow release period of relay PM, and steps once to outlet 2, 9 or 16. Further pulses continue to step the uniselector until it reaches outlet 7, 14 or 21, when an earth is extended to the rack which operates relay Z. Contact Z4 initiates a prompt alarm, contact Z3 lights the rack lamp, contact Z5 lights the shelf lamp, and contact Z1 releases relay S, but holds relay Z via contact ST2 until the alarm condition has been cleared. The release of relay S releases the delay-set at S3, and uniselector DS self-drives to outlet 1, 8 or 15.



(*b*)

Q6 For a sleeve-control auto-manual switchboard:

(a) Explain, with the aid of sketches of the circuit elements concerned, how the calling and clearing signals control a cord-circuit supervisory lamp

(i) when the SPEAK *key is normal, and*
(ii) when the SPEAK *key is operated,*

(b) Draw the circuit element of a terminating relay-set which detects whether or not the cord-circuit SPEAK *key is operated and, explain how it functions.*

Q7 (a) List the sequence of operations of the equipment concerned when a test clerk uses the test selectors for gaining access to a subscriber's direct exchange line. Assume the line is free.

(b) Explain

(i) the principle of the electrical test for continuity, and
(ii) why the test is less satisfactory if made over a long test junction to a remote exchange.

(c) Explain the principle of the voltmeter test for wire-to-wire insulation-resistance measurement and derive a formula to express this resistance in terms of the voltmeter deflexion and voltmeter resistance.

A7 (*a*) The sequence of operation is:

(*i*) The test cord is plugged in to a free test-selector circuit (indicated by BUSY lamp unlit).

(*ii*) The DIAL key is operated, the required number dialled and the DIAL key restored.

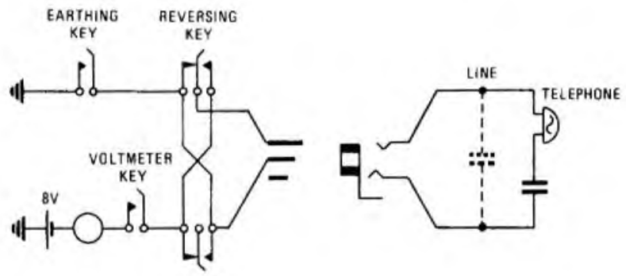
(*iii*) If the line is unoccupied (indicated by the BUSY lamp unlit), the HOLD AND TEST key is operated which operates the subscriber's K relay, thus removing exchange battery and earth from the line and guarding the circuit against seizure by a final selector.

(*iv*) The TEST CORD keys are operated as appropriate to test the condition of the line and telephone.

(*v*) To test the exchange conditions, the PRIVATE CONTROL key is operated (to release the subscriber's K relay) and the TEST CORD keys operated as appropriate.

(*vi*) On completion of testing, the test cord is removed from the test-selector circuit and the HOLD AND TEST key and the PRIVATE CONTROL key restored to normal.

(*b*) The circuit arrangements for continuity testing are shown in the sketch.



When the VOLTMETER and EARTHING keys are operated, the capacitor in the subscriber's instrument is charged. If the REVERSING key is then operated and restored several times, the capacitor is discharged and recharged in the opposite direction according to the key operations. This will produce a series of partial deflexions of the voltmeter pointer. If the line is discontinuous, the deflexions will not take place.

(*ii*) The capacitance of the line between the A and B wires is also charged and discharged at the same time as the capacitor in the instrument. If the line is relatively short, the line capacitance is negligible compared with the instrument capacitance. However, where a long junction is used for access, the line capacitance may obscure the effects of the capacitor in the instrument.

Q8 For a TXK1 (crossbar) local exchange:

(a) Draw a trunking diagram to show the routing of an own-exchange call (include the principal items of common equipment).

(b) Give TWO *important facilities provided by*

(i) the distributors,
(ii) the markers, and
(iii) the routers.

(c) Outline the method used to provide an automatic second attempt to set up a call in the event of failure of the first attempt.

A8 See A8, Telephony B 1976, *Supplement*, Vol. 70, p. 35, July 1977 and A4, Telephony B 1973, *Supplement*, Vol. 67, p. 44, July 1974.

Q9 *(a) What is meant by a linked-numbering scheme (LNS) for a local telephone area, and why is it used?*

(b) For a large LNS, explain why the use of director (register-translator) working permits savings in junction costs compared with a non-director system.

(c) List FOUR *other advantages offered by director working.*

A9 (*a*) An arrangement whereby several exchanges, serving different parts of an area of comparatively high telephone density, are interconnected, and share a common numbering system, is known as a *linked-numbering scheme*. For example, a large town could be served by a central exchange for the business area, together with a number of satellite exchanges, each covering a suburb. A subscriber would dial the same number to reach a given local destination whichever exchange he was calling. Such an arrangement also leads to savings in line plant compared with the provision of a large central exchange, since traffic between different areas of the town is largely carried over junction cables between the exchanges rather than on individual pairs between each subscriber and a central exchange.

(*b*) In the director system, the dialled digits which identify the objective exchange are translated into routing digits to route the call. Up to 6 routing digits may be used and this provides great flexibility in switching arrangements. Full interconnexion, using common dialling codes, can be provided within the LNS without the need to provide direct routes between each pair of exchanges. This is achieved by the use of tandem switching centres, through which traffic between exchanges which do not justify having direct connexion between them (because the amount of traffic is small) is routed. In this manner, more efficient larger routes are utilized, with the consequent savings in costs.

(*c*) (*i*) All routing digits are mechanically generated within closely controlled impulse-speed and ratio limits and with adequate inter-digit pauses.

(*ii*) The use of tandem exchanges, combined with the translation facility, permits the emergency re-routing of traffic without change of dialling codes.

(*iii*) More than one dialling code can be translated to route to the same objective exchange. This enables an exchange to be opened hypothetically, using another exchange's equipment, before its own equipment is ready, thus reducing future number changes.

(*iv*) The translation facility enables large routes to be served from early stages of switching equipment, thus reducing equipment costs.

Q10 *(a) Ten shelves of 100-outlet first selectors are trunked to second selectors.*

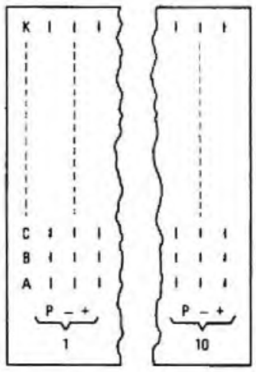
(i) What determines whether or not a grading is used to interconnect a particular level? and

(ii) by means of a sketch, show how the first-selector banks are terminated in a manner that facilitates grading.

(b) A group of 11-and-over PBX final selectors serves one subscriber having 90 lines and another having 100 lines. If the 90-line subscriber requires the addition of 15 lines, explain how this could be arranged without changing either subscriber's directory number.

A10 (*a*) (*i*) A grading is required when the number of circuits on a route exceeds the outlet availability of the selectors serving the route.

(*ii*) Assuming a 10-bank multiple, the selector banks would be terminated as shown in the sketch.



(*b*) Since there are no spare levels, it would be necessary to split the final-selector multiple to provide graded access to the 105-line group. Alternatively, it might be acceptable to the subscriber to have full facilities on 100 lines only and to have outgoing-only service on the remaining 5.

TELECOMMUNICATION PRINCIPLES C 1979

Students were expected to answer any 6 questions

Q1 *(a) The characteristic impedance, Z_0, and the velocity of propagation, v_p, of a loss-free transmission line are related to the inductance and capacitance per metre by*

$$Z_0 = \sqrt{\frac{L}{C}} \text{ and } v_p = \frac{1}{\sqrt{(LC)}}.$$

A 50 Ω, coaxial line with a solid polyethylene dielectric has a velocity of propagation of 2×10^8 m/s. Calculate the inductance and capacitance per metre.

(b) A 12 m length of this line has a 2 V peak, 40 MHz sinusoidal source of negligible internal impedance connected to one end, and the other is terminated in a 50 Ω resistor.

Determine

(i) the wavelength of the line, and

(ii) the total time delay over the line.

(c) For the arrangement in part (b), make a sketch of the instantaneous voltage against distance at an instant when the source voltage is at zero and is positive-going.

A1 (*a*) Using the relationships given, two equations result:

$$50 = \sqrt{\frac{L}{C}}, \qquad \ldots\ldots (1)$$

$$2 \times 10^8 = \frac{1}{\sqrt{(LC)}}. \qquad \ldots\ldots (2)$$

$$\sqrt{\left(\frac{L}{C}\right)} \times \frac{1}{\sqrt{(LC)}} = \frac{1}{C}.$$

Thus, the capacitance per metre, C, is given by

$$\frac{1}{50 \times 2 \times 10^8} \text{ F},$$

$$= \underline{100 \text{ pF.}}$$

$$\frac{1}{\sqrt{(LC)}} \div \sqrt{\frac{L}{C}} = \frac{1}{L}.$$

Thus, the inductance per metre, L, is given by

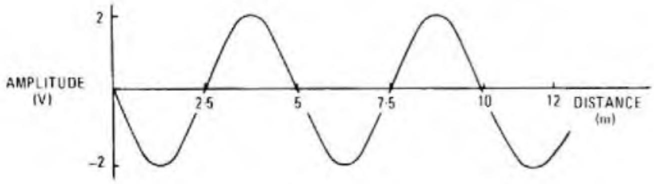
$$\frac{5}{2 \times 10^8} \text{ H},$$

$$= \underline{0{\cdot}025\ \mu\text{H.}}$$

(*b*) (*i*) The wavelength is calculated from the expression $v_p = f\lambda$, where v_p is the velocity of propagation, f is the frequency and λ is the wavelength.

Thus, $$\lambda = \frac{2 \times 10^8}{40 \times 10^6} = \underline{5 \text{ m.}}$$

(*ii*) Delay time is the time taken for the wave to travel 12 m. The time taken to travel 1 m is $\frac{1}{2 \times 10^8} = 5 \times 10^{-9}$ s. Thus, the time taken to travel 12 m is 60 ns.



(*c*) The graph is shown in the sketch.

Since 5 m corresponds to a wavelength, the phase is observed to change by a full 360° over a distance of 5 m. The 12 m length corresponds to 2·4 wavelengths and the phase shift at the receive end is thus 0·4 × 360° = 144°.

Q2 (a) Describe, with the aid of a circuit diagram, the principle of the Q-meter.

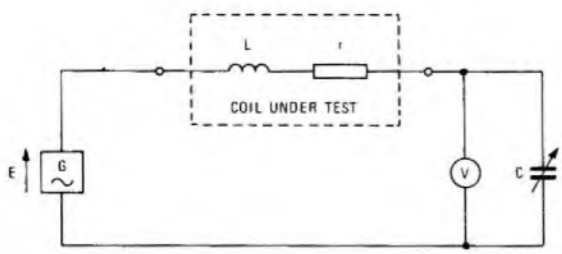
(b) Measurements made on a coil at 40 kHz and 80 kHz, using a Q-meter, gave the following results:

Frequency	*Q-factor*	*Capacitance setting for resonance*
40 kHz	*180*	*815 pF*
80 kHz	*220*	*185 pF*

Assuming that the inductance of the coil does not vary with frequency and that all the stray capacitance can be assumed to be in parallel with the tuning capacitance, determine

(i) the stray capacitance,
(ii) the inductance of the coil,
(iii) the series resistance at 40 kHz, and
(iv) the series resistance at 80 kHz.

A2 (*a*) The sketch shows the theoretical circuit of a Q-meter.



C is calibrated. The voltmeter is calibrated in terms of Q-factor

To measure the Q-factor of the test coil, the capacitance is varied until resonance occurs, indicated by a maximum reading on the voltmeter. The ratio between the source voltage and the voltmeter reading is the required Q-factor.

(*b*) (*i*) The resonant condition is given in both cases by the expression

$$f = \frac{1}{2\pi\sqrt{(LC_T)}},$$

where f is the frequency, L is the inductance of the coil and C_T is the total capacitance, including the stray capacitance (C_S).

Thus, $$40 \times 10^3 = \frac{1}{2\pi\sqrt{\{L(815 + C_S) \times 10^{-12}\}}}, \quad \ldots\ldots (1)$$

and $$80 \times 10^3 = \frac{1}{2\pi\sqrt{\{L(185 + C_S) \times 10^{-12}\}}}. \quad \ldots\ldots (2)$$

Dividing equation (2) by equation (1) gives:

$$2 = \sqrt{\left(\frac{815 + C_S}{185 + C_S}\right)}.$$

$$\therefore \quad 4C_S + 740 = 815 + C_S.$$

$$\therefore \quad C_S = \underline{25\text{ pF.}}$$

(*ii*) Substituting the value for C_S obtained in part (*i*) into equation (1)

$$16 \times 10^8 = \frac{1}{4\pi^2 L \times 840 \times 10^{-12}}.$$

Thus, $$L = \frac{1}{4\pi^2 \times 16 \times 10^8 \times 840 \times 10^{-12}}\text{ H} = \underline{18{\cdot}8\text{ mH.}}$$

(*iii*) The Q-factor of the coil is $2\pi fL/r$, where r is the series resistance of the coil.

Thus, at 40 kHz, $$r = \frac{2\pi \times 40 \times 10^3 \times 0{\cdot}0188}{180} = \underline{26{\cdot}2\ \Omega.}$$

(*iv*) At 80 kHz, $$r = \frac{2\pi \times 80 \times 10^3 \times 0{\cdot}0188}{220} = \underline{42{\cdot}9\ \Omega.}$$

Q3 (a) Show how a Thévènin equivalent circuit may be obtained from a Norton equivalent circuit.

(b) Determine the Thévènin equivalent circuit at terminals A and B of the network shown in Fig. 1.

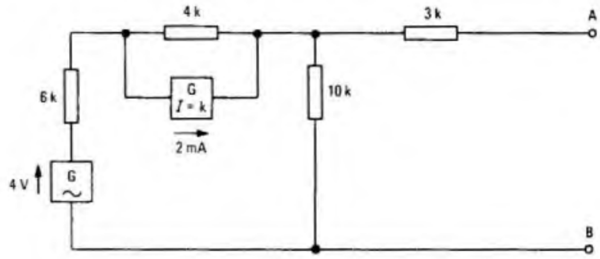


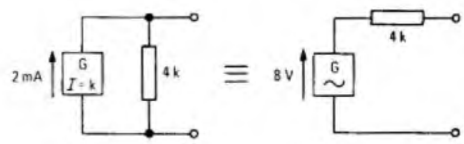
Fig. 1

A3 (*a*) See A2, Telecommunication Principles C 1977, *Supplement*, Vol. 71, p. 60, Oct. 1978.

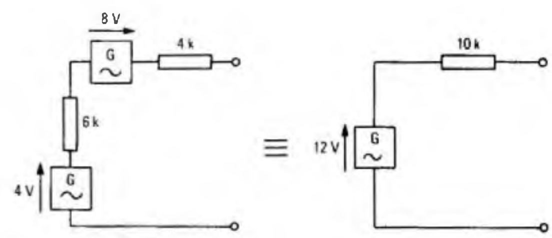
(*b*) The first step is to convert the current source into its equivalent Thévènin source, as shown in sketch (*a*).

The voltage sources can be added as shown in sketch (*b*).

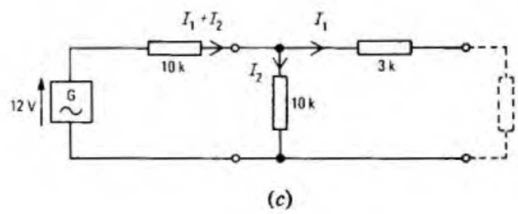
It is necessary to calculate the open-circuit voltage and short-circuit current when the circuit is terminated as shown in sketch (*c*). The open-circuit voltage is clearly 6 V. The short-circuit is the value of I_1 when R_T is zero.



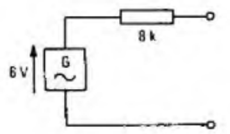
(*a*)



(*b*)



(*c*)



(*d*)

Now, $3I_1 = 10I_2$, ... (1)

and $12 = 10(I_1 + I_2) + 3I_1 = 16I_1$.

$\therefore \quad I_1 = 0{\cdot}75$ mA.

As shown in part (*a*), the Thévenin series impedance is

$$6/0{\cdot}75\ \text{k}\Omega = 8\ \text{k}\Omega.$$

Thus, the overall Thévenin equivalent circuit is as shown in sketch (*d*).

Q4 (*a*) *Discuss the factors which cause power loss in iron-cored inductors.*

(*b*) *An iron-cored inductor has an inductance of 0·75 H. At 800 Hz it has a Q-factor of 60, while at 1600 Hz the Q-factor is 90. Calculate the effective series resistance at EACH frequency.*

(*c*) *The inductor in part* (*b*) *is connected to a 5 V sinusoidal supply. Determine, for frequencies of 800 Hz and 1600 Hz,*

(*i*) *the current, and*
(*ii*) *the power dissipated.*

A4 (*a*) See A3, Telecommunication Principles C 1976, *Supplement*, Vol. 70, p. 54, Oct. 1977.

(*b*) The Q-factor at any frequency is given by the expression $2\pi fL/r_s$, where f is the frequency, L is the inductance and r_s is the series resistance.

At a frequency of 800 Hz, the factor-Q is 60.

Thus, $$r_s = \frac{2\pi \times 800 \times 0{\cdot}75}{60} = \underline{62{\cdot}8\ \Omega.}$$

At a frequency of 1600 Hz, the Q-factor is 90.

Thus, $$r_s = \frac{2\pi \times 1600 \times 0{\cdot}75}{90} = \underline{83{\cdot}8\ \Omega.}$$

(*c*) (*i*) The current at any frequency is given by

$$I = \frac{5}{\sqrt{\{r_s^2 + (2\pi fL)^2\}}} = \frac{5}{r_s\sqrt{(1 + Q^2)}}.$$

If the Q-factor is very much greater than 1, this approximates to $\dfrac{5}{Qr_s}$.

Therefore, at 800 Hz, $$I = \frac{5}{60 \times 62{\cdot}8}\ \text{A} = \underline{1{\cdot}33\ \text{mA},}$$

and at 1600 Hz, $$I = \frac{5}{90 \times 83{\cdot}8}\ \text{A} = \underline{0{\cdot}66\ \text{mA}.}$$

(*ii*) The power dissipated at each frequency is given by substituting the appropriate values in the expression I^2r_s.

Thus the power dissipated at 800 Hz is $\underline{111\ \mu\text{W}}$ and at 1600 Hz, $\underline{36\ \mu\text{W}.}$

Q5 (*a*) *Explain, with the aid of suitable diagrams, the principles by which a number of signals may be sent over a common link using time-division multiplex* (*TDM*).

(*b*) *A TDM link has 20 signal channels and each channel is sampled 8000 times per second. A guard of 1 μs is allowed between each sample on the link.*

Calculate

(*i*) *the time interval over which all channels are sampled once,*
(*ii*) *the duration of each sample,*
(*iii*) *the total number of samples per second, and*
(*iv*) *the number of additional channels which could be accommodated if the sample duration were reduced to 4 μs.*

A5 (*a*) See A4 (a)(ii), Telecommunication Principles C 1976, *Supplement*, Vol. 70, p. 54, Oct. 1977.

(*b*) (*i*) The sampling rate is 8 kHz. Thus, all channels must be sampled once during the period of an 8 kHz sampling signal; that is, once every $\underline{125\ \mu\text{s}.}$

(*ii*) The duration of each sample is $\dfrac{125}{20} - 1 = \underline{5{\cdot}25\ \mu\text{s}.}$

(*iii*) The total number of samples per second is $20 \times 8000 = \underline{160\,000.}$

(*iv*) If the sample duration is reduced to 4 μs, then, assuming the same guard interval, the maximum number of samples per second is 200 000. Assuming the same sampling rate, the maximum number of channels is $\dfrac{200\,000}{8000} = \underline{25.}$

Q6 (*a*) *A 200 kHz sinusoidal carrier with a peak voltage of 25 V is amplitude modulated to a depth of 60% by a 4 kHz sinusoidal signal. Write down an expression for the instantaneous voltage of the modulated wave. Expand this expression to show that the wave comprises three separate frequency components. Calculate the frequency and the RMS voltage of EACH component and the RMS voltage of the whole wave.*

(*b*) *The wave in part* (*a*) *is applied to a 75 Ω resistor. Determine*

(*i*) *the carrier power,*
(*ii*) *the power at each side-frequency, and*
(*iii*) *the total power.*

A6 (*a*) The modulated wave can be expressed as

$$V = 25\,(1 + 0{\cdot}6 \sin 8\pi \times 10^3 t) \cos 4\pi \times 10^5 t.$$

This can be expanded as

$$V = 25 \cos 4\pi \times 10^5 t + \frac{15}{2}\{\sin (4\pi \times 10^5 + 8\pi \times 10^3)t + \sin (4\pi \times 10^5 - 8\pi \times 10^3)t\}.$$

The frequency of the carrier is $\underline{200\ \text{kHz}}$ with an RMS amplitude of

$$\frac{25}{\sqrt{2}} = \underline{17{\cdot}68\ \text{V}.}$$

The side frequencies are $\underline{196\ \text{kHz}}$ and $\underline{204\ \text{kHz},}$ each with an RMS amplitude of

$$\frac{15}{2\sqrt{2}} = \underline{5{\cdot}3\ \text{V}.}$$

The RMS amplitude of the modulated wave is $\sqrt{(5{\cdot}3^2 + 5{\cdot}3^2 + 17{\cdot}68^2)} = \underline{19{\cdot}2\ \text{V}.}$

(*b*) (*i*) The carrier power is $\dfrac{17{\cdot}68^2}{75} = \underline{4{\cdot}17\ \text{W}.}$

(*ii*) The power at each side-frequency is $\dfrac{5{\cdot}3^2}{75} = \underline{0{\cdot}37\ \text{W}.}$

(*iii*) The total power is $4{\cdot}16 + 0{\cdot}37 + 0{\cdot}37 = \underline{4{\cdot}9\ \text{W}.}$

Q7 (*a*) *Discuss briefly the relative advantages of amplitude modulation and frequency modulation.*

(*b*) *A frequency-modulated wave can be represented by the expression*

$$e_m = 30 \sin (2\pi \times 10^5 t + 15 \sin 500\pi t)\ \text{volts}.$$

Determine

(*i*) *the carrier frequency,*
(*ii*) *the signal frequency,*
(*iii*) *the modulation index,*
(*iv*) *the peak frequency deviation,*
(*v*) *the RMS voltage, and*
(*vi*) *the voltage at the instant t = 25 μs.*

A7 (*a*) The main advantages of amplitude modulation are the simplicity of implementation and the bandwidth conservation which is possible using single-sideband and vestigial-sideband techniques.

Frequency modulation, on the other hand, has the advantage that the signal-to-noise performance can be improved by increasing the modulation index, with a consequent increase in required bandwidth, without increasing the transmitted power.

(*b*) (*i*) The carrier frequency is $\underline{100\ \text{kHz}.}$

(*ii*) The signal frequency is $\underline{250\ \text{Hz}.}$

(*iii*) The modulation index is $\underline{15.}$

(*iv*) The modulation index is the ratio of the peak frequency deviation to the modulating frequency. Thus, the peak frequency deviation is given by $250 \times 15 = \underline{3{\cdot}75\ \text{kHz}.}$

(*v*) The RMS voltage is $\dfrac{30}{\sqrt{2}} = \underline{21{\cdot}2\ \text{V}.}$

(*vi*) At $t = 25\ \mu$s,

$$e_m = 30 \sin (2\pi \times 10^5 \times 25 \times 10^{-6} + 15 \sin 500\pi \times 25 \times 10^{-6}),$$

$$= 30 \sin\left(2\pi \times \frac{5}{2} + 0{\cdot}588\right),$$

$$= \underline{-16{\cdot}64\ \text{V}.}$$

Q8 (*a*) *Explain the effect of applying a small amount of*

(*i*) *negative feedback, and*
(*ii*) *positive feedback*
to a 2-port amplifier.

(*b*) *A negative-feedback amplifier is found to have a voltage gain of 25. When the feedback leads are interchanged at one end, the gain is 85. Determine*

(*i*) *the feedback fraction, and*
(*ii*) *the amplifier gain without feedback.*

(*c*) *Sketch a possible circuit diagram for a negative-feedback amplifier showing clearly the feedback components and the feedback path,*

A8 (*a*) When applying feedback to a 2-port amplifier, a fraction of the output signal is added to the input signal to form the actual input. The addition may be in phase (positive feedback) or in antiphase (negative feedback). Clearly, positive feedback results in an increased gain and negative feedback in a reduced gain.

(*b*) Let A be the gain without feedback and β the feedback factor. Then, the gain with feedback is given by the expression $\frac{A}{1 + \beta A}$.

For the conditions given,

$$\frac{A}{1 + \beta A} = 25, \qquad \ldots\ldots (1)$$

and

$$\frac{A}{1 - \beta A} = 85. \qquad \ldots\ldots (2)$$

Dividing equation (2) by equation (1) gives

$$\frac{1 + \beta A}{1 - \beta A} = \frac{85}{25} = 3{\cdot}4.$$

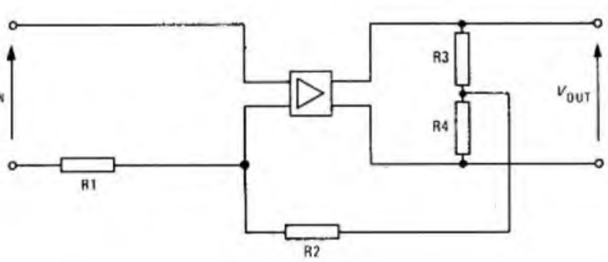
$$\therefore \quad 1 + \beta A = 3{\cdot}4 - 3{\cdot}4\beta A$$

$$\therefore \quad \beta A = \frac{2{\cdot}4}{4{\cdot}4} = 0{\cdot}545.$$

Substituting this value of βA into equation (1), gives a value of A of $25 \times 1{\cdot}545 = \underline{38{\cdot}6}$ (the gain without feedback).

Hence the value of $\beta = \frac{0{\cdot}545}{38{\cdot}6} = \underline{0{\cdot}014}$ (the feedback factor).

(*c*) The sketch shows a possible feedback connexion. Resistors R3 and R4 form a potential divider. The feedback current is applied through R2. The generator impedance and the output load will affect the amount of feedback applied.



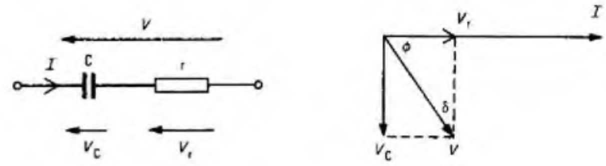
Q9 (*a*) *Sketch a phasor diagram showing the relationship between voltage and current in a practical capacitor. Identify the loss angle and the phase angle on the diagram and explain why the power factor can be taken as equal to the loss angle in radians.*

(*b*) *A 2 μF capacitor with a loss angle of* 5×10^{-4} *rad is connected in series with a 3 μF capacitor which has a loss angle of* 8×10^{-4} *rad. Calculate, for a frequency of 20 kHz, the equivalent series resistance of each capacitor and hence, or otherwise, determine the overall loss angle of the series combination.*

A9 (*a*) Sketch (*a*) represents a possible equivalent circuit for a practical capacitor. C is the capacitance and r is the equivalent series resistance.

The phasor diagram is shown in sketch (*b*) where δ is the loss angle and ϕ is the phase angle.

The power factor is $\cos\phi$ which is equal to $\sin\delta$. If the loss angle is small, $\sin\delta = \delta$ if δ is in radians.



(*a*) (*b*)

(*b*) From sketch (*b*), $\cos\phi$ is approximately equal to

$$\frac{V_r}{V_C} = \frac{I \times r}{I/\omega C} = \omega C r = \text{the loss angle},$$

where V_r is the applied voltage, V_C is the voltage across the capacitor. I is the current flowing in the circuit and $\omega = 2\pi f$ where f is the frequency.

Thus, for the 2 μF capacitor, the equivalent series resistance is

$$\frac{5 \times 10^{-4}}{2\pi \times 20 \times 10^{3} \times 2 \times 10^{-6}} = \underline{0{\cdot}198\ \text{m}\Omega.}$$

For the 3 μF capacitor, the equivalent series resistance is

$$\frac{8 \times 10^{-4}}{2\pi \times 20 \times 10^{3} \times 3 \times 10^{-6}} = \underline{0{\cdot}212\ \text{m}\Omega.}$$

The two capacitors in series have a capacitance of 1·2 μF.

Thus, the loss angle is $2\pi \times 20 \times 10^{3} \times 1{\cdot}2 \times 10^{-6} \times 0{\cdot}41 \times 10^{-3} = \underline{6{\cdot}18 \times 10^{-5}\ \text{rad.}}$

Q10 (*a*) *Fig. 2 shows the circuit diagram of a transistor amplifier. The transistor has parameters* $h_{ie} = 1{\cdot}5\ k\Omega$, $h_{fe} = 60$ *with* h_{oe} *and* h_{re} *negligible and the capacitors have negligible reactance at the source frequency. Calculate*

(*i*) *the voltage gain from AB to CD,*
(*ii*) *the input impedance at AB,*
(*iii*) *the output impedance at CD,*
(*iv*) *the signal voltage at AB, and*
(*v*) *the signal voltage at CD.*

(*b*) *What would be the effect on the frequency response of the amplifier if the capacitors did not have negligible reactances?*

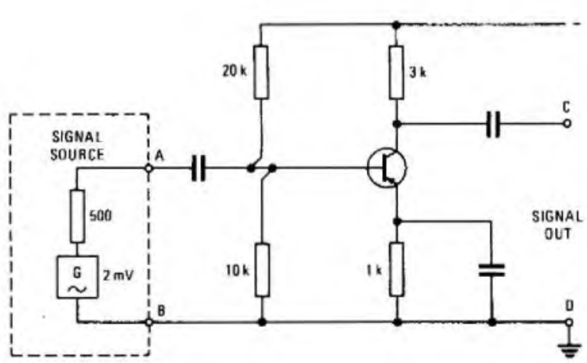


Fig. 2

RADIO AND LINE TRANSMISSION A 1979

Students were expected to answer any 6 questions

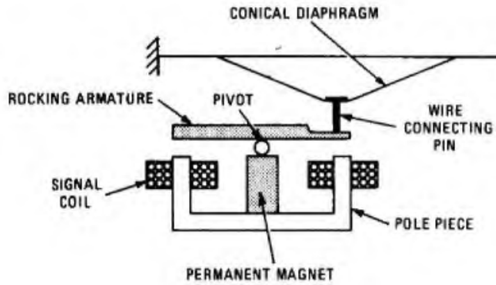
Q1 (*a*) *State the function of the receiver in a telephone instrument.*

(*b*) *With the aid of a labelled diagram, explain how a balanced-armature receiver operates.*

(*c*) *State* TWO *advantages of the balanced-armature receiver compared with a simple moving-iron receiver.*

A1 (*a*) The function of the receiver is to convert the incoming electrical signals, produced by the microphone of the distant subscriber, into the original sound waves.

(*b*) The sketch shows the essential features of a balanced-armature receiver.



It consists of a rocking armature connected to a conical diaphragm. The armature is held in equilibrium, when no signals are present, by the equal attraction of the two pole pieces of a permanent-magnet system. When signals are received in the two coils wound on the pole pieces, the magnetic balance is upset, and the armature tends to rock in sympathy with the variations in signal current. This movement is transmitted to the conical diaphragm, which is made from a non-magnetic material, to produce sound waves.

(*c*) Some of the advantages of the balanced-armature receiver over the moving-iron receiver are:

improved sensitivity;
cheaper;
supplied as a sealed capsule and therefore easier maintenance;
better frequency response.

Q2 (*a*) *Draw the circuit diagram of a two-stage audio-frequency transistor amplifier with R-C coupling. Label input, output and power-supply connexions.*

(*b*) *Describe how the frequency response of the amplifier in part* (*a*) *could be obtained using a signal generator and oscilloscope. Include a diagram showing how the instruments would be connected.*

(*c*) *Sketch a typical frequency response for such an amplifier, showing values on the axes.*

A2 (*a*) See A4 (*a*), Radio and Line Transmission A 1978, *Supplement*, Vol. 72, p. 9, Apr. 1979.

(*b*) and (*c*) See A6, Radio and Line Transmission A 1977, *Supplement*, Vol. 70, p. 92, Jan. 1978.

Q3 (*a*) *Draw the circuit diagram of a tuned-collector transistor oscillator, indicating the point from which the output is obtained.*

(*b*) *Outline its principle of operation, referring to the frequency-determining components and the bias arrangement.*

(*c*) *Sketch* TWO *ways of coupling the oscillator to a following stage.*

A3 (*a*) See A10, Radio and Line Transmission A 1977, *Supplement*, Vol. 70, p. 93, Jan. 1978.

Q4 (*a*) *State typical carrier frequencies and radio-frequency bandwidths for* EACH *of the following:*

(*i*) *intercontinental sound broadcasting,*
(*ii*) *commercial mobile radio, and*
(*iii*) *television broadcasting.*

(*b*) *Two telephone exchanges, A and B, are connected by a repeatered audio junction. Draw a labelled block diagram of the equipment and links between a subscriber connected to exchange A and one connected to exchange B.*

A4 (*a*) (*i*) For intercontinental broadcasting, carrier frequencies in the high-frequency band (3–30 MHz) are used. The bandwidth required is in the order of 10 kHz.

(*ii*) For commercial mobile radio, carrier frequencies in the very-high frequency or ultra-high-frequency bands allocated for the purpose are used (60–470 MHz). The bandwidth required is either 12·5 kHz or 25 kHz, depending on the type of system used.

(*iii*) For television broadcasting, carrier frequencies in the very-high-frequency and ultra-high-frequency bands allocated for the purpose are used (50–800 MHz). The bandwidth required is in the order of 5–8 MHz, depending largely on the number of lines comprising a picture.

(*b*) See A10 (*a*), Radio and Line Transmission A 1975, *Supplement*, Vol. 69, p. 12, Apr. 1976.

Q5 (*a*) (*i*) *Give the formulae for expressing a power ratio in decibels.*
(*ii*) *State the assumption that is made when a voltage ratio is expressed in decibels.*

(*b*) *Give* THREE *reasons why the decibel is a convenient unit for use in transmission work.*

(*c*) *Express*

(*i*) *a voltage ratio of 15 in decibels,*
(*ii*) *a power ratio of* ¼ *in decibels, and*
(*iii*) *a power of 10 W in dBm.*

(*d*) *Express*

(*i*) *35 dB as a voltage ratio, and*
(*ii*) *−17 dB as a power ratio.*

A5 (*a*) (*i*) If the ratio of 2 powers, P_1 and P_2, is to be expressed in decibels, the number of decibels, N, is given by

$$N = 10 \log_{10} \frac{P_1}{P_2} \text{ decibels.} \qquad \ldots\ldots (1)$$

(*ii*) When the ratio of 2 voltages, V_1 and V_2, is expressed in decibels, the number of decibels, N, is given by

$$N = 20 \log_{10} \frac{V_1}{V_2} \text{ decibels.} \qquad \ldots\ldots (2)$$

This expression is valid only when the 2 resistances across which V_1 and V_2 are developed are equal.

(*b*) The advantages are

(*i*) the large range of currents, voltages and powers involved in radio and line-communication work can be expressed in simpler numbers,

(*ii*) in complicated circuits, involving several sections in tandem, such as amplifiers, attenuators and lines, it is easier to determine the overall output-to-input ratios of the powers, voltages and currents by taking the sum of logarithmic ratios for the different parts rather than multiplying and dividing, and

(*iii*) the effect of sound intensity on the ear is approximately proportional to the logarithm of the sound intensity.

(*c*) (*i*) From equation (2)

$$N = 20 \log_{10} 15 \text{ dB,}$$
$$= \underline{23 \cdot 52 \text{ dB.}}$$

(*ii*) From equation (1)

$$N = 10 \log_{10} \tfrac{1}{4} \text{ dB,}$$
$$= -10 \log_{10} 4 \text{ dB,}$$
$$= \underline{-6 \cdot 021 \text{ dB.}}$$

(*iii*) A power expressed in dBm is the ratio of that power to 1 mW. Therefore, from equation (1)

$$N = 10 \log_{10} \frac{10}{1 \times 10^{-3}} \text{ dBm,}$$
$$= 10 \log_{10} 10^4 \text{ dBm,}$$
$$= \underline{40 \text{ dBm.}}$$

(*d*) (*i*) From equation (2)

$$35 = 20 \log_{10} \frac{V_1}{V_2}.$$

$$\therefore \quad \log_{10} \frac{V_1}{V_2} = \frac{35}{20}.$$

$$\therefore \quad \frac{V_1}{V_2} = \text{antilog}_{10}\, 1 \cdot 75,$$
$$= \underline{56 \cdot 24.}$$

(*ii*) From equation (1)

$$-17 = 10 \log_{10} \frac{P_1}{P_2}.$$

$$\therefore \quad \log_{10} \frac{P_1}{P_2} = -1{\cdot}7.$$

$$\therefore \quad \frac{P_1}{P_2} = \text{antilog}_{10} -1{\cdot}7,$$

$$= \underline{0{\cdot}020.}$$

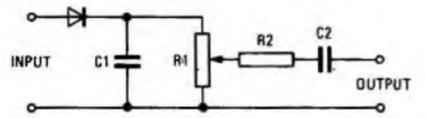
Q6 (a) Why is a detector necessary in a radio receiver for the reception of an amplitude-modulated wave?

(b) Draw the circuit diagram of a semiconductor-diode detector suitable for demodulating an amplitude-modulated wave and explain the purpose of EACH *component.*

(c) Sketch the characteristics of a typical semiconductor diode, clearly labelling the axes.

A6 (*a*) Both the upper and lower envelopes of the modulated signal contain the required intelligence. It is the function of the detector stage in the receiver to recover the intelligence from the modulated signal, by means of an amplitude detector. In general, a linear detector is used that performs the operation of detection by rectifying the amplitude-modulated signal such that the mean value of the output current varies at the modulating frequency.

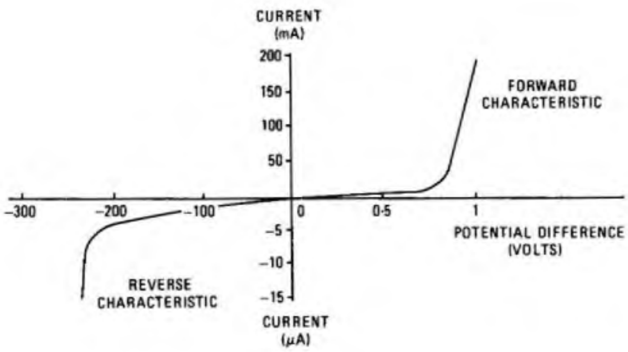
(*b*) The circuit diagram is shown in sketch (*a*).



(*a*)

The diode rectifies the incoming amplitude-modulated signal. The rectified signal is applied to the resistor-capacitor combination, R1 and C1. By choosing suitable values for these components, the envelope of the waveform appearing across them may be made to follow closely the envelope of the original modulated signal applied to the diode. This waveform, besides containing the required modulation envelope, also includes a DC component and a residual amount of the radio-frequency (RF) carrier signal. Capacitor C1, if it is of a large enough value, tends to short-circuit the RF component, any residual RF signal being removed by resistor R2 and the input capacitance of the next stage. Capacitor C2 has a low reactance at the frequencies of modulation, but blocks the DC component. Hence, with the RF and DC components largely eliminated, the output waveform closely resembles the original modulating signal.

(*c*) The characteristic is shown in sketch (*b*).



(*b*)

Q7 (a) Define the following transistor parameters for the common-emitter configuration:

(i) current gain,
(ii) input resistance, and
(iii) output resistance.

(b) (i) Sketch typical output characteristics of an n p n transistor in the common-emitter configuration, labelling the axes clearly.

(ii) Show how ONE *of the parameters in part (a) can be obtained from the characteristics.*

(c) A transistor connected in the common-emitter configuration shows a change in collector current of 4·9 mA when a change in emitter current of 5 mA occurs. Determine the common-emitter current gain of the transistor.

A7 (*a*) (*i*) The current gain is defined as the ratio of the change in collector current (I_c) to the change in base current (I_b) with a constant collector–emitter voltage (V_{ce}); that is,

$$\text{current gain} = \frac{\Delta I_c}{\Delta I_b}.\ (V_{ce} \text{ constant}).$$

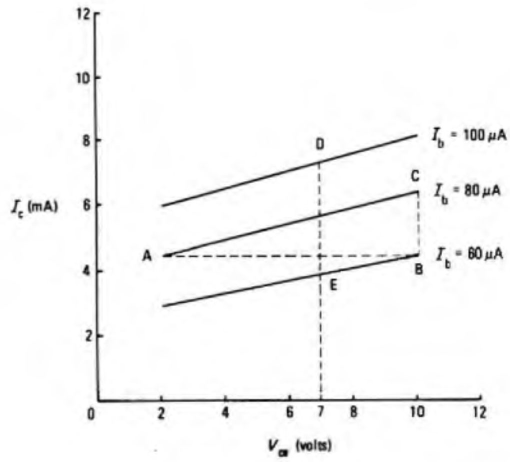
(*ii*) The input resistance is defined as the ratio of the change in base–emitter voltage (V_{be}) to the change in base current (I_b) with a constant collector–emitter voltage; that is,

$$\text{input resistance} = \frac{\Delta V_{be}}{\Delta I_b}\ (V_{ce} \text{ constant}).$$

(*iii*) The output resistance is defined as the ratio of the change in collector–emitter voltage to the change in collector current (I_c) with a constant base current (I_b); that is

$$\text{output resistance} = \frac{\Delta V_{ce}}{\Delta I_c}\ (I_b \text{ constant}).$$

(*b*) (*i*) The output characteristics for an n p n transistor in the common-emitter configuration are shown in the sketch.



(*ii*) From the characteristics, at a collector voltage of 7 V, the current gain is

$$\frac{\text{DE}}{\text{change in } I_b} = \frac{(7{\cdot}3 - 4) \times 10^{-3}}{(100 - 60) \times 10^{-6}} = \underline{82{\cdot}5.}$$

From the characteristics at $I_b = 80\ \mu$A, the output resistance is

$$\frac{\text{AB}}{\text{BC}} = \frac{10 - 2}{(6{\cdot}5 - 4{\cdot}5) \times 10^{-3}} = \underline{4\ \text{k}\Omega.}$$

Note: Only one example was asked of students, but 2 are given here.

(*c*) The total current flowing into a transistor must be equal to the total current flowing out of it; hence, the emitter current, I_e, is equal to the sum of the collector current, I_c, and the base current, I_b.

$$\therefore \quad I_e = I_c + I_b. \qquad \ldots\ldots (1)$$

Hence, for a small change in emitter current

$$\Delta I_e = \Delta I_c + \Delta I_b. \qquad \ldots\ldots (2)$$

For a small change in base current

$$\Delta I_b = \Delta I_e - \Delta I_c. \qquad \ldots\ldots (3)$$

Given $\Delta I_e = 5$ mA and $\Delta I_c = 4{\cdot}9$ mA, from equation (3)

$$\Delta I_b = 5 - 4{\cdot}9 = 0{\cdot}1 \text{ mA}.$$

For the common-emitter configuration, the current gain is defined in part (*a*) (*i*).

$$\therefore \quad \text{current gain} = \frac{4{\cdot}9}{0{\cdot}1} = \underline{49.}$$

Q8 (a) Draw the circuit diagram of a tuned transistor-amplifier.

(b) Sketch a typical voltage/frequency characteristic for a parallel-tuned circuit and use the characteristic to explain what is meant by the −3 dB bandwidth.

(c) Fig. 1 represents a parallel-tuned circuit using an inductance, L,

of 600 μH having an effective self-capacitance, C_s, of 20 pF. Calculate the value of the tuning capacitance, C, required to give a frequency of resonance of 500 kHz.

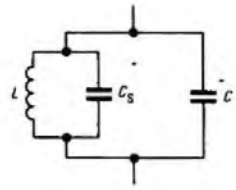
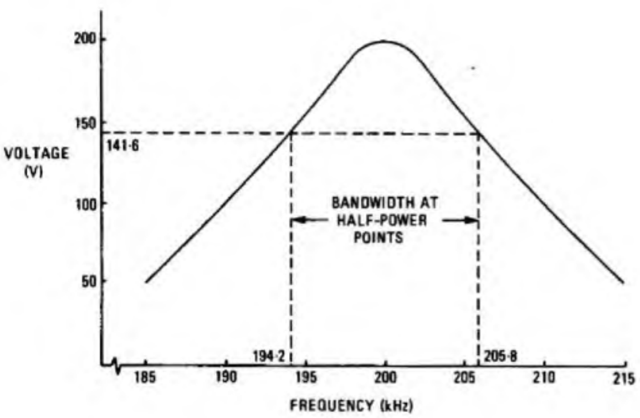


Fig. 1

A8 (*a*) See A7 (*c*), Radio and Line Transmission A 1976, *Supplement*, Vol. 72, p. 10, Apr. 1979.

(*b*) The characteristic is shown in the sketch.



The half-power points are the points at which the response is 3 dB below the maximum value. Using voltages,

$$20 \log_{10} \frac{200}{V} = 3 \text{ dB}$$

where V is the voltage at the 3 dB points.

$$\therefore \quad 3/20 = \log_{10} \frac{200}{V}.$$

$$\therefore \quad \frac{200}{V} = \text{antilog}_{10}\, 3/20,$$

$$= 1{\cdot}413.$$

$$\therefore \quad V = \frac{200}{1{\cdot}413} = 141{\cdot}6 \text{ V}.$$

From the graph, this voltage is obtained at frequencies of about 194·2 kHz and 205·8 kHz.

Therefore, the bandwidth at the half-power points is 205·8 − 194·2 = 11·6 kHz.

(*c*) The frequency of resonance, f_o, of a tuned circuit having a capacitance C_T farads and inductance L henrys is given approximately by

$$f_o = \frac{1}{2\pi\sqrt{(LC_T)}} \text{ hertz.} \qquad \ldots\ldots (1)$$

From equation (1)

$$C_T = \frac{1}{4\pi^2 f_o^2 L}.$$

Substituting the given values,

$$C_T = \frac{1}{4\pi^2(500 \times 10^3)^2 \times 600 \times 10^{-6}} \text{ F},$$

$$= 169 \text{ pF}.$$

But, $C_T = C + C_s$.

$$\therefore \quad C = 169 - 20 = \underline{149 \text{ pF}}.$$

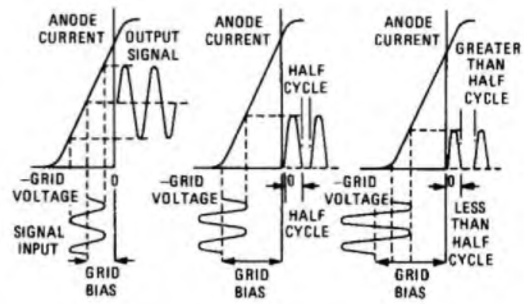
Q9 (*a*) *With reference to the anode-current/grid-voltage characteristic of a triode valve, draw sketches to show what is meant by* EACH *of the following classes of amplification:*

(*i*) *class-A,*
(*ii*) *class-B, and*
(*iii*) *class-C.*

(*b*) *Give typical values for the current, voltage and power gains of the common-emitter and common-base configurations of transistor amplifiers.*

(*c*) *Give* TWO *advantages and* ONE *disadvantage of transistor amplifiers compared with valve amplifiers.*

A9 (*a*) The characteristics are shown in sketches (*a*)–(*c*).



(*a*) (*b*) (*c*)

(*i*) In class-A operation (sketch (*a*)), the operating point and amplitude of the input signal are so adjusted that anode current flows at all times during the cycle of the input signal. This type of amplifier is operated within the straight portion of its characteristic so that minimum distortion occurs.

(*ii*) In class-B operation (sketch (*b*)), the valve is biased so that the output ceases in the absence of an input signal, and an output is obtained only during alternate half-cycles of the input signal.

(*iii*) In class-C operation (sketch (*c*)), the valve is biased beyond cut-off, so that anode current flows for less than half of each input cycle.

(*b*) The following table gives typical values for the current, voltage and power gains for the two configurations.

Characteristic	Configuration: Common emitter	Configuration: Common base
Current gain	Medium (30–80)	Low (less than unity)
Voltage gain	High (200–400)	Medium-high (100–400)
Power gain	High (30–40 dB)	Medium (15–30 dB)

(*c*) The transistor amplifier has the advantage of a smaller size, less weight, immediate operation after being switched on and less power consumption as it does not require a heater supply. The main disadvantages are its lower power-handling capability and distortion resulting from the transistor's non-linear behaviour.

Q10 (*a*) *Explain why* EACH *of the following components is unsuitable for use at high frequencies:*

(*i*) *a wire-wound resistor,*
(*ii*) *a paper-dielectric capacitor, and*
(*iii*) *a laminated iron-cored inductor.*

(*b*) *What type of resistor, capacitor and inductor would be suitable for use under the conditions of part* (*a*).

(*c*) *In respect of a resistor, explain the meaning of*

(*i*) *stability, and*
(*ii*) *tolerance.*

A10 (*a*) (*i*) A wire-wound resistor consists of a length of resistance wire wound on a ceramic rod or tube. It has good stability and can be manufactured to a close tolerance. It is usually used in situations where a relatively large amount of power must be dissipated.

As it is essentially a coil consisting of a number of turns of wire, a magnetic field is set up around the coil when a current flows. If the current changes, an EMF is induced in the winding, and this effect is know as *self-inductance*.

Adjacent turns of the winding of the coil, together with the insulation separating them, constitute small capacitances. These collectively give the resistor a capacitive effect, known as *self-capacitance*.

At high frequencies, self inductance and self capacitance have a greater effect than at low frequencies and hence the impedance of the resistor changes with frequency. Ideally, a resistor for use at high frequencies should have the same impedance at all frequencies and this requires the self-capacitance and self-inductance to be as low as possible.

(*ii*) It is not possible to manufacture paper-dielectric capacitors to close tolerance and they have poor stability. In addition, paper-dielectric capacitors have high loss and low working voltages. They are normally used for coupling, DC-blocking and decoupling applications in audio-frequency sections of radio receivers.

For operation at high frequencies, it is essential for capacitors to have good stability, close tolerance, low loss and high working voltages. Hence, paper-dielectric capacitors are not suitable for this type of application.

(*iii*) Basically, an inductor consists of a coil of wire wound on a former. Unfortunately, the changing magnetic flux not only links the windings of an inductor but also links the core around which the windings are wound. Therefore an EMF is induced in the core. This EMF causes eddy currents to flow in the core. In order to reduce this loss, the type of core employed in an inductor must be carefully chosen.

For use at audio frequencies, the cores of inductors may consist of thin strips of magnetic material called *laminations*. These are insulated from each other and this reduces the flow of eddy currents since it is not possible for the currents to flow round the complete core; each eddy current is restricted to the high-resistance path offered by an individual lamination.

As the power loss caused by the flow of eddy currents is proportional to the square of the frequency of operation, increasingly thin laminations are required as the operating frequency is raised. Hence, the use of sufficiently thin laminations at high frequencies becomes impracticable.

(*b*) (*i*) Suitable types of resistor are:
carbon, specially-wound types (for example, bifilar, Ayrton-Perry, fish line).

(*ii*) Suitable types of capacitor are:
polyester, mica.

(*iii*) Suitable types of inductor are:
iron-dust or air cored.

(*c*) (*i*) The stability of a resistor is the amount by which its value can be expected to change in operation during its working life. It is usually expressed as a percentage of its nominal value.

(*ii*) The tolerance of a resistor is the maximum error from its nominal value. It is normally expressed as a precentage of the nominal value.

TELEPHONY AND TELEGRAPHY A 1978

Students were expected to answer any 6 questions

Q1 (*a*) *For an ordinary telephone instrument suitable for connexion to an automatic exchange, explain the purpose of each of the gravity-switch and dial contacts.*

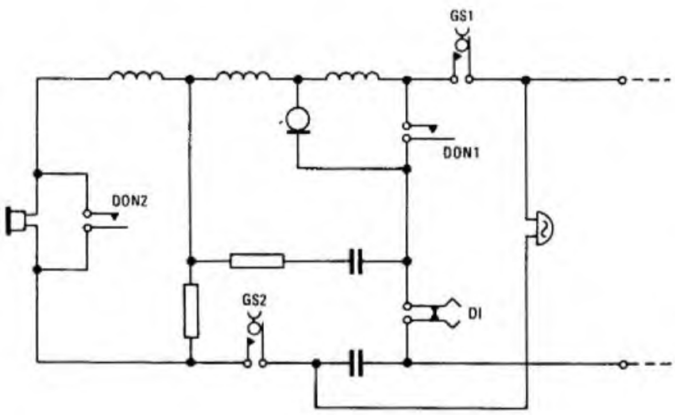
(*b*) *For a shared-service (two-party line) system, explain how*

(*i*) *additional contacts within the telephone instrument are used for calling the exchange,*

(*ii*) *the exchange is informed of which subscriber is calling, and*

(*iii*) *separate metering is arranged for the two subscribers.*

A1 (*a*) A basic telephone instrument circuit is shown in sketch (*a*).



(*a*)

The functions of the various contacts are:

(*i*) **GS1** This is a gravity switch contact controlled by the handset. When the handset is lifted, the operation of contact GS1 creates a low-resistance loop via the transmitter and contacts DI of the dial. This low-resistance loop is the calling signal to the exchange.

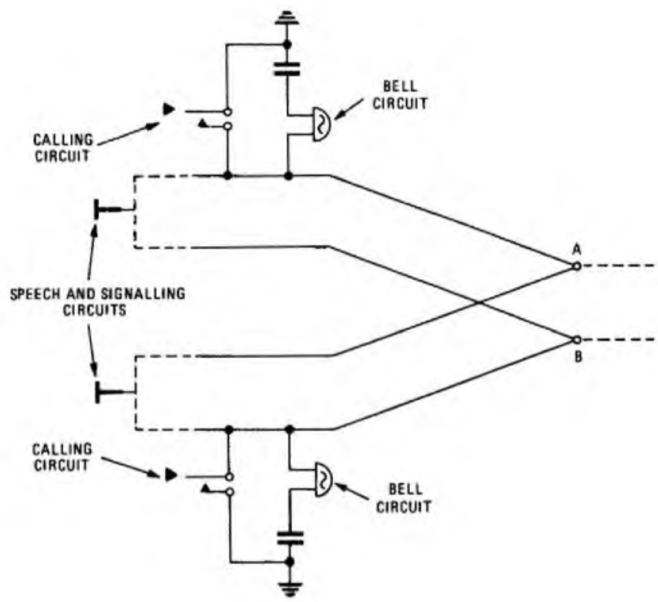
(*ii*) **GS2** This is another gravity switch contact which connects the receiver portion of the circuit and the spark-quench circuit. This contact is provided so that these portions are isolated when the handset is not in use and thus do not interfere with the bell circuit.

(*iii*) **DON1** This is a dial-off-normal contact which is operated when the dial finger-plate is moved away from its stop, and remains operated until the dial returns to rest. It short-circuits the transmitter and the winding of the induction coil which forms part of the calling loop.

(*iv*) **DON2** This is another dial-off-normal contact which short-circuits the receiver during pulsing and thus prevents dial clicks in the earpiece which could otherwise cause acoustic shock.

(*v*) **DI** These are the dial impulsing contacts which make and break the low-resistance loop under the control of the dial, thus signalling the required number to the exchange in the form of loop-disconnect pulses.

(*b*) Sketch (*b*) shows an explanatory diagram of the arrangement at the subscriber's end for shared-service working.



(*b*)

(*i*) When the handset is lifted, a transmitter loop is placed on the line in the same way as for an exclusive line. However, the exchange line circuit for a shared-service line does not respond to a loop. The calling signal is given when the subscriber operates a press-button which places an earth on one leg of the line.

(*ii*) Although both sharing subscribers use a common line, and both signal with an earth on one leg of that line, the circuits are arranged as mirror images of each other. Thus, one partner calls with an earth on the A-leg, while the other subscriber calls with an earth on the B-leg.

(iii) Shared-service subscribers have separate uniselector circuits with separate L and K relays, as well as separate meters. Only one L relay operates to the calling earth and thus only one K relay operates. The meters are connected to earth via a K-relay contact and, consequently, the sharing subscriber's meter is disconnected and cannot operate.

Q2 (a) (i) Sketch transmission bridges of the capacitor-type and the transformer-type.

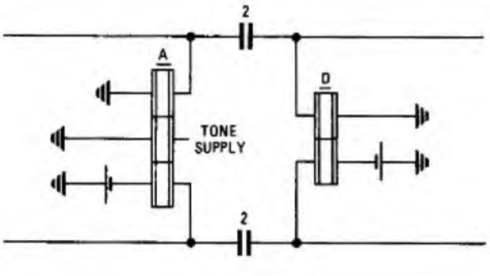
(ii) Show suitable values for the bridge capacitors.

(iii) Show how supervisory tones are returned to the caller from a capacitor-type bridge.

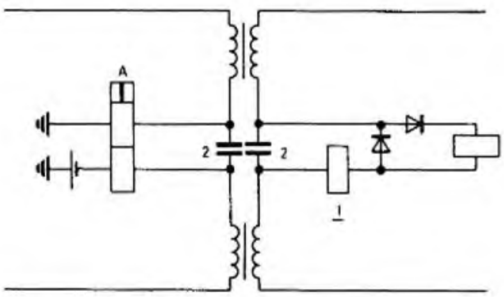
(b) State TWO *features which contribute to the high inductance of a relay used in a capacitor-type transmission bridge.*

(c) Explain why the transformer-type transmission bridge offers advantages for the reception of dial pulses.

A2 *(a) (i)* Sketch *(a)* shows a capacitor-type transmission bridge and sketch *(b)* shows a transformer-type bridge.



(a)



(b)

(ii) Typical values for the bridge capacitors are shown in the sketches.

(iii) Supervisory tones are fed via the central winding of the line relay in the capacitor-type transmission bridge. From this central winding the tones are induced into the line windings and thus fed to the calling subscriber.

(b) The principal method of ensuring that the relays are of a high inductance is the provision of 3 nickel-iron sleeves over the relay core, beneath the windings. Other factors which contribute to the high inductance are the large number of turns wound on the relay and the pattern of winding the 3 coils.

(c) The capacitor-type transmission bridge is used in final-selector circuits. For junction circuits, particularly where a number of junction links (and thus transmission bridges) are to be connected in series, the performance of the capacitor-type bridge is inadequate and transformer-type bridges are used. The design of the bridge permits the use of a high-speed, low-impedance A relay, and this gives much reduced pulse distortion. The use of a transformer also prevents longitudinal current surges passing across the bridge and thus permits each link in a chain of such circuits to be considered independently. In addition, the use of low-impedance D and I relays reduces initial and subsequent pick-up problems which can arise with capacitor-type bridges using high-impedance I coils.

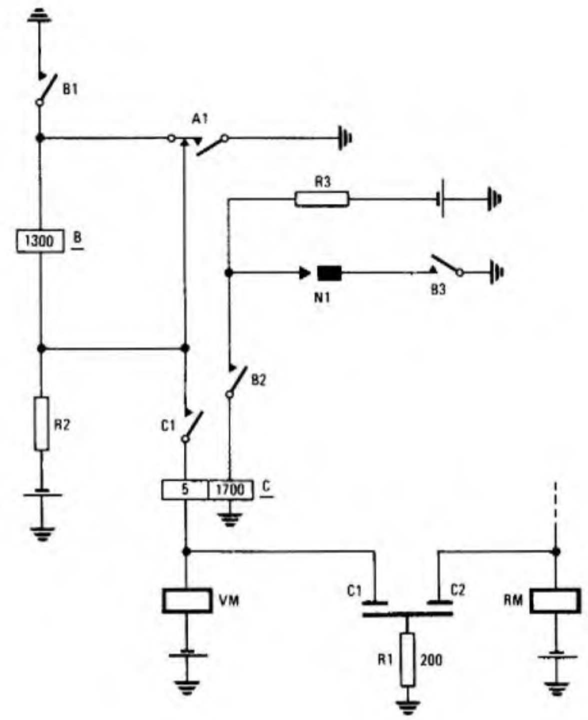
Q3 (a) (i) Sketch a circuit element for the vertical stepping of a group selector and show how a resistor-capacitor spark-quench circuit is associated with the selector magnet.

(ii) Explain how the resistive and capacitive components of the spark-quench circuit help to reduce contact wear.

(b) (i) If the spark-quench circuit were omitted, which relay contact points would suffer excessive wear?

(ii) Describe briefly the process by which the wear occurs.

A3 *(a) (i)* The vertical stepping circuit of a group selector is shown in the sketch. The spark-quench circuit associated with the vertical stepping magnet is formed by capacitor C1 and resistor R1. R1 is also part of the rotary-magnet spark-quench circuit, as is C2 which shares a common plate with C1.



(ii) The process of contact wear is explained in part *(b) (ii)*. In order to prevent such wear, it is necessary to absorb the inductive energy released by the collapse of the magnetic flux. This may be achieved by placing a high-value capacitor across the contacts. When the contacts open, the EMF across the contacts charges the capacitor and, provided the value of the capacitor is sufficiently large, the voltage rise is low during the early stages of contact separation. It is during this period that arc formation is likely. The energy thus released in the collapse of the magnetic field is therefore stored in the capacitor, and this is ultimately released when the contacts close again. It is for this reason that the resistance is included in the circuit. If a capacitor alone were used it would give rise to a very high initial current surge across the contacts when they re-operated. The inclusion of a resistor limits the value of such a surge.

(b) (ii) If the spark-quench circuit were omitted, the BREAK contacts of contact-unit A1 would suffer excessive wear.

(ii) If no spark-quench circuit were provided, these contacts would wear rapidly by a process of spark erosion. On the break of contact A1, the rapid fall of the heavy current in the highly-inductive magnet circuit causes a rapid change in flux which, in turn, induces a back-EMF which attempts to sustain the magnet operating current. This back-EMF gives rise to a high voltage across the A1 BREAK contacts as they are opening. This high voltage leads to the formation of an arc across the contacts which erodes metal from one contact and forms a crater on the contact surface. A proportion of this eroded material is deposited on the other contact, building up a pip; the remainder is vapourized in the arc and dispersed.

Q4 (a) For a telegraph system

(i) state what is meant by double-current signalling, and

(ii) state the advantages of double-current signalling over single-current signalling, giving reasons for your answer.

(b) For a telegraph relay

(i) sketch the magnetic circuit and show the flux paths, and

(ii) state TWO *features of the relay which contribute to a reduction in pulse distortion.*

A4 *(a) (i)* A double-current-signalling telegraph system is one in which the MARK and SPACE signals are represented by currents of opposite polarity.

(*ii*) Double-current signalling allows faster signalling over a given line or, alternatively, the same speed over a longer line. The limiting factor in each case is the rise and decay time of the relay current due to line capacitance. The use of an opposing current when changing from the MARK condition to the SPACE condition or, *vice versa*, actively discharges the line capacitance and thus speeds the operation of the distant-end relay.

Double-current signalling also reduces pulse distortion since it uses a polarized relay which can be manufactured with equal operating time in each direction. In contrast, single-current working utilizes both the operate and release times of an unpolarized relay and, since this device is not physically symmetrical, it is much more difficult to arrange for the operating and releasing times to be equal.

(*b*) (*i*) See A3, Telephony and Telegraphy A 1976, *Supplement*, Vol. 70, p. 49, Oct. 1977.

(*ii*) Pulse distortion is minimized by:

(1) The symmetrical construction of the relay, giving symmetrical operate and release times in each direction.

(2) The use of permanent magnets in the magnetic circuit, which permits the pulsing performance to remain almost constant over a wide range of line conditions.

Q5 (*a*) (*i*) *By means of a sketch, show how 2-wire-to-4-wire terminations are used to connect a 4-wire junction between 2 exchanges.*

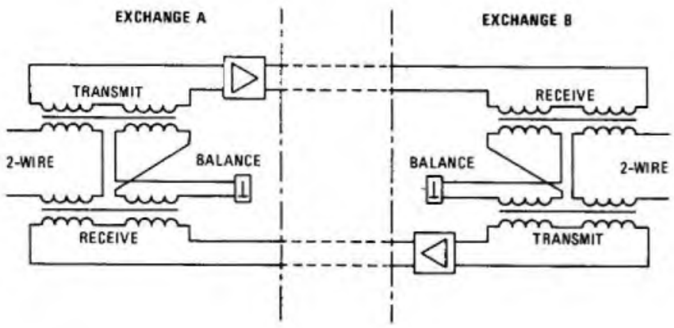
(*ii*) *Describe the paths taken by the speech currents while sending and receiving.*

(*iii*) *Explain how the 2-wire-to-4-wire termination reduces the risk of unwanted oscillation.*

(*b*) (*i*) *Sketch the theoretical circuit comprising a 3-winding transformer and balance network used for reducing sidetone in a telephone instrument.*

(*ii*) *Show how its action, when transmitting, is similar to that of a 2-wire-to-4-wire termination.*

A5 (*a*) (*i*) The sketch shows a 4-wire amplified junction together with its 2-wire-to-4-wire terminating units (hybrid transformers) and the local ends.



(*ii*) A speech current originating at exchange A flows in the 2-wire winding of the hybrid transformer. A current is thereby induced into both the transmit and receive windings. If the balance impedance is equal to the impedance of the 2-wire line, speech currents induced in the balance winding cancel out and thus no current flows in the balance winding and half of the power in the 2-wire winding is transferred to each of the TRANSMIT and RECEIVE windings.

At the receiving end, the current flowing in the RECEIVE winding induces currents in the balance and 2-wire winding. Currents induced in the transmit winding cancel out when the impedance of the balance winding is equal to the impedance of the 2-wire winding. Thus, the received power is divided equally between the 2-wire winding and the balance winding.

(*iii*) Oscillation in a circuit occurs when there is a net gain of greater than unity around a closed path. In the 4-wire path shown in sketch (*a*), the closed path runs from the transmit side at exchange A, via the receive side at exchange B, the transmit side at exchange B and the receive side at exchange A to the transmit side at exchange A. If the 2-wire-to-4-wire terminations were replaced by direct connexions, the circuit would become unstable and oscillate if the gain of the amplifiers exceeded the loss of the path. However, as explained in part (*ii*), at each end of the 4-wire circuit there is theoretically an infinite loss between the transmit and receive windings. In practice, the loss is not infinite but, because of the close matching of the 2-wire and balance impedances, it is large.

(*b*) See A1(*b*), Telephony and Telegraphy A 1974, *Supplement*, Vol. 68, p. 18, Apr. 1975.

Q6 *For a telephone-type relay,*

(*a*) *explain how eddy currents*

(*i*) *are generated in the core and yoke when the winding is de-energized, and*

(*ii*) *influence the relay release timing.*

(*b*) *Explain how eddy currents can be*

(*i*) *increased, and* (*ii*) *decreased.*

A6 (*a*) (*i*) While the winding is energized, there is a constant magnetic flux in the core, yoke, armature, residual air-gap and pole face. When the winding is de-energized, this flux starts to decay. However, the change in flux gives rise to induced eddy currents in the core, yoke and armature and, by Lenz's law, these eddy currents give a secondary flux which opposes the change (decay) in flux which causes them. Thus, the effect of the eddy-current flux is to maintain the flux holding the relay operated.

(*ii*) Since the eddy-current flux acts in the same direction as the collapsing main flux, the effect is to prolong the period during which the flux is sufficient to hold the relay operated, and so it will make the relay slow to release.

(*b*) (*i*) Eddy currents can be deliberately utilized by the addition of a closed path of low electrical resistance around the core. The most common method of achieving this is by the provision of a thick copper ring, termed a *slug*, at one end of the core over the winding. A slug acts as a short-circuited winding of very low resistance and hence the eddy currents induced in it are considerably larger than those induced in the core and the yoke. Such a slug gives a slow-to-release effect. It may also, if fitted at the armature end of the coil, give an increased operate time. Similar slow-to-release effects can also be obtained by the use of a conventional winding short-circuited either permanently or by a relay contact.

(*ii*) Eddy currents may be decreased by the use of a material having a higher electrical resistivity for some or all parts of the magnetic circuit. The material usually used for the core in such cases is nickel-iron alloy. With such a nickel-iron core and suitable circuit conditions, an appreciably faster release time may be acheived.

Q7 (*a*) *Sketch earth-testing and battery-testing elements for controlling the stepping, testing and switching actions of a uniselector hunter.*

(*b*) *For* EACH *case describe the circuit operation.*

(*c*) *What are the relative advantages of the battery-testing arrangement?*

A7 (*a*) (*b*) See A7, Telephony and Telegraphy A 1975, *Supplement*, Vol. 69, p. 35, Apr. 1976.

(*c*) Battery testing offers a number of advantages over earth testing.

(*i*) It offers greater immunity from double switching by the use of marginal-operate or marginal-hold circuitry.

(*ii*) It permits testing and seizure to take place simultaneously rather than sequentially.

(*iii*) It offers greater immunity to switching to faulty outlets because it will not switch to a disconnexion.

Q8 *Refer to a reed-relay switching matrix.*

(*a*) *Compare the efficiency of a 25 × 25 array with a 3 × 3 array.*

(*b*) (*i*) *For a 3 × 3 matrix, draw a circuit to show how the speech and control wires of one inlet may be switched to any of the outlets.*

(*ii*) *Explain how a system of co-ordinate marking signals may be used to operate any desired crosspoint.*

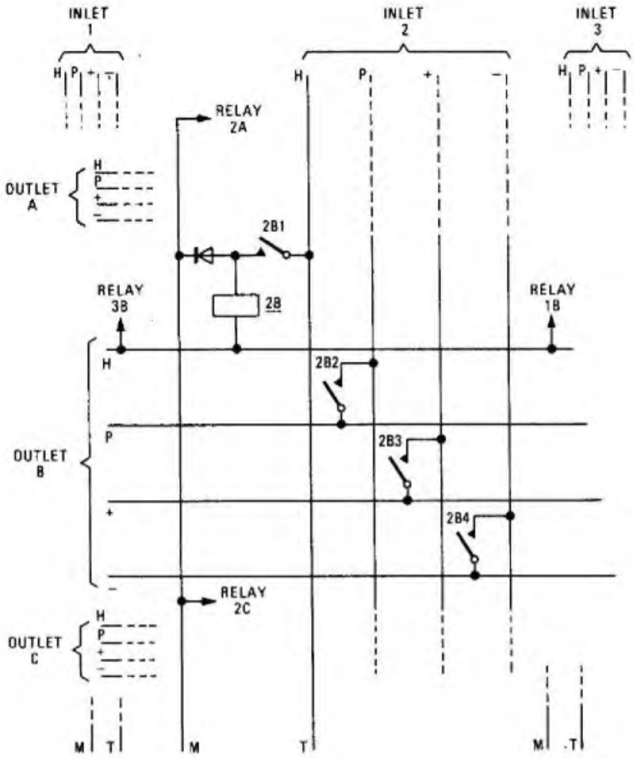
(*c*) *State* TWO *reasons why the matrix switching operations in an automatic exchange are directed from a common-control equipment.*

A8 (*a*) A 25 × 25 matrix contains $25 \times 25 = 625$ sets of crosspoints and can handle a maximum of 25 simultaneous calls. It thus requires $\frac{625}{25} = 25$ sets of crosspoints per call. A 3 × 3 matrix contains 9 sets of crosspoints and can handle a maximum of 3 simultaneous calls. It thus requires 3 sets of crosspoints per call. A 3 × 3 matrix is thus considerably more efficient than a 25 × 25 matrix in terms of its utilization of crosspoints.

Note: In this answer, efficiency has been defined as the number of crosspoints per call. In practice, other factors such as the quantity of control circuitry (which is proportionately less for larger arrays) would also be taken into account when deciding the size of array to be employed.

(*b*) (*i*) The sketch shows the switching arrangements for a 3 × 3 array.

(*ii*) Three of the 4 wires of each inlet and outlet (−, +, P) take no part in the switching itself; they are connected to relay contacts at the intersection of each inlet and outlet.



To switch an inlet to an outlet, the H-wires of both the inlet and the outlet are marked: the inlet with an earth and the outlet with a positive battery. The switching is initiated by application of an earth to the M-wire associated with the imlet. Thus, if both inlet 2 and outlet B were marked and an earth potential applied to the M-wire of inlet 2, relay 2B would operate from the battery, via the H-wire of outlet B, the coil of relay 2B, and the diode to the M-wire earth. Relay 2B in operating provides a holding path independant of the M-wire; namely, positive battery via the H-wire of outlet B, the coil of relay 2B, contact 2B1 to the earth on the H-wire of inlet 2. Contacts 2B2, 2B3 and 2B4 switch the P, + and − wires respectively from inlet 2 to outlet B.

(*c*) The principal reason why matrix switching operations are directed from a common-control area is that such operations occur only once in the duration of a call. There is thus an economic advantage in concentrating the control functions in a common area, available to the entire exchange, rather than distributing them where they would perform their function and then remain idle, but unavailable to any other switching operations taking place during the duration of the call.

The centralization of control offers other advantages in the form of facilities, such as repeat-attempt calls via an alternative security plane. In this way, calls which would otherwise fail through equipment faults are redirected via a completely new route between the inlet and outlet concerned, thus ensuring that a single fault cannot affect the repeat attempt. Such a feature would be difficult, if not impossible, to provide if the control functions were distributed throughout the exchange.

Q9 *(a) (i) Explain briefly the terms "calling rate" and "traffic intensity".*

(ii) Show how these terms are related to the average call-holding time.

(b) If 1000 subscribers originate 6 erlangs in the busy hour with an average call-holding time of 2·4 min, what is the busy-hour calling rate?

(c) If these subscribers lose 3 calls in the busy hour due to congestion, what grade of service do they experience?

A9 (*a*) (*i*) The calling rate during any particular period is the average number of calls originated by each subscriber during that period. The traffic intensity during any particular period is the average number of simultaneous calls in progress during that period.

(*ii*) Calling rate and traffic intensity are related to the average call-holding time by the expression

traffic intensity in erlangs =
number of subscribers × calling rate × average call-holding time in hours.

(*b*) Using the same expression given in part (*b*) (*ii*),

$$6 = 1000 \times \text{calling rate} \times \frac{2\cdot4}{60}.$$

Thus, calling rate $= \dfrac{6 \times 60}{2\cdot4 \times 1000} = \underline{0\cdot15}.$

(*c*) Grade of service $= \dfrac{\text{calls lost}}{\text{calls offered}}$.

Calls offered = number of subscribers × calling rate,
= 1000 × 0·15 = 150 calls.

$$\therefore \quad \text{grade of service} = \frac{3}{150} = \underline{0\cdot02.}$$

Q10 *(a) For a uniselector mechanism, explain, with the aid of sketches, how good electrical contact is achieved*

(i) at the input to the rotating wiper blades, and

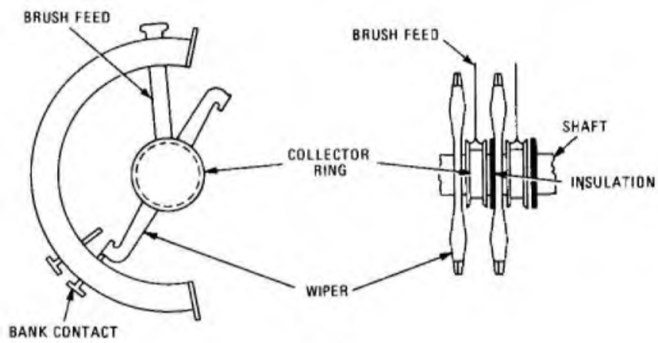
(ii) between the wiper blades and the bank contacts.

(b) For a subscriber's uniselector circuit

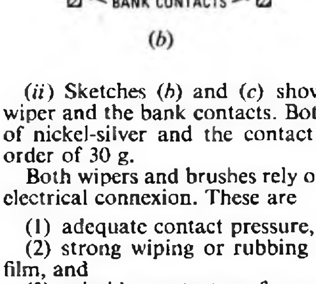
(i) state which of the wipers are of the bridging type and which non-bridging, and

(ii) state ONE reason why a bridging wiper is used.

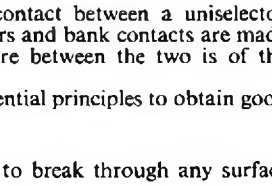
A10 (*a*) (*i*) Sketch (*a*) shows the brush-feed assembly which is the input to the rotating wiper blades. A series of nickel-silver brushes are tensioned outwards with the ends of the brushes rubbing against the side of a U-shaped collector ring mounted on the uniselector hub. The collector ring is constructed of brass or nickel-silver.



(*a*)



(*b*)



(*c*)

(*ii*) Sketches (*b*) and (*c*) show the contact between a uniselector wiper and the bank contacts. Both wipers and bank contacts are made of nickel-silver and the contact pressure between the two is of the order of 30 g.

Both wipers and brushes rely on 3 essential principles to obtain good electrical connexion. These are

(1) adequate contact pressure,

(2) strong wiping or rubbing action to break through any surface film, and

(3) suitable contact surfaces which do not readily form a non-conductive oxide layer,

(*b*) (*i*) The − and + line wires are fitted with non-bridging wipers and the P-wire with a bridging wiper.

(*ii*) A bridging wiper is used on the P-wire because the testing circuit is an earth-testing circuit. With this circuit, an earth is the *busy* condition and the absence of an earth the *free* condition. If a non-bridging wiper were used there would be a considerable danger of the testing circuit responding to the momentary disconnexion between bank contacts as a *free* condition, and thus false or double switching would result.

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