SUPPLEMENT

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GUIDANCE FOR STUDENTS

Contents

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.

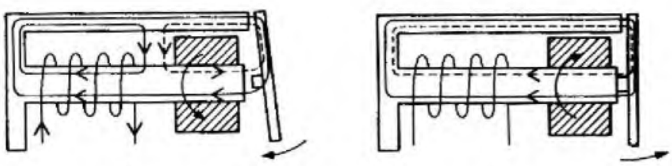
TELEPHONY AND TELEGRAPHY A 1979

Students were expected to answer any 6 questions

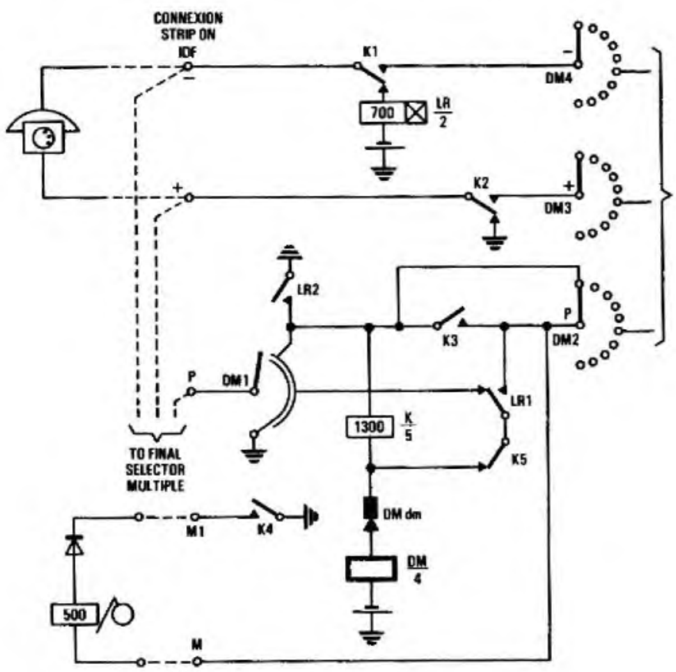
Q1 (a) For a telephone relay incorporating an armature-end slug, describe the action of the magnetic circuit under OPERATE *and* RELEASE *conditions.*

(b) Sketch a circuit element that employs such a relay and explain the need for the slug.

A1 (*a*) The magnetic circuits under OPERATE and RELEASE conditions are shown in sketches (*a*) and (*b*) respectively.



(*a*) (*b*)



IDF: Intermediate distribution frame
(*c*)

On energization of the winding, the main flux starts to rise and, consequently, eddy currents flow in the slug. The flux set up by the slug causes most of the main flux to leak from the core to the yoke without passing through the armature and air-gap. The eddy-current flux decreases as the rate of change of the main flux decreases; consequently, the flux in the air-gap gradually increases. After a period determined in the main by the size of the slug and the load on the armature, the relay operates.

When the current is disconnected, the main flux begins to collapse and this again causes the slug to set up a flux; in this case, however, its direction will be the same as that of the main flux. This tends to delay the decay of flux in the relay, with the result that the armature takes longer to release, giving a slow-to-release effect.

(*b*) An example of such a relay is relay LR in the subscriber's uniselector circuit. The circuit elements are shown in sketch (*c*).

The release lag of the relay ensures that the holding earth for relay K is not disconnected at contact LR2 before the earth from the private wire holds relay K. The operate lag allows the relay to be substantially fluxed before the uniselector commences hunting; this ensures that the full slow-release time is always obtained, and is important should the uniselector switch to an early-choice contact.

Q2 (a) Describe, with the aid of a sketch, the mechanical action of a 2-motion selector during rotary stepping.

(b) Explain why lubrication of the selector is necessary. What special properties should the lubricants have?

A2 See A6, Telephony and Telegraphy A 1975, *Supplement*, Vol. 69, p. 34, July 1976.

Q3 Explain, with the aid of a simple circuit diagram, how a subscriber connected to a Telex exchange

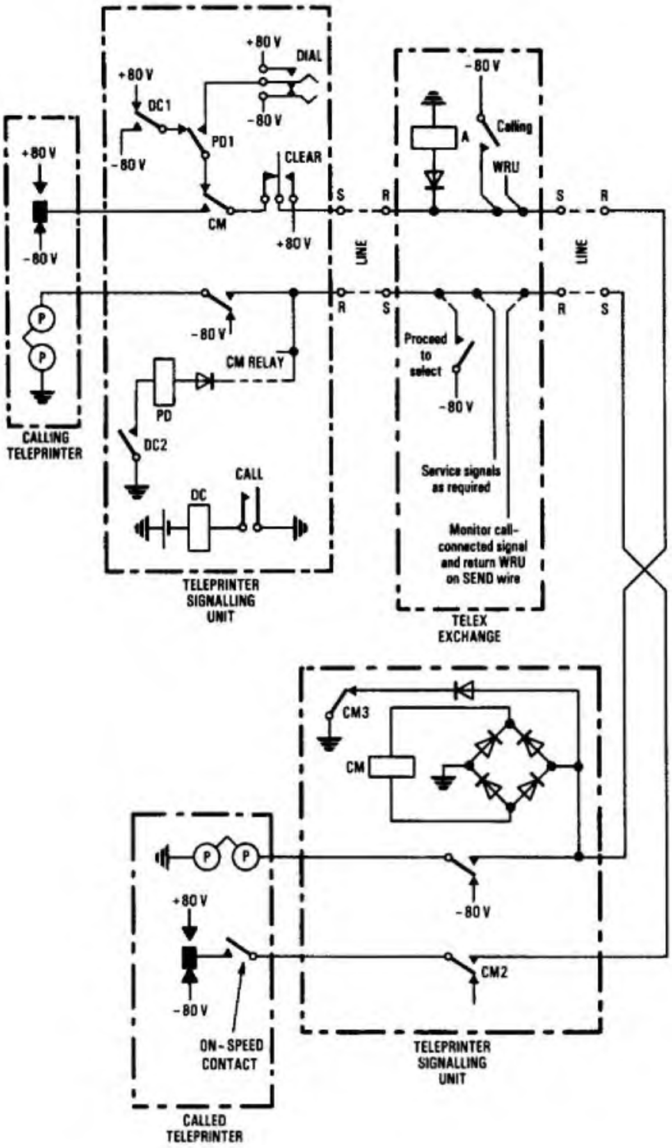
(a) calls the exchange,

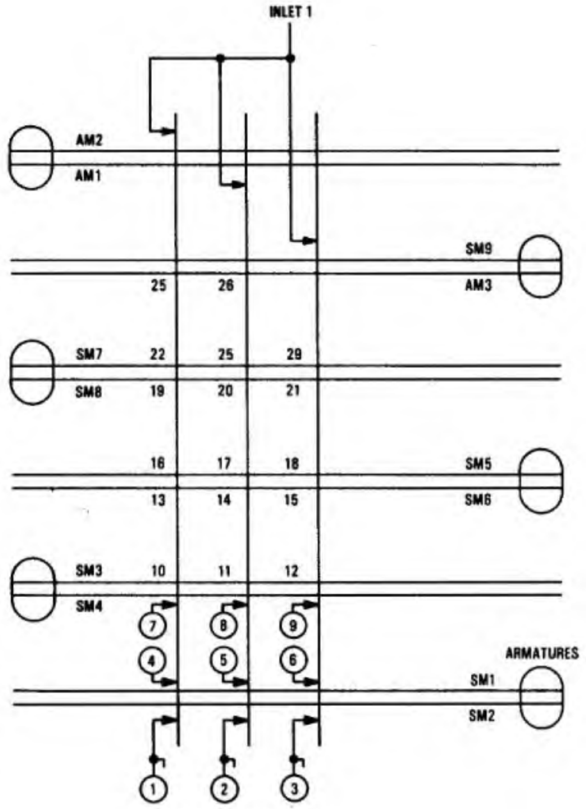
(b) dials into the exchange to make a local call, and

(c) clears the connexion at the end of the call.

A3 (*a*) Referring to the sketch, when the subscriber depresses the CALL button, relay DC operates. Contact DC1 changes the S-wire condition from a SPACE to a MARK potential, which operates relay A and thus seizes equipment in the Telex exchange. Contact DC2 prepares relay PD. When the exchange is ready to receive dial pulses, the *proceed-to-select* signal, which is a pulse of MARKING battery on the R-wire, is sent from the exchange to the calling subscriber. This operates relay PD which, at contact PD1, connects the S-wire to the dial contacts.

(*b*) Operating the dial interrupts the steady MARK condition with SPACING pulses, which release and re-operate relay A at the exchange. A contact of relay A is used to control the selector in the same way as in a telephone exchange. Dialling continues in the same manner through successive selector stages. Service signals are returned as required by the





exchange equipment at the point shown.

(*c*) The operation of the CLEAR key connects SPACING battery to the S-wire long enough to release relay A associated with the final selector; thus all the exchange equipment is released. This results in both R-wires becoming disconnected, releasing both CM relays and thus reverting the subscribers' lines to the normal or free condition.

Q4 (*a*) *Describe, with the aid of sketches, the mechanical operation of a crossbar switch.*

(*b*) *A crossbar switch consists of 10 bridge assemblies and 6* SELECT *bars. Explain how the number of outlets may be increased by the use of auxiliary magnets.*

A4 (*a*) See A7, Telephony and Telegraphy A 1977, *Supplement*, Vol. 71, p. 41, July 1978.

(*b*) If 2 springsets are operated simultaneously, the number of outlets can be increased by coding the outlet number according to the combination of springsets that are operated. Connecting strips of conducting material known as *bridge commons* connect the 2 operated springsets together. The arrangement is shown in the sketch.

Operation of magnet SM1 will move the SELECT fingers on the SELECT bar in a downward direction, so that springsets 1, 2 and 3 are prepared for operation. If magnet AM1 (auxiliary magnet 1) is also operated, the finger will be tilted upward and, when the BRIDGE magnet is operated, inlet 1 will be connected via the AM1 springset, the bridge commons and the SM1 springset, to outlet 1. Access is obtained to outlet 26 by the simultaneous operation of magnets SM9 and AM2. Likewise, by operation of suitable combinations of the SELECT magnets and the auxiliary magnets, connexion is obtained to any of the 26 outlets. The switch size has therefore been increased from 10 × 12 to 10 × 26.

Q5 *For a reverse-drive uniselector-hunter,*

(*a*) *sketch an earth-testing circuit element and describe the circuit operation,*

(*b*) *explain why a bridging wiper should be used on the uniselector testing arc, and*

(*c*) *indicate how the uniselector could be made to home to a predetermined outlet on release of the circuit.*

A5 See A7, Telephony and Telegraphy A 1975, *Supplement*, Vol. 69, p. 35, July 1976, and A5, Telephony and Telegraphy A 1977, *Supplement*, Vol. 71, p. 40, July 1978.

Q6 (*a*) *Describe, with the aid of a block diagram, a 1VF signalling system for use on a junction between 2 exchanges.*

(*b*) *State what types of signals are used*

(*i*) *to seize the distant exchange equipment, and*

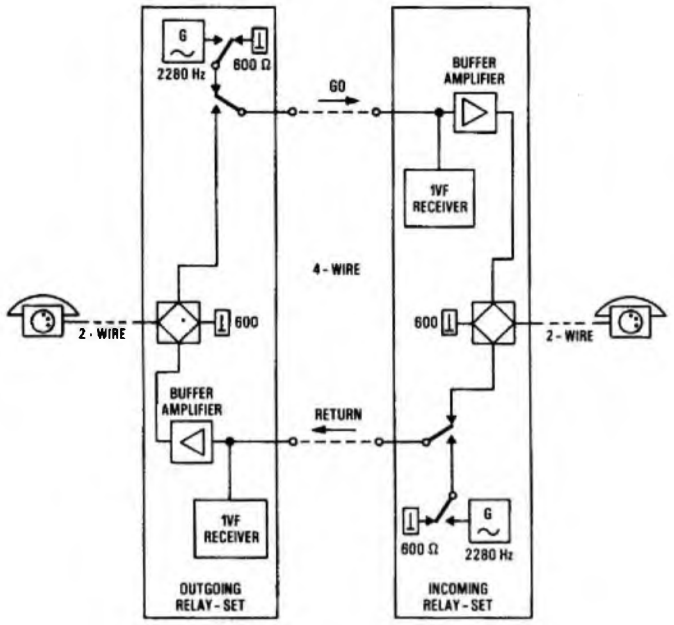
(*ii*) *to release the connexion.*

(*c*) *Of the 2 signals in part* (*b*), *which needs to have the stronger protection against signal imitation, and why?*

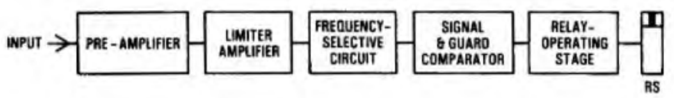
A6 (*a*) A block diagram of a 1VF signalling system is shown in sketch (*a*).

The outgoing and incoming relay-sets are connected by a 4-wire line, consisting of a TRANSMIT pair and a RECEIVE pair, often referred to as GO and RETURN. Two-wire ends give access from and to the switching equipment. The hybrid transformers are necessary to convert the 2-wire line into 4 wires at the outgoing end, and *vice versa* at the incoming end. The voice-frequency receiver is connected across each RECEIVE pair, continuously monitoring the line for the presence of signalling tone.

Sketch (*b*) shows a block diagram of the receiver. All incoming signals, including speech, control signals and noise, are amplified to a given level by the pre-amplifier and the limiter amplifier. The frequency-selective circuit is designed to give a signal output when the input from the limiter amplifier is within 50 Hz either side of the signal frequency of 2280 Hz, and a GUARD output which is not frequency-dependent. These two outputs are applied to the comparator. If the signal frequency of 2280 Hz is present with minimal GUARD-circuit output, relay RS will be operated by the operating stage. If, however, there is a high output from the GUARD circuit, the operation of relay RS is inhibited. Thus, the requirement that a GUARD circuit be used to reduce the possibility of signal imitation is satisfied.



(*a*)



(*b*)

Q7 In a Strowger-type telephone exchange, the subscriber's line-circuit switching stage is provided by means of a 24-point uniselector followed by 100-outlet first group-selectors. Explain

(a) why the traffic carried in the busy hour is less than the traffic offered,

(b) what the essential difference is between the methods of connecting 18 trunks from the subscriber's uniselector to first group-selectors and 18 trunks from a level of the first group-selectors to second group-selectors, and

(c) which arrangement in part (b) would give the better grade of service and why? (It should be assumed that the traffic offered is the same in each case.)

A7 (*a*) As the traffic offered approaches the value for which a switching stage is designed, the traffic carried will be less than that offered. This is because it is not economic to provide sufficient equipment to carry all the designed busy-hour traffic. Each switching stage is therefore designed to a specified grade of service which results in a given percentage of the offered calls being lost (when that traffic reaches its designed value).

(*b*) For the uniselector stage to first group-selectors, the 18 trunks would be connected as a full-availability group, since each uniselector has an availability of 24.

For the first group-selector to second group-selector stage, the 18 trunks would be connected by a grading, since 100-outlet group selectors have an availability of 10.

(*c*) In part (*b*), the better grade of service, assuming the same traffic offered to each arrangement, will be given by the full-availability interconnexion between uniselectors and first group-selectors. This is because, in a full-availability arrangement, all sources have access to all trunks but, in a grading arrangement, any one source can only access a limited number of the trunks and is therefore not so efficient.

Q8 (a) Sketch a trunking diagram of a typical 3000-line step-by-step automatic telephone exchange.

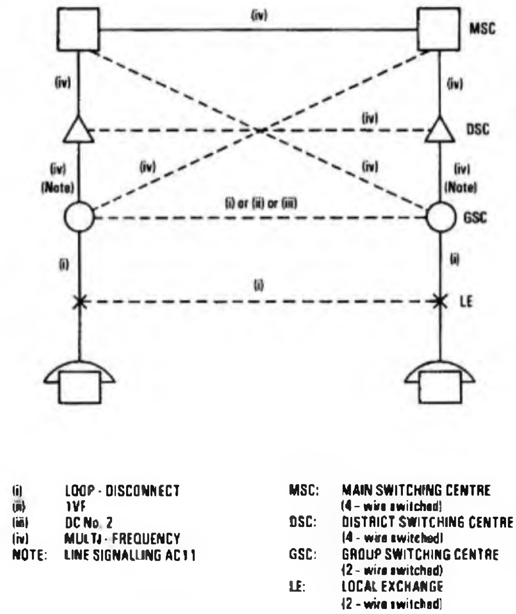
(b) Give FIVE *facilities provided by a final selector and* FOUR *facilities provided by a first group-selector.*

(c) Sketch a circuit element of a typical final-selector transmission bridge. Mention TWO *special features of the relays which improve the transmission performance.*

A8 See Telephony and Telegraphy A: A8 1974, A4 1975, A2 1976 and A5 1976 (*Supplements*: Vol. 68, p. 20, Apr. 1975; Vol. 69, p. 34, July 1976; Vol. 70, pp. 50 and 51, Oct. 1977).

Q9 Describe, with the aid of a sketch, a switching plan suitable for a national telephone network catering for large cities, towns and small isolated communities. Indicate the type of signalling which could be employed on the various routes.

A9 A switching plan suitable for a telephone network of the type specified is shown in the sketch.



The exchanges in such a network would be connected together in a hierarchical manner. The outlying local exchanges in a particular area would each be connected to the most prominent exchange in the area, termed a *group switching centre*, which would provide the trunk switching facilities for the exchanges in its group. Because of the likely numbers of exchanges involved, it would not be possible for each group switching centre to be connected to every other group switching centre; therefore a number of group switching centres would be connected to a *district switching centre* (of which there are many). If the number of district switching centres is still too great to enable full interconnexion, a number of district switching centres would each be connected to a main switching centre. All main switching centres would be fully interconnected with each other. District switching centres and main switching centres are known collectively as *transit switching centres*.

At any point in the hierarchy, interconnexion of exchanges may be provided if the level of traffic is sufficient to warrant it. For example, in a large city it is probable that many of the local exchanges would be connected to each other. These auxiliary routeings are shown by the dashed lines in the sketch. In fact, the majority of traffic is carried over these auxiliary routeings.

The types of signalling which would be used on the various routes are indicated on the sketch.

Q10 (a) What is the purpose of an automatic regulator used in a modern telephone?

(b) Describe, with the aid of a sketch of the circuit elements, the operation of the automatic regulator in part (a)

(i) during transmission of speech, and

(ii) during reception of speech.

TELEPHONY B 1979
Students were expected to answer any 6 questions

Q1 With the aid of a simple trunking diagram, describe the setting up of the following types of call from a group selector satellite exchange.

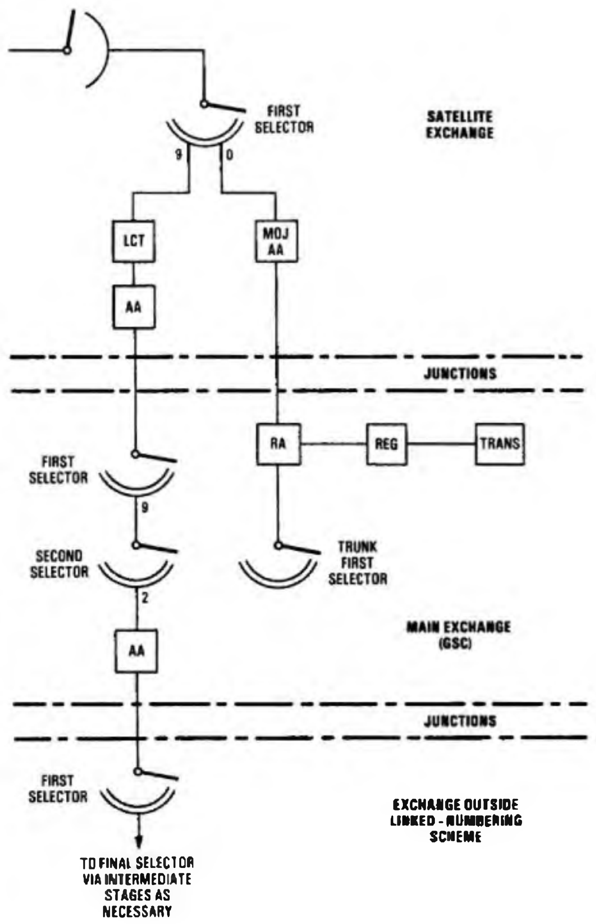
(a) An STD call as far as the first trunk selector at the main (group switching centre) exchange, and

(b) a non-STD call via the main exchange to an exchange outside the linked-numbering scheme.

A1 (*a*) When the calling subscriber lifts his receiver, his uniselector hunts in search of a free first selector and having found one, switches to it. Dialling tone is returned from the first selector. When digit 0 is dialled, the first selector steps to level 0 and hunts for a free STD junction, switches to it and remains held to the earth from the metering-over-junction (MOJ) relay-set.

At the group switching centre (GSC), seizure of the junction causes the register access relay-set to seize the associated trunk first selector and to hunt for and seize a free register.

(*b*) The first selector is seized in the manner described in part (*a*) and dialling tone returned to the caller. The caller dials a code (for example, 992) followed by the required number. The first code digit will step the satellite exchange first selector to level 9 and the selector will hunt for and seize a free junction to the main exchange, after which the satellite equipment will remain held by the auto-to-auto relay-set .The remaining code digits step the selectors at the main exchange in turn and the last selector in the train will hunt for a free junction to the objective exchange. When this is seized, the main-exchange equipment remains held by the auto-to-auto relay-set at the main exchange. The digits of the required number step the group and final selectors at the objective exchange in sequence. If the line is free, ringing current will be applied and when it is answered the line reversal applied by the final selector will be relayed via the main-exchange auto-to-auto relay-set to the satellite-exchange auto-to-auto relay-set, which will initiate the first meter pulse and activate the call-timing relay-set.



LCT: Local-call-timing relay-set
AA: Auto-to-auto relay-set
REG: Register
MOJ AA: Auto-to-auto relay-set with metering over junction
RA: Register-access relay-set with metering over junction
TRANS: Translator

Q2 Consider a pay-on-answer coin-collecting box and the coin-and-fee checking (C and FC) relay-set to which it is connected at the exchange.

(a) For a dialled local call, state

(i) when the coin slots open,
(ii) what signal is returned from the exchange C and FC relay-set to open the coin slots, and
(iii) what signals are transmitted by the coin-collecting box to indicate the value of the coins inserted.

(b) State THREE circumstances under which the coin slots are locked and explain why the locking action is provided.

A2 (*a*) (*i*) The coin slots are unlocked when the called subscriber answers.

(*ii*) The C and FC relay-set applies a line reversal to open the coin slots.

(*iii*) The value of coins inserted is signalled to the exchange by increasing the line loop resistance by 5 kΩ in pulses, the number of which depend on the value of the coin inserted. These pulses are sent at a rate of approximately 4 pulses per second with a signalling-resistance-to-loop-resistance timing ratio of 1:1·6. Each coin pulse train terminates with a line disconnexion of 60 ms and if this final disconnexion is absent the pulse train is not accepted by the exchange equipment.

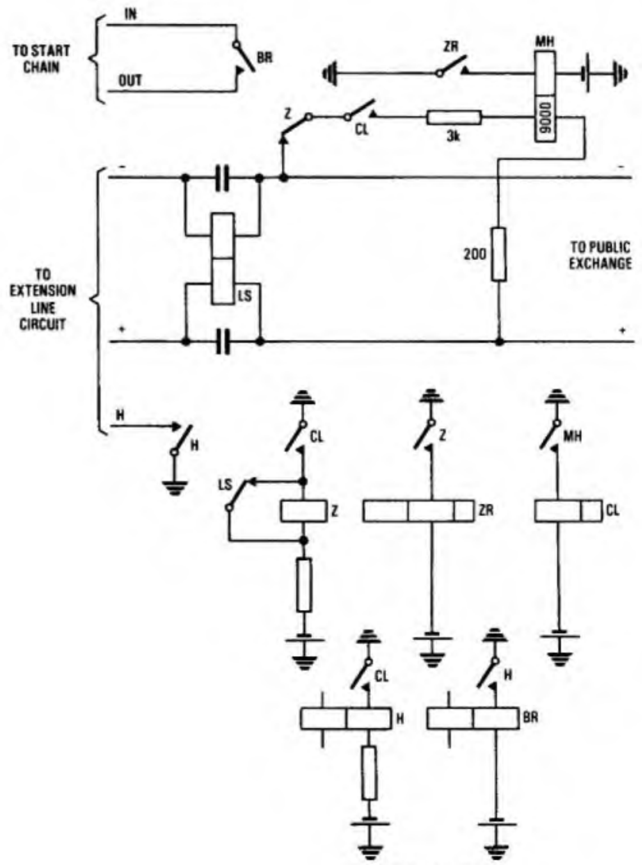
(*b*) The coin slots are locked under the following conditions:

(*i*) Prior to the called subscriber answering; this prevents the caller from inserting coins until the connexion has been established satisfactorily.

(*ii*) If the value of the coins inserted exceeds the capacity of the exchange equipment to record the value of credit; this prevents the caller from inserting coins for which he would receive no credit and, therefore, no service.

(*iii*) When the line is force cleared because the caller fails to insert further coins after pay tone has been returned during the progress of a call; this action again prevents the caller from inserting coins for which he would obtain no service.

Q3 (a) For a PABX, explain with the aid of sketches of the circuit elements concerned, how a calling extension is prevented from seizing an exchange line which is in the process of releasing from a previous call set up by an extension to the main exchange.



EXCHANGE LINE CIRCUIT

(*b*) *How does a public exchange line circuit serving a PABX differ from one serving an ordinary subscriber? Why is this difference necessary?*

A3 (*a*) The circuit arrangement which ensures that the equipment at the public exchange is normal before it can be seized by a call from the PABX is shown in the sketch.

When an extension is speaking on a call via the public exchange, all the relays are normal as shown in the sketch.

When the PABX extension clears, the disconnexion of the loop releases relay LS and indicates to the public exchange that the call is finished. A contact of relay LS short-circuits relay Z, one contact of which starts the release of relay ZR and another connects the 9000 Ω coil of relay MH across the positive and negative lines. The time at which relay ZR releases the holding circuit for relay MH depends on the condition extended on the positive and negative wires from the public exchange. For example, if the call was via the operator at the public exchange and she had not removed the calling and answering plugs, the manual-hold condition maintains a battery and earth on the line which holds relay MH in the exchange line circuit, Relays CL, H and BR remain operated, thus busying the exchange-line circuit. When the operator clears the connexion, the manual hold condition is removed and relay MH releases, initiating the release of relays CL, H and BR to unbusy the exchange line circuit.

It is therefore impossible for another extension dialling the access digit to seize this exchange line until the equipment at the public exchange has restored to normal.

(*b*) In the public exchange line circuit the contact on relay K that is normally connected to earth is sleeved. If a line circuit that operates to loop calling were used, the battery and earth extended from the public exchange to the PABX would cause relay MH to be permanently operated, causing the exchange line circuit to lock up.

Q4 (*a*) *Sketch those circuit elements of a final selector which control the connexion of ringing current to the called subscriber's line and return ring tone to the caller. The sketch should include the operating and holding circuits for the P-wire testing relay.*

(*b*) *State* TWO *features of the ring-trip relay which prevents its operation until the called subscriber answers.*

(*c*) *What would be the effect of an earth fault on the positive wire of an ordinary subscriber's telephone line when it is being rung from a final selector?*

Q5 (*a*) (*i*) *Define the terms "full availability" and "limited availability" as applied to groups of trunks.*

(*ii*) *With which of the above terms is grading associated and why?*

(*b*) *Design and sketch the best 4-group grading for 22 trunks from a level of 100-outlet first group selectors to second group selectors.*

A5 (*a*) (*i*) *Full availability* exists when all inlets to a switching block have access to all outgoing trunks connected to a subsequent switching block or junction route.

Limited availability exists when the number of outlets available to any inlet is less than the total number of circuits in the route to which access is to be provided.

(*ii*) When limited availability exists, grading is adopted as the means of interconnecting switch outlets to outgoing trunks. The switches are divided into a suitable number of equal-sized groups and the early-choice outlets on each group are allocated individual trunks. On later outlets, trunks are allocated to 2 or more groups commoned together, and the commoning is progressively increased until the last outlets are common over all groups. This is illustrated in the sketch in part (b).

(*b*) Number of trunks = 22.
Availability = 10.
Number of grading groups = 4.

Four groups will provide for individuals, pairs and full commons.

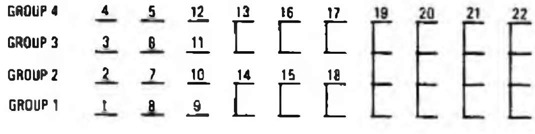
Let a be the number of individuals, b be the number of pairs and c be the number of commons.

Therefore,
$$4a + 2b + c = 22. \quad ......(1)$$
$$a + b + c = 10. \quad ......(2)$$

Subtracting equation (2) from equation (1),
$$3a + b = 12.$$

Therefore,

if $a = 4$, then $b = 0$ and $c = 10 - 4 = 6$,
if $a = 3$, then $b = 12 - 9 = 3$ and $c = 10 - 3 - 3 = 4$,
if $a = 2$, then $b = 12 - 6 = 6$ and $c = 10 - 2 - 6 = 2$,
if $a = 1$, then $b = 12 - 3 = 9$ and $c = 10 - 1 - 9 = 0$.



The best grading is that with the least sum of successive differences as determined in the table and illustrated in the sketch.

a	*b*	*c*	Sum of successive differences
4	0	6	10
3	3	4	1 (best)
2	6	2	8

Q6 (*a*) *Explain, with the aid of sketches of the circuit elements involved how unguarded intervals arise in an earth testing selector when*

(*i*) *switching to an outlet, and*
(*ii*) *releasing from a call.*

(*b*) *Show how these unguarded intervals are reduced or eliminated by the use of battery testing.*

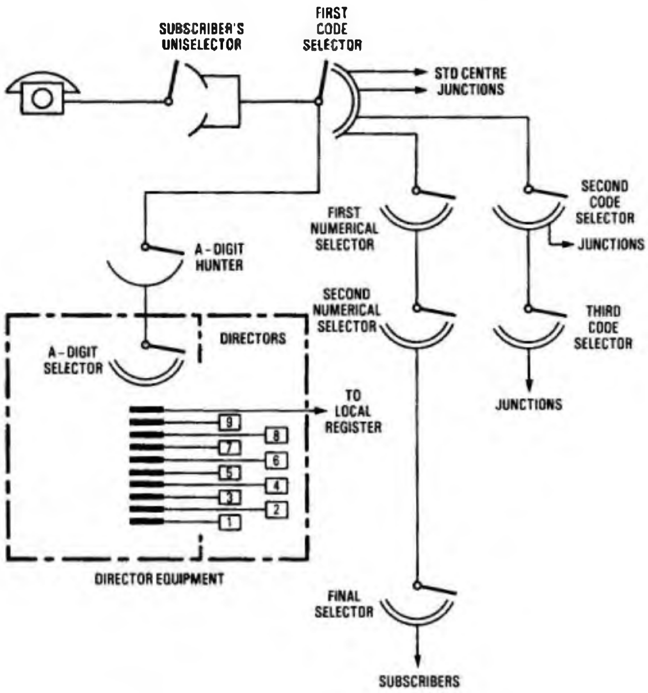
Q7 *For a Strowger director exchange*

(*a*) *draw a simplified trunking diagram, and*

(*b*) *explain briefly the sequence of operations in the setting up of*

(*i*) *an own-exchange call,*
(*ii*) *a call between subscribers connected to exchanges which are on opposite sides of the director area, and*
(*iii*) *a call to an assistance operator (code 100).*

A7 (*a*) A simplified trunking diagram of a Strowger director exchange is shown in the sketch.



(*b*) (*i*) On originating a call, the calling subscriber is connected initially to a free first code selector. An A-digit hunter (ADH) associated with the first code selector then finds a free A-digit selector (ADS) from which dial tone is returned. The first code selector does not step in response to the dialled pulses, but repeats the first, A, digit of the exchange code to the ADS, which steps and searches for a free director in the appropriate group. The second, B, digit and third, C, digit are then repeated by the first code selector. In the director the B and C digits of the exchange code step a 6-bank 100-outlet 2-motion selector in both the vertical and rotary direction to a particular set of contacts.

A contact position is allocated to each exchange in the director area and for each of these positions a unique combination of the wires from the 6 banks determines the routeing, causing the director to send the routeing code of between one and 6 digits appropriate to the required exchange. For an own-exchange call, the translation consists of only one digit. The routeing code is pulsed-out by the director via the ADS and the ADH to step the first code selector, which then selects an ideal first numerical selector in the exchange. The remaining four digits of the wanted subscriber's number are repeated by the first code selector to the director where they are stored and retransmitted to the first and second numerical selectors and the final selector in the local exchange. When the last digit has been retransmitted, the director and ADS are released and are available to process further calls.

(*ii*) When a call is made to a director exchange which is located at the opposite side of a large director area, the sequence of operations is the same as for an own-exchange call up to the point at which the director sends out the translated routeing code. The translation will now comprise sufficient digits to route the call, via selectors at one or more intermediate (tandem) switching centres, to the first numerical selector at the required exchange. As before, the director stores and retransmits the numerical part of the wanted subscriber's number and steps the first and second numerical selectors and the final selector at the remote exchange.

(*iii*) For a call to the assistance operator the caller dials only the code (100); that is, there are no numerical digits. The director is so arranged that it transmits the necessary routeing digits and then releases without waiting for numerical digits to be dialled. This is arranged by the method of connexion, in the translation field, of the BC-switch bank positions appropriate to the code.

Q8 *(a) Consider a crosspoint switching matrix which has 5 inlets and 10 outlets.*

(i) How many simultaneous calls can it carry?
(ii) What is the efficiency of this particular matrix?

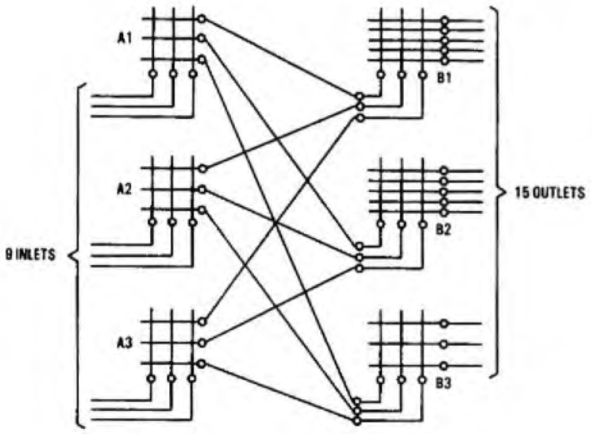
(b) Explain how adequate accessibility between a large number of inlets and a large number of outlets can be achieved more efficiently than with a single matrix.

(c) What is internal blocking and how can it be reduced?

A8 (*a*) A single matrix to connect 5 inlets to 10 outlets will be equipped with 50 crosspoints. A maximum of 5 simultaneous calls can be connected, thus achieving an efficiency of 10%.

(*b*) The matrix shown in the sketch is a combination of 6 small matrices giving access from 9 inlets to 15 outlets. A total of 72 crosspoints are provided, 2 of which are required to connect each of the 9 calls which can be carried simultaneously.

A single matrix would require 135 crosspoints. Thus, by suitable trunking, on a number of small matrices, the number of crosspoints can be reduced and the efficiency increased.



(*c*) The circuits connecting the outlets of one stage to the inlets of the next stage are called *links*. Internal blocking occurs when an inlet on the A switches cannot be connected to a particular outlet, or one of a group of outlets, on the B switches due to the absence of a free link. For example, if inlet 1 on A1 is required to be connected to outlet 5 on B2 and the link between A1 and B2 is engaged, the call cannot be connected due to internal blocking.

Internal blocking can be reduced by

(*i*) distributing the circuits in any group as evenly as possible over all the B switches,

(*ii*) providing additional links between A and B switches, and

(*iii*) introducing one or more intermediate switching stages between the A and B stages, thus increasing the number of possible paths between each A and B switch combination.

Q9 *(a) Give* FOUR *advantages of a small reed-relay exchange (TXE2) compared with a small Strowger exchange.*

(b) Draw a simple block diagram of a TXE2 exchange.

(c) (i) Explain the setting-up of an own-exchange call in an exchange where most of the calls are own-exchange calls.
(ii) In what way would the answer to part (i) be modified if the call were to the main exchange?

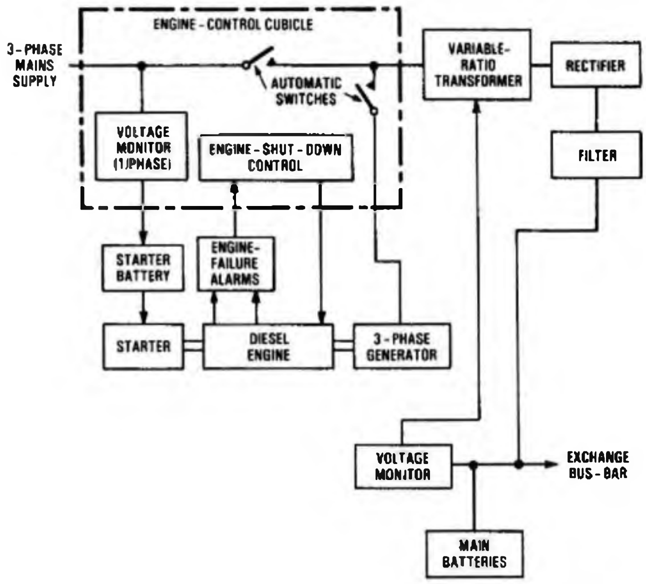
Q10 *The power plant for an exchange of medium size is of the floated-battery type, mains powered and includes a fixed engine set for stand-by.*

(a) Draw a diagram of the system.

(b) Give an outline description of the engine set and its principal auxiliaries.

(c) What considerations would determine the ampere-hour capacity for the main battery?

A10 (*a*) The sketch shows a diagram of a floated-battery mains-operated power plant with a fixed stand-by engine set.



(*b*) A description of the operation and arrangement of the engine set and its auxiliary equipment is given below.

If the voltage monitor in the engine-control cubicle detects an unacceptable fall in the mains voltage, it causes the starter battery to drive the starter. The diesel engine starts and drives the generator. When the engine reaches its working speed, the mains supply is disconnected and the generator's output is substituted, by means of automatic switches in the engine-control cubicle.

Fuel for the engine is normally supplied from an underground storage tank, and the cooling water from a further storage tank. The engine exhausts to the atmosphere. The engine temperature and oil pressure are continuously monitored and malfunctions are signalled to the engine-control cubicle, which shuts down the engine. If the engine fails to start, or stops for any reason, an alarm condition is extended to the nearest attended exchange, and the local-exchange power supply is taken over by the main batteries.

When the mains voltage returns to normal, the mains supply is reconnected, but the engine continues to run for a period sufficient to ensure that the starter battery is recharged.

(*c*) If an exchange is provided with a fixed stand-by engine set, the main batteries are not called upon to supply power unless both the mains supply and the engine set fail simultaneously. The battery's capacity can, therefore, be relatively small. Typically, it is sufficient to be able to maintain the exchange's peak load for a period of 3 h.

The peak load consists of a small miscellaneous load, approximately proportional to the number of exchange lines, plus a switching load due to the busy-hour traffic. For each switching stage, the average current taken by a selector carrying traffic is known, and so is the average number of simultaneous calls (busy-hour traffic flow in erlangs). The product of these 2 factors gives the current load in amperes for that switching stage. Thus, the capacity of the battery can be calculated by multiplying the sum of the 2 loads by the number of hours for which it is required to give service.

LINE TRANSMISSION C 1979

Students were expected to answer any 6 questions

Q1 (a) Explain how a fault on a transmission line can be located by plotting an impedance/frequency characteristic and observing the pattern of maximum and minimum values.

(b) A cable pair having a loop inductance of 1·5 mH/km and a loop capacitance of 0·08 μF/km shows a spacing of 2·5 kHz between adjacent maximum values. Calculate the distance of the fault from the testing end.

A1 (*a*) A fault on a transmission line will cause an impedance irregularity and, because of the resulting mismatch between the irregularity and the rest of the cable, a signal sent from one end will undergo some degree of reflection at the fault. The part of the incident signal which is reflected by the fault will return to the sending end, and will modify the normal input impedance of the cable according to the phase relationship between the outgoing signal and its delayed reflection. If the 2 signals are in phase, the input impedance will be increased, and if they are out of phase the impedance will be decreased. Successive maxima and minima will occur at frequencies for which the reflected wave is again in phase or out of phase with the outgoing signal; that is, at 2π multiples of phase.

If the phase characteristic of the cable is known, the distance between the sending end and the fault can be calculated from the pattern of impedance maxima and minima in the following way:

Let f_1 and f_2 be the frequencies of two adjacent impedance maxima in hertz;

α_1 and α_2 be the known phase change of the cable at f_1 and f_2 in radians/kilometre;

β_1 and β_2 be the unknown phase change that the reflected signal undergoes at the fault in radians; and

x be the unknown distance of the fault from the sending end in kilometres.

At f_1, the total phase change of the signal being reflected back to the sending end will be $x\alpha_1$ for the outgoing signal, β_1 at the fault, and $x\alpha_1$ for the reflection, which totals $2x\alpha_1 + \beta_1$. Similarly for f_2, the total phase change is $2x\alpha_2 + \beta_2$.

Since the difference in phase between two successive maxima (or minima) is 2π,

$$2x\alpha_2 + \beta_2 = 2x\alpha_1 + \beta_1 + 2\pi \qquad (\text{for } f_2 > f_1).$$

$$\therefore \quad x = \frac{2\pi + (\beta_1 - \beta_2)}{2(\alpha_2 - \alpha_1)} \text{ kilometres.}$$

Since β_1 and β_2 are both small and approximately equal,

$$\beta_1 - \beta_2 \approx 0.$$

$$\therefore \quad x \approx \frac{\pi}{\alpha_2 - \alpha_1} \text{ kilometres.}$$

But $\alpha \approx \omega\sqrt{(LC)}$, where L and C are the primary coefficients for loop inductance and capacitance per kilometre.

$$\therefore \quad x \approx \frac{\pi}{\omega_2\sqrt{(LC)} - \omega_1\sqrt{(LC)}} = \frac{\pi}{(\omega_2 - \omega_1)\sqrt{(LC)}}.$$

$$\therefore \quad x \approx \frac{1}{2(f_2 - f_1)\sqrt{(LC)}} \text{ kilometres.}$$

(*b*) For $L = 1{\cdot}5$ mH/km and $C = 0{\cdot}08$ μF/km, the distance to the fault from the sending end is

$$\frac{1}{2 \times 2{\cdot}5 \times 10^3 \times \sqrt{(1{\cdot}5 \times 10^{-3} \times 0{\cdot}08 \times 10^{-6})}},$$
$$= \underline{18{\cdot}3 \text{ km}}.$$

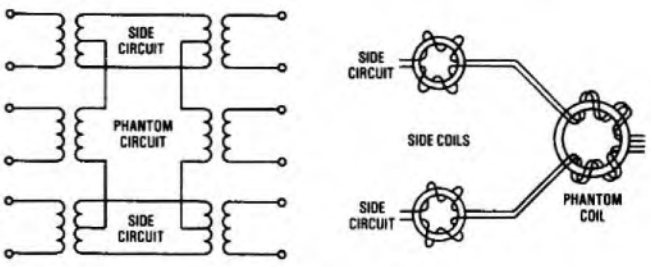
Q2 (a) Show how a superposed (phantom) circuit can be added to 2 existing cable pairs.

(b) What conditions have to be met to minimize crosstalk between phantom and side circuits?

(c) Explain how loading coils can be used on both phantom and side circuits.

A2 (*a*) A phantom circuit can be provided over 2 cable pairs by using centre-tapped transformers, as shown in sketch (*a*). Each leg of the phantom circuit consists of the 2 wires of one of the pairs connected in parallel. Signals in the phantom circuit do not pass through the side-circuit transformers, for they are cancelled by the action of the centre-tapped windings.

(*b*) To avoid overhearing, or crosstalk, between the phantom and side circuits, it is essential to ensure that the centre-taps on the line transformers are accurately made, and that the 2 wires of each pair are of equal impedance. If the phantom is to be used only for DC signalling, it does not need its own transformers; otherwise, they are necessary for impedance matching.



(*a*) (*b*)

(*c*) A specially-wound coil is used to load the phantom circuit. It has bifilar windings, thus presenting inductance to currents in the phantom circuit but appearing non-inductive to the side circuits. Sketch (*b*) shows the arrangement.

Usually, the phantom-circuit coils are put in the same loading pot as the side-circuit coils. Toroidal cores that have negligible external magnetic fields are used to prevent mutual interference by inductive coupling.

Q3 (a) Sketch the circuit of a 2-wire-to-4-wire terminating set.

(b) Explain its function in a 4-wire repeatered circuit.

(c) Calculate the balance return-loss for a 2-wire line of impedance 900 ∠−30° Ω and a balancing resistor of 600 Ω.

A3 (*a*) and (*b*) See A3 (*b*) and (*a*), Line Transmission C 1977, *Supplement*, Vol. 71, p. 78, Oct. 1978.

(*c*) Balance return-loss is a measure of the degree of match between a balancing impedance, Z_B, and a 2-wire line having impedance Z_O. It is calculated as

$$\text{balance return-loss} = 20 \log_{10} \left| \frac{Z_O + Z_B}{Z_O - Z_B} \right| \text{ decibels.}$$

If the match is perfect, $Z_O = Z_B$, and the balance return-loss is infinite.

For the values given, balance return-loss

$$= 20 \log_{10} \left| \frac{900\angle{-30} + 600\angle 0}{900\angle{-30} - 600\angle 0} \right| \text{dB},$$
$$= 20 \log_{10} \left| \frac{1380 - j450}{180 - j450} \right|,$$
$$= 20 \log_{10} \frac{1451}{485},$$
$$= \underline{9{\cdot}5 \text{ dB}}.$$

Q4 A cable pair has a characteristic impedance of 75 Ω. At a particular frequency its transmission loss is 6 dB and it is one quarter of a wavelength long. The far end is short-circuited.

(a) Obtain by phasor diagrams (i) the current and (ii) the voltage at the input to the line assuming it to be fed from a matched source.

(b) Calculate the input impedance.

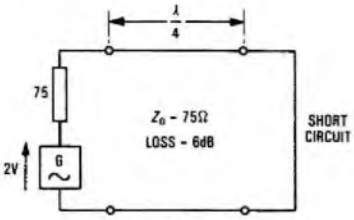
A4 (*a*) Sketch (*a*) shows the circuit arrangement in which the source has an EMF of 2 V and an internal impedance of 75 Ω.

The incident voltage will be 1 V, and the current 1/75 A; that is, 13·3 mA. Sketch (*b*) shows the phasor diagram for the voltage.

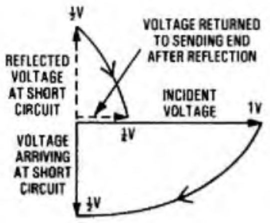
On reaching the far end, the initial voltage will have changed in phase by $\pi/2$ rad (90°), and will have been attenuated from its initial value of 1 V by 6 dB to 0·5 V. The wave arriving at the far end will be reversed in phase (that is, 180° phase change) at the short circuit, and will be reflected back to the sending end, undergoing a further phase change of 90°, and being further attenuated by 6 dB. Thus the reflected wave arrives at the sending end in phase with the outgoing signal, but of reduced magnitude of 0·25 V. The total voltage at the sending end is therefore 1 + 0·25 = 1·25 V.

Sketch (*c*) shows the phasor diagram for the current.

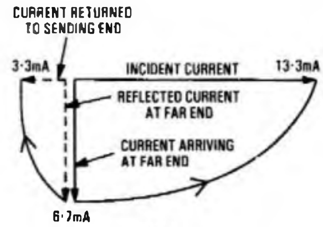
On reaching the far end, the initial current of 13·3 mA will have been attenuated by 6 dB to 6·7 mA, and will have undergone a 90° phase



(*a*)



(*b*)



(*c*)

change. At the short circuit, the phase remains unchanged, and the reflected current will return to the sending end, undergoing further attenuation of 6 dB, to arrive with a magnitude of 3·3 mA, and with a further phase change of 90°, making 180° in all. Since the reflected current is out of phase with the outgoing current, the total current at the sending end is 13·3 − 3·3 = 10 mA.

(*b*) The impedance at the sending end is given by

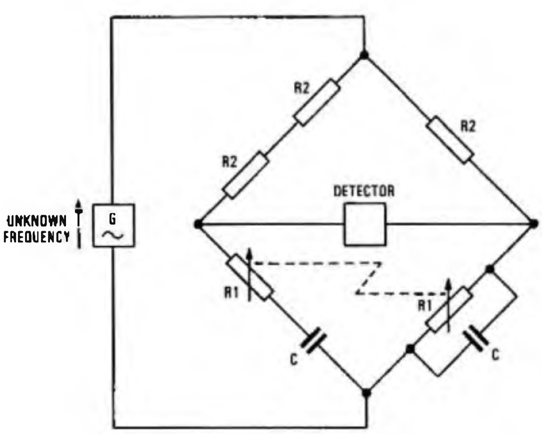
$$Z = \frac{\text{total voltage}}{\text{total current}} = \frac{1\cdot 25}{0\cdot 01} = \underline{125\ \Omega}.$$

Q5 (a) Sketch a bridge arrangement by which audio frequencies can be measured.

(b) Derive an expression for the measured frequency in terms of the bridge components.

(c) State the precautions necessary to ensure a reasonable degree of accuracy in measurement.

A5 (*a*) Any bridge which balances at only one frequency can be used to measure the frequency of the source if the bridge components are known. The sketch shows the arrangement of the Wien bridge, which is commonly used for frequency measurements.



The fixed resistance arms are in the ratio of 2:1, while the 2 variable resistance arms are equal in value and ganged so that they can be adjusted simultaneously to achieve balance. The capacitors are of the same fixed value, which can be changed to alter the frequency range of the bridge. A commonly used detector is a telephone receiver.

(*b*) At balance

$$\frac{2R_2}{R_1 + 1/(j\omega C)} = \frac{R_2}{1/\{(1/R_1) + j\omega C\}}.$$

$$\therefore \quad \frac{2R_2}{R_2} = \left(R_1 + \frac{1}{j\omega C}\right)\left(\frac{1}{R_1} + j\omega C\right).$$

$$\therefore \quad 2 = 1 + \frac{1}{j\omega CR_1} + j\omega CR_1 + 1 \quad \ldots.(1)$$

$$\text{Thus, } \frac{1}{j\omega CR_1} = j\omega CR_1,$$

giving

$$\omega^2C^2R_1^2 = 1.$$

$$\therefore \quad f = \frac{1}{2\pi CR_1}\ \text{hertz}.$$

The choice of the ratio of 2:1 for the fixed arms can be seen by substituting X and Y for $2R_2$ and R_2 respectively in equation (1). Equation (1) becomes

$$\frac{X}{Y} = 1 + \frac{1}{j\omega CR_1} + j\omega CR_1 + 1.$$

Equating the real parts gives

$$\frac{X}{Y} = 2.$$

Thus balance is achieved for $2\pi CR_1 f = 1$ and *also* for $X/Y = 2$.

(*c*) To ensure accuracy of measurement, the following precautions must be taken.

(*i*) All bridge components must be of a high quality and properly calibrated.

(*ii*) The fixed resistance arms must be exactly in the ratio 2:1.

(*iii*) The variable resistance arms must be exactly in step.

(*iv*) Stray capacitances must be minimized by careful layout of the components.

(*v*) A balanced and screened transformer (not shown in the sketch) must be used between the bridge and the unknown source.

(*vi*) Detection of the balance point can be simplified by including a filter in either the source or detector connexions to exclude any harmonics that may be present.

Q6 (a) State the expressions for the characteristic impedance and attenuation coefficient of a uniform transmission line in terms of its primary coefficients.

(b) A coaxial cable has a loss of 6 dB/km at 2 MHz, of which 1 dB/km is due to the dielectric. Estimate the loss of the cable at 8 MHz, stating clearly the assumptions made.

A6 (*a*) For a uniform transmission line, the characteristic impedance, Z_o, can be expressed as

$$Z_o = \sqrt{\left(\frac{R + j\omega L}{G + j\omega C}\right)}\ \text{ohms}.$$

and the propagation coefficient, γ, as

$$\gamma = \sqrt{\{(R + j\omega L)(G + j\omega C)\}},$$

where ω is the angular velocity in radians per second, R is the loop resistance in ohms per kilometre, L is the loop inductance in henrys per kilometre, G is the loop leakance in siemens per kilometre, C is the loop capacitance in farads per kilometre. R, L, C and G are the primary coefficients.

The attenuation coefficient is found from the real part of the complex quantity γ, and is expressed in nepers per kilometre.

In calculating both Z_o and γ it is preferable to find values of $R + j\omega L$ and $G + j\omega C$ before substituting in the equations.

(*b*) At high frequencies, where $\omega^2 \gg \omega$, the attenuation coefficient, α, can be found from

$$\alpha = \frac{R}{2}\sqrt{(C/L)} + \frac{G}{2}\sqrt{(L/C)}\ \text{nepers per kilometre.}$$

In this equation, the first term represents the series loss, and the second term the shunt (or dielectric) loss. At 2 MHz, the effective resistance becomes proportional to the square root of the frequency due to the skin effect, so that the series loss is proportional to $\sqrt{f}$, while the dielectric loss is assumed to be directly proportional to f.

Thus, total loss = series loss + shunt (dielectric) loss,

$$= A\sqrt{f} + Bf,$$

where A and B are constants.

For the given data,
total loss at 2 MHz = 6 dB/km,
dielectric loss at 2 MHz = 1 dB/km, and
∴ series loss at 2 MHz = 5 dB/km.
Hence, $A = 5 \div \sqrt{(2 \times 10^6)}$ and $B = 1 \div (2 \times 10^6)$.
Thus, at 8 MHz, the cable loss will be

$$A \times \sqrt{(8 \times 10^6)} + B \times 8 \times 10^6,$$

$$= 5 \times \sqrt{\left(\frac{8 \times 10^6}{2 \times 10^6}\right)} + \frac{8 \times 10^6}{2 \times 10^6},$$

$$= 10 + 4,$$

$$= \underline{14 \text{ dB/km}}.$$

Q7 (*a*) *Draw a block schematic diagram showing the requirements for a CCITT 12-channel group for carrier telephony.*

(*b*) *Explain the function of* EACH *block.*

(*c*) *Sketch the attenuation/frequency characteristic of a typical channel filter and show how it relates to that of an adjacent filter.*

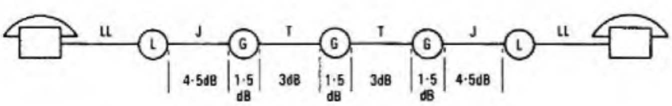
(*d*) *Explain why each channel filter needs to have a sharp cut-off. State how this is achieved.*

A7 See A4, Line Transmission C 1976, *Supplement*, Vol. 70, p. 77. Oct. 1977.

Q8 (*a*) *Describe the transmission plan for a typical telephone network showing the losses allowable in each part of a trunk connexion between two subscribers.*

(*b*) *Explain the advantages of 4-wire switching in the trunk network.*

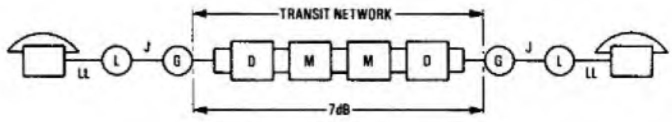
A8 (*a*) The purpose of a transmission plan is to ensure that any two telephone subscribers can be connected in a manner which ensures adequate quality of speech transmission, wherever they may be. Clearly, the main degradation introduced by cascaded links in a long trunk connexion is loss, and a transmission plan seeks to provide the necessary interconnexion while controlling the overall transmission loss. The way in which this is achieved in the British Post Office (BPO) network is shown in sketch (*a*).



LL: Local Line
J: Junction
T: Trunk circuit
L: Local exchange (LE)
G: Group switching centre (GSC)

(*a*)

Sketch (*a*) shows the BPO reference limiting connexion, which is the most adverse connexion, from the point of view of loss, that is permitted. Each group switching centre (GSC) serves a group of local exchanges (LEs), and provides access to and from the trunk network. Ideally all GSCs would be fully interconnected, so that any one could be directly connected to any other; however, where the quantity of traffic does not justify full interconnexion, an extra tandem GSC is used, providing connexion in the trunk network via a maximum of 2 trunk circuits. This arrangement gives a satisfactory compromise between cost and performance, the maximum planned loss between any 2 LEs being 19·5 dB. There are, however, some routes over which the traffic would be too light to justify even the availability of tandem trunk circuits in spite of the requirement that, for full STD, any interconnexion must be possible. For such traffic, and also to provide overflow capability on heavily used trunk routes, an additional network known as the *transit network* is provided. This is a high-quality 4-wire network, using fast signalling and is shown in sketch (*b*),



D: District switching centre
M: Main switching centre

(*b*)

The transit network carries a few percent of total traffic via district switching centres (DSCs), each of which serve several GSCs, and via main switching centres (MSCs), which interconnect the DSCs. In the UK, the overall loss in the transit network is fixed at 7 dB, regardless of the complexity of the routeing; other countries have arrangements in which the basic loss is 3 dB with an extra 0·5 dB for each link in the connexion. The transit network gives a loss between LEs of 20 dB.

The remaining parts of a telephone connexion are the 2 local telephone circuits (LTCs), which are the assembly of telephone set, local line and exchange feeding bridge; since these are all very interdependent, the complete assembly is always treated as one complete element of a connexion. Unlike trunk and junction circuits, in which the attenuation/frequency characteristics are reasonably flat and predictable, an LTC consists of a combination of many different lengths and sizes of cable pairs together with a regulated telephone instrument; consequently, the conventional 800 Hz decibel measurements of loss are not appropriate. The planning rule for local lines is that the sum of the 1600 Hz attenuations for all the cables used in an LTC should not exceed 10 dB. This rule ensures that any LTC, whatever its particular make-up of cables, and hence attenuation/frequency characteristic shape, will provide users with adequate transmission performance.

(*b*) Normal 4-wire trunk circuits are lined-up and operated at 3 dB (one-way) loss between 2-wire points for stability reasons. Owing to the additional loss introduced by cabling, and mismatch introduced by switching multiples, each GSC is assigned an additional 1·5 dB loss. Thus a single 3 dB trunk circuit is in fact assigned 1·5 + 3 + 1·5 = 6 dB loss to allow for switching and mismatch in the GSC, while two 3 dB circuits in tandem are assigned 1·5 + 3 + 1·5 + 3 + 1·5 = 10·5 dB. If complicated multi-link connexions such as those used in the transit network were allowed, the cumulation of loss would be unacceptable. Four-wire switching overcomes these problems on 2 counts:

(*i*) the individual 4-wire circuits can be lined-up between the switch points, thus accounting for cabling and mismatch losses without any degradation of stability, and

(*ii*) any complete 4-wire circuit which is 2-wire presented at each end has only one loop, so that in principle a complicated routeing could be operated at the same 3 dB loss as a normal trunk circuit. In practice in this country, this figure is 7 dB to allow for lining-up tolerances and variations with time of the individual 4-wire circuits, thus providing adequate stability margins.

Q9 (*a*) *Explain the need for equalizers in line transmission systems.*

(*b*) *With the aid of sketches, explain how the insertion-loss/frequency characteristic of a line equalizer can be measured.*

(*c*) *List the precautions necessary to ensure a reasonable degree of accuracy in measurement.*

A9 See A5, Line Transmission C 1976, *Supplement*, Vol. 70, p. 78, Oct. 1977.

Q10 (*a*) *Sketch the cabling layout for a typical rack of mains-operated carrier-transmission equipment in a terminal station.*

(*b*) *Show how power can be maintained in the event of mains failure.*

(*c*) *Explain how interference between power circuits and transmission circuits can be kept to an acceptable level.*

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.

ELECTRONICS 2 1978–79

Students are advised to read the notes above

Q1 Consider Fig. 1 and indicate the truth or falsehood of the statements.

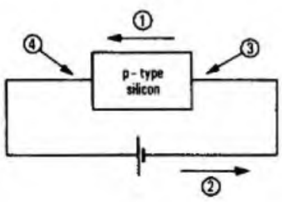


Fig. 1

(a) P-type silicon has a net positive charge.

(b) The density of holes present in p-type silicon is approximately equal to the density of acceptor atoms.

(c) The direction of hole current flow is shown by arrow 1.

(d) The direction of electron current flow in the external circuit is shown by arrow 2.

(e) Holes are neutralized by electrons entering the p-type material at point 3.

(f) Minority current carriers enter the material at point 4. *(5 min)*

A1 (*a*) FALSE [*Tutorial note*: Every atom in the material, whether acceptor or silicon, is electrically neutral; that is, the number of electrons is balanced by an equal number of protons in the nucleus. Therefore, the material must also be electrically neutral.]

(*b*) TRUE

(*c*) FALSE [*Tutorial note*: The positive side of the battery is indicated by the longer vertical line. The holes will therefore drift away from this terminal.]

(*d*) TRUE

(*e*) TRUE

(*f*) FALSE [*Tutorial note*: The minority current carriers (electrons) flow in the opposite direction to the majority current carriers. They therefore enter the material at point 3.]

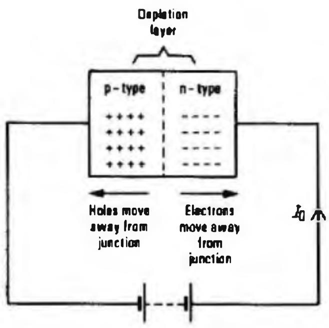
Q2 (a) Draw and label a p n junction connected in reverse bias mode. Indicate the direction of movement of majority carriers in the diode when the supply is connected and the current flows in the external circuit.

(b) (i) Name the type of carriers constituting the current in the external circuit.

(ii) What is this external current called?

(iii) State whether this current would be higher for a germanium or for a silicon diode. *(8 min)*

A2 (*a*)



(*b*) (*i*) Minority carriers. [This current is usually very small, typically less than 1 μA.]

(*ii*) Reverse saturation current.

(*iii*) Germanium.

Q3 Two diodes, one germanium and the other silicon, have similar current ratings. If the silicon diode requires a forward bias of 0·95 V to conduct a current of 12 mA, what will be the approximate value of forward bias required by the germanium diode to pass the same value of current?

(a) 0·2 V (b) 0·4 V (c) 0·6 V (d) 1·3 V *(2 min)*

A3 (*c*)

[*Tutorial note*: The threshold voltages of junction potential for germanium and silicon diodes is usually taken to be 0·2 V and 0·6 V respectively. For diodes of similar current rating conducting a given value of current, the junction potential required across a germanium diode will be in the order of 0·3–0·4 V less than that required across a silicon diode.]

Q4 Which of the following statements best describes the reason for Zener breakdown?

(a) The thermal generation of large numbers of minority carriers.

(b) Intense electric fields pulling electrons out of their covalent bonds.

(c) High electric fields accelerating electrons which then "knock" other electrons out of the valance band.

(d) A large surge of current resulting from the release of stored carriers at the p n junction. *(2 min)*

A4 (*b*)

Q5 (a) Referring to Fig. 2, sketch the waveforms of

(i) the load voltage,

(ii) the load current, and
(iii) the diode currents.

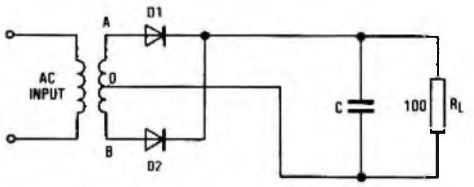
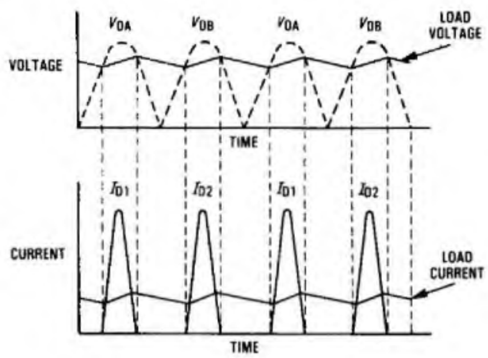


Fig. 2

(b) If the voltage across terminals A and B is 14·14 V RMS, what should be the reverse voltage rating of the diodes?

(c) If the diodes, which can be assumed to be ideal, start to conduct when the load current falls to a value of 90 mA, what is the value of the voltage across points O and A with this load current? *(15 min)*

A5 *(a)*



(b) Peak voltage across terminals A and B $= 14 \cdot 14 \times \sqrt{2}$,
$= 20$ V.

Peak inverse voltage across each diode is $2 \times V_m = V_{OA} = V_{OB}$.

But, $$V_m = \frac{V_{AB}}{2} = \frac{20}{2} = 10 \text{ V}.$$

Therefore, the peak inverse voltage across each diode $= 2 \times 10$,
$=$ 20 V.

(c) The diodes will start to conduct when the input voltage equals the load voltage.

The load voltage = load current × load resistance,
$= 90 \times 10^{-3} \times 100$,
$= 9$ V.

Therefore the diodes conduct when the voltage across OA = 9 V.

Q6 *The circuit in Fig. 3 is used to produce an output of 10 V at a fixed load current of 100 mA from a rectified supply which varies between 15–20 V. Four Zener diodes are available with the following characteristics*

Diode No.	*Breakdown voltage, V_z (V)*	*Minimum Zener current, $I_{Z(min)}$ (mA)*	*Maximum power dissipation, P_{max} (W)*
1	*10*	*5*	*0·5*
2	*10*	*5*	*1·0*
3	*10*	*5*	*1·5*
4	*10*	*5*	*2·0*

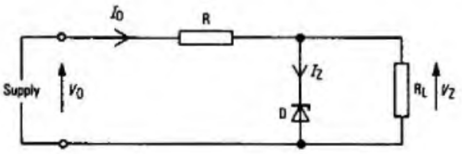


Fig. 3

Determine the following:

(a) The value of R which will stabilize the supply.

(b) Which of the 4 Zener diodes can be safely used in the circuit. *(15 min)*

A6 *(a)* The value of R is given by

$$R = \frac{V_{o(min)} - V_Z}{I_{o(min)}} = \frac{V_{o(min)} - V_Z}{I_L + I_{Z(min)}},$$

$$= \frac{15 - 10}{100 \times 10^{-3} - 5 \times 10^{-3}},$$

$$= \frac{5}{95 \times 10^{-3}},$$

$$= 52 \cdot 6\ \Omega.$$

The nearest preferred value is 51 Ω.

(b) The only Zener diodes which should be used are those whose maximum Zener current is not exceeded when the supply voltage (V_o) is a maximum.

$$I_o = \frac{V_{o(max)} - V_Z}{R},$$

$$= \frac{20 - 10}{51} = 196 \text{ mA}.$$

The corresponding maximum current drawn by the Zener diode is

$$I_Z = I_o - I_L,$$
$$= (196 - 100) \times 10^{-3} \text{ A},$$
$$= 96 \text{ mA}.$$

The Zener current must be less than the rated current of the diode, which can be determined from the table from the expression

$$I_{Z(max)} = \frac{P_{(max)}}{V_Z}.$$

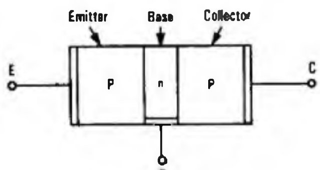
Thus the maximum rated Zener currents for the diodes are given in the table.

Zener No.	Maximum Zener current (mA)
1	50
2	100
3	150
4	200

Hence, Zener diodes numbers 2, 3 and 4 may be safely used.

Q7 *Sketch and label a simple diagram of a grown p n p transistor.* *(4 min)*

A7



Q8 *(a) Define the short-circuit current gain of a transistor connected in*

(i) commom-emitter mode (β or h_{fe}), and

(ii) common-base mode (α or h_{fb}).

(b) State the relationship between α and β. *(5 min)*

A8 *(a) (i)* $\beta = h_{fe} = \frac{I_c}{I_b}$, where I_c is the small-signal collector current and I_b is the small-signal base current.

(ii) $\alpha = -h_{fb} = \frac{I_c}{I_e}$ where I_e is the small-signal emitter current.

(b) $\beta = \frac{\alpha}{1 - \alpha}$.

Q9 (*a*) *Using the transistor output characteristics in Fig. 4, determine for* $V_{CE} = 7 \cdot 5$ *V and* $I_B = 200\ \mu A$,

(*i*) *the small-signal open-circuit output resistance* (R_{out}), *and*
(*ii*) *the value of the common-emitter current gain* (β_{DC} *or* h_{FE}).

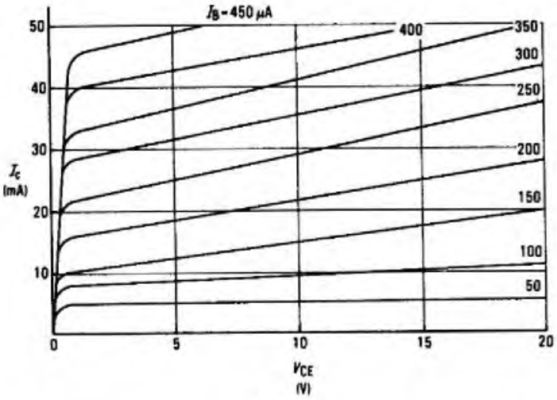


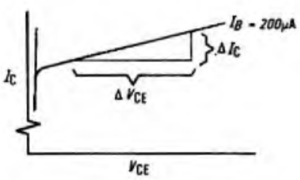
Fig. 4

(*b*) *Sketch the current transfer characteristic for* $V_{CE} = 7 \cdot 5$ *V.*

(*c*) *Determine the value of small-signal common-emitter current gain* (β *or* h_{fe}). (*15 min*)

A9 (*a*) (*i*) $R_{out} = \dfrac{\Delta V_{CE}}{\Delta I_C}$, where ΔV_{CE} = a small change in V_{CE} and ΔI_C = a small change in I_C.

Selecting the characteristic for $I_B = 200\ \mu A$, R_{out} is given by the reciprocal of the slope of the line, as shown in sketch (*a*).



(*a*)

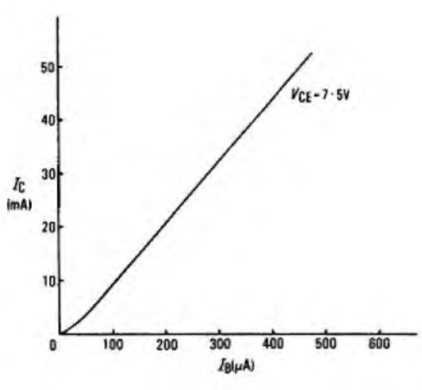
Hence $R_{out} \approx 1 \cdot 7\ k\Omega$.

(*ii*) β_{DC} or $h_{FE} = \dfrac{I_B}{I_C}$.

From the characteristic, when $I_B = 200\ \mu A$ and $V_{CE} = 7 \cdot 5$ V, $I_C = 21$ mA.

$$\therefore \quad \beta_{DC} = \frac{21 \times 10^{-3}}{200 \times 10^{-6}},$$
$$= 105.$$

(*b*) The current transfer characteristic is shown in sketch (*b*)



(*b*)

(*c*) β or $h_{fe} = \dfrac{\Delta I_C}{\Delta I_B}$, which is the slope of the current transfer characteristic.

Thus $\beta = 120$.

Q10 *Use the transistor input characteristic in Fig. 5 to determine the small-signal short-circuit input resistance when* $V_{BE} = 1 \cdot 0$ *V.* (*5 min*)

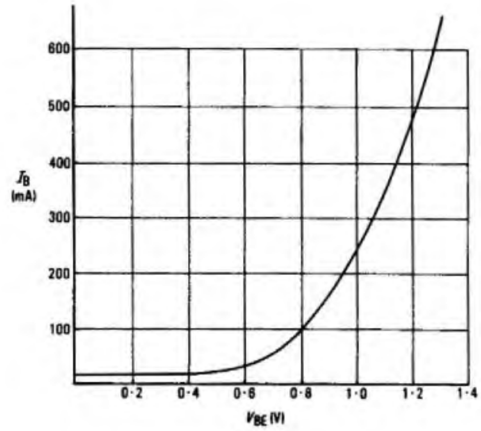


Fig. 5

A10 Input resistance, $R_{IN} = \dfrac{\Delta V_{BE}}{\Delta I_E}$, where V_{BE} is the base/emitter voltage and I_E is the emitter current. This expression is represented by the reciprocal of the slope of the curve shown in Fig. 5 for any given value of V_{BE}.

Thus, when $V_{BE} = 1 \cdot 0$ V, $R_{IN} \approx 1\ k\Omega$.

Q11 *Use the anode characteristics of a triode shown in Fig. 6 to determine*

(*a*) *the anode resistance* (r_a),
(*b*) *the mutual conductance* (g_m), *and*
(*c*) *the amplification factor* (μ)

Explain your procedures. (*15 min*)

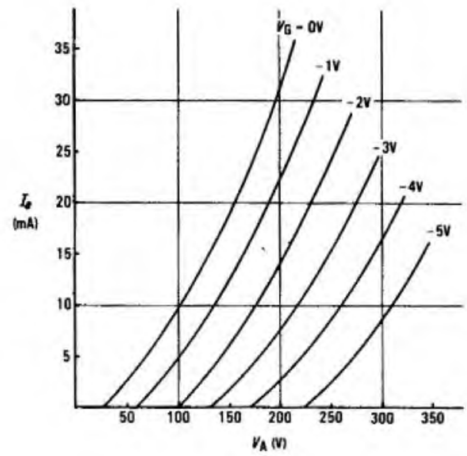


Fig. 6

A11 (*a*) $r_a = \dfrac{\Delta V_a}{\Delta I_a}$ (with V_g constant),

where V_a is the anode voltage, I_a is the anode current and V_g is the grid voltage.

Hence, with V_g constant at 1 V measure the changes in V_a and the corresponding changes in I_a on a linear part of the curve.

Choosing $V_a = 150$ V (say) and increments of 25 V above and below this point gives

$$\Delta V_a = 175 - 125 = 50\text{ V},$$

and the corresponding change in I_a is

$$\Delta I_a = 17 - 8 = 9\text{ mA},$$

$$\therefore \quad r_a = \frac{50}{9 \times 10^{-3}} \approx \underline{5{\cdot}6\text{ k}\Omega.}$$

(*b*) $$g_m = \frac{\Delta I_a}{\Delta V_g} \text{ (with } V_a \text{ constant).}$$

Hence, with V_a constant at 150 V, a change of V_g from -1 V to -2 V will produce a corresponding change in I_a from 12·5 mA to 6·5 mA.

$$\therefore \quad g_m = \frac{(12{\cdot}5 - 6{\cdot}5)10^{-3}}{-1-(-2)} = 6{\cdot}0 \times 10^{-3}\text{ S},$$

$$= \underline{6\text{ mS}.}$$

(*c*) $$\mu = g_m \times r_a,$$

$$= 6 \times 10^{-3} \times 5{\cdot}6 \times 10^3,$$

$$= \underline{33{\cdot}6.}$$

Q12 *For the 12 statements in the table, indicate whether each refers to thermionic or semiconductor diodes by placing a tick in the appropriate box.*

Characteristic	*Thermionic*	*Semiconductor*
(*a*) *Small size*		
(*b*) *Fragile*		
(*c*) *Long operating life*		
(*d*) *Forward voltage drop less than 1 V*		
(*e*) *Characteristic independent of ambient temperature*		
(*f*) *Excellent reverse bias characteristics*		
(*g*) *Maximum reverse bias hundreds of volts*		
(*h*) *Requires cathode heater supply*		
(*i*) *Forward voltage drop greater than 10 V*		
(*j*) *Maximum reverse bias thousands of volts*		
(*k*) *Satisfactory reverse bias characteristics*		
(*l*) *Dissipates more power for a given current rating*		

(*5 min*)

A12

Characteristic	*Thermionic*	*Semiconductor*
(*a*)		√
(*b*)	√	
(*c*)		√
(*d*)		√
(*e*)	√	
(*f*)	√	
(*g*)		√
(*h*)	√	
(*i*)	√	
(*j*)	√	
(*k*)		√
(*l*)	√	

Q13 *Label the diagram of the cathode ray tube shown in Fig. 7 by inserting the correct terms for the numbered components in the list provided.*

1	....	*6*	....
2	....	*7*	....
3	....	*8*	....
4	....	*9*	....
5	....	*10*	....

(*5 min*)

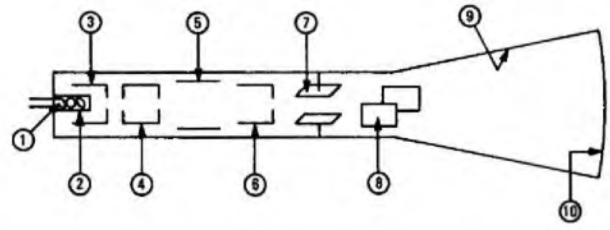


Fig. 7

A13
1 Heater filament
2 Cathode
3 Control grid
4 First accelerating anode
5 Focusing anode
6 Final anode
7 Electrostatic vertical deflexion plates
8 Electrostatic horizontal deflexion plates
9 Aquadag coating
10 Glass screen coated with phosphor on its inner surface

Q14 *Which of the following diagrams shows the way in which the electron beam is focused in the electron gun?* (*2 min*)

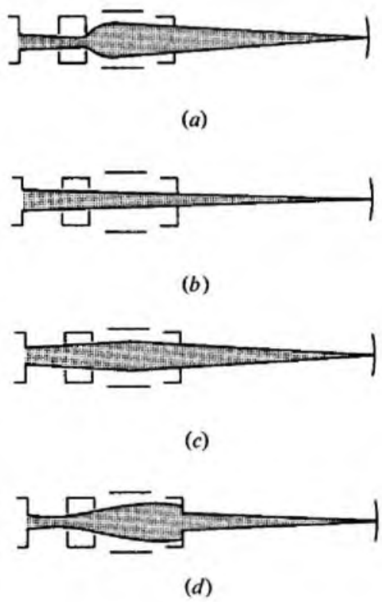


Fig. 8

A14 (*a*)

Q15 *What is the purpose of the blanking pulses applied to a cathode ray tube?*

(*a*) *To produce the black level on a line scan.*

(*b*) *To synchronize the time base to the control-grid signal.*

(*c*) *To switch off the beam during flyback.*

(*d*) *To inhibit current surges on the beam and so prevent it from burning the screen.* (*2 min*)

A15 (*c*)

Q16 *The circuit diagram of an amplifier employing a silicon transistor is shown in Fig. 9. Resistors R_L and R2 have been removed from the circuit and the only data available is:*

Amplifier voltage gain = 43·6 dB.

Transistor DC common emitter gain (h_{FE}) = 50.

Total load power (P_T) = 7 mW RMS when the collector voltage (V_c) = 8 V and an AC signal (v_i) = 20 mV peak is applied to the input.

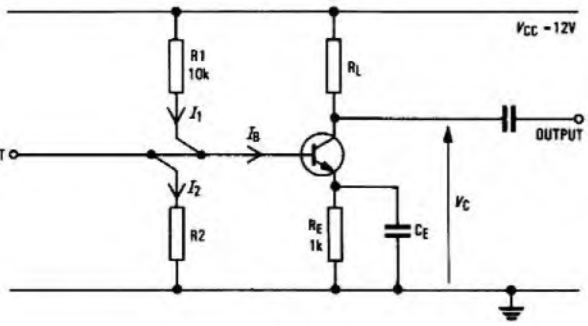


Fig. 9

Calculate

(a) The value of the replacement load resistor (R_L),

(b) The DC base current (I_B), and

(c) The value of the replacement resistor R2. *(30 min)*

A16 (*a*)

$$P_T = \frac{V_L^2}{R_L} + \frac{v_o^2}{R_L}, \quad \ldots\ldots(1)$$

where V_L is the DC load voltage and v_o is the RMS AC output voltage across R_L.

Now,

$$V_L = V_{cc} - V_c,$$
$$= 12 - 8 = 4 \text{ V},$$

and

$$v_o = v_{irms} \times A_v \quad \ldots\ldots(2)$$

where A_v is the AC voltage gain.

$$v_{irms} = \frac{v_i}{\sqrt{2}},$$
$$= \frac{20 \times 10^{-3}}{\sqrt{2}} = 14{\cdot}14 \times 10^{-3} \text{ V}.$$

$$20 \log_{10} A_v = 43{\cdot}6.$$
$$\therefore \quad \log_{10} A_v = 2{\cdot}18.$$
$$\therefore \quad A_v = 152.$$
$$\therefore \quad v_o = 14{\cdot}14 \times 10^{-3} \times 152,$$
$$= 2{\cdot}15 \text{ V}.$$

Rearranging equation (1),

$$R_L = \frac{V_L^2 + v_o^2}{P_T}.$$

Substituting the value obtained in this equation,

$$R_L = \frac{4^2 + 2{\cdot}15^2}{7 \times 10^{-3}} = \frac{16 + 4{\cdot}6}{7 \times 10^{-3}},$$
$$= \frac{20{\cdot}6}{7 \times 10^{-3}} = 2{\cdot}94 \times 10^3 \ \Omega.$$

The nearest preferred value to the calculated value is 3 kΩ.

(*b*)

$$I_B = \frac{I_c}{h_{FE}}.$$
$$I_c = \frac{V_L}{R_L} = \frac{4}{3 \times 10^3} = 1{\cdot}33 \text{ mA}.$$
$$\therefore \quad I_B = \frac{1{\cdot}33 \times 10^{-3}}{50} = 26{\cdot}6 \times 10^{-6} \text{ A}.$$
$$\approx 27 \ \mu\text{A}.$$

(*c*) $R_2 = \frac{V_2}{I_2}$, where V_2 is the voltage across R2 and I_2 is the current flowing in R2.

$$V_2 = V_{BE} + V_E,$$
$$= V_{BE} + I_E R_E,$$
$$= V_{BE} + (I_C + I_B) R_E,$$
$$= 0{\cdot}6 + (1{\cdot}33 + 0{\cdot}027) \times 10^{-3} \times 1 \times 10^3,$$
$$= 0{\cdot}6 + 1{\cdot}36 \approx 2 \text{ V}.$$
$$I_2 = I_1 - I_B.$$

From part (*b*),

$$I_B = 27 \ \mu\text{A}.$$
$$I_1 = \frac{V_1}{R_1},$$
$$= \frac{V_{cc} - V_2}{R_1},$$
$$= \frac{12 - 2}{10 \times 10^3},$$
$$= \frac{10}{10000} \text{ A},$$
$$= 1 \text{ mA}.$$
$$\therefore \quad I_2 = (1000 - 27) \times 10^{-6},$$
$$= 973 \ \mu\text{A}.$$
$$\therefore \quad R_2 = \frac{2}{973 \times 10^{-6}},$$
$$= 2055 \ \Omega.$$

The nearest preferred value is 2 kΩ.

Q17 *The triode valve amplifier shown in Fig. 10 has the following circuit conditions:*

Anode voltage, $V_A = 250$ V,

Anode current, $I_A = 9$ mA,

Grid voltage, $V_G = -8$ V,

Load resistance, $R_L = 10$ kΩ.

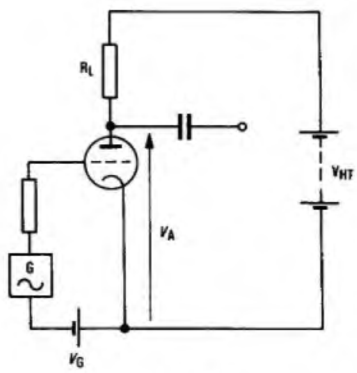


Fig. 10

(a) Calculate the value of the supply voltage, V_{HT}.

(b) If the supply voltage is then fixed at 430 V, calculate the load resistance required to keep the valve working at the same operating point.

(c) The anode characteristics of the triode are shown in Fig. 11. Construct the load line for the value of load resistance found in part (b), marking the operating point (Q) clearly.

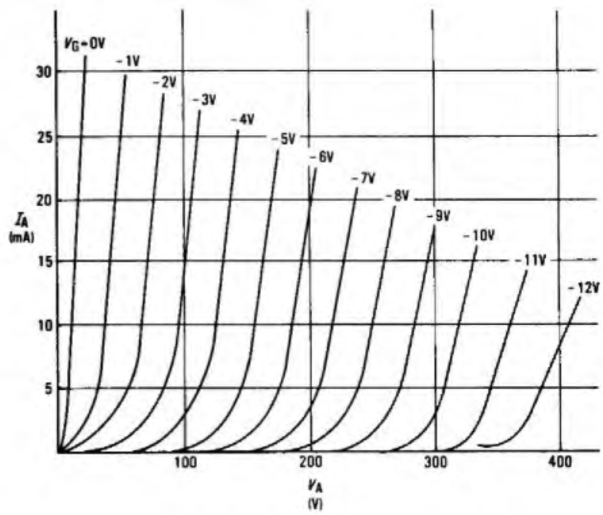


Fig. 11

(*d*) *Use Fig. 11 to find the voltage gain, A_V, of the stage.*

(*e*) *If the grid bias battery (V_G) is removed and the amplifier is automatically biased by means of a resistor in series with the cathode, calculate the required value of this resistor.* (*30 min*)

A17 (*a*)

$$V_{HT} = I_A R_L + V_A,$$
$$= (9 \times 10^{-3} \times 10 \times 10^3) + 250,$$
$$= 90 + 250 = \underline{340\text{ V}}.$$

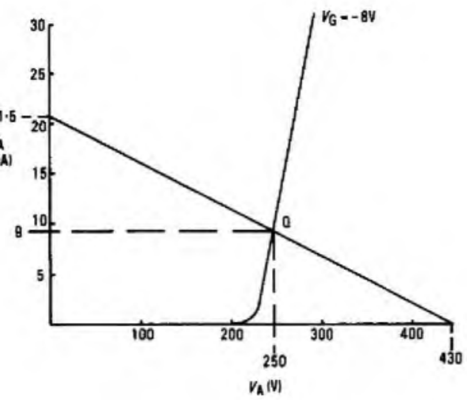
(*b*) If $V_{HT} = 430$ V, $I_A = 9$ mA and $V_A = 250$ V to give the same operating point, and

$$R_L = \frac{V_{HT} - V_A}{I_A} \quad \text{(as in part (a))},$$

then

$$R_L = \frac{430 - 250}{9 \times 10^{-3}} = \frac{180}{9 \times 10^{-3}},$$
$$= \underline{20\text{ k}\Omega}.$$

(*c*) From the information already given, the operating point, Q, can be marked on the characteristics at $I_A = 9$ mA and $V_A = 250$ V, as shown in the sketch.



As the load line must pass through the operating point, only one other point is needed in order that it may be drawn. This point is given by *either* of the following two methods.

(*i*) $V_{HT} = I_A R_L + V_A$.

When $I_A = 0$, $V_{HT} = V_A = 430$ V.

Therefore, the line passes through the point, $I_A = 0$, $V_A = 430$ V.

(*ii*) $V_{HT} = I_A R_L + V_A$.

When $V_A = 0$, $V_{HT} = I_A R_L$.

$$\therefore \quad I_A = \frac{V_{HT}}{R_L} = \frac{430}{20 \times 10^3}$$
$$= 21 \cdot 5\text{ mA}.$$

Therefore the line passes through the point, $I_A = 21 \cdot 5$, $V_A = 0$.

(*d*)

$$A_v = \frac{v_o}{v_G} = \frac{\Delta V_A}{\Delta V_G},$$

where ΔV_A is the change in output (anode) voltage and ΔV_G is the change in input (grid) voltage.

Taking a grid-voltage swing of ± 1 V about the operating point, Q, along the load line gives

for $V_G = -7$ V, $V_A = 220$ V, and

for $V_G = -9$ V, $V_A = 280$ V.

$$\therefore \quad A_v = \frac{280 - 220}{-9 - (-7)} = -\frac{60}{2} = \underline{-30}.$$

(*e*) The bias resistor, R_c, has a voltage drop of 8 V across it, which is very small compared to a supply voltage of 430 V and so will have little effect on the anode current. Thus, it can be assumed that

$$R_c = \frac{V_{bias}}{I_A} = \frac{8}{9 \times 10^{-3}} = \underline{889\ \Omega}.$$

Q18 *Indicate the type of oscillator waveforms which would be used in the applications given in the table by placing a tick(s) in the relevant boxes.*

Application	*Waveform*		
	Sinusoid	*Square*	*Sawtooth*
(*a*) *Cathode ray tube time-base generator*			
(*b*) *Radio-receiver local oscillator*			
(*c*) *Digital timing circuits*			
(*d*) *Counting circuits*			
(*e*) *Audio sweep-frequency oscillator*			
(*f*) *Radio carrier-frequency generator*			

(*5 min*)

A18

Application	Waveform		
	Sinusoid	Square	Sawtooth
(*a*)			√
(*b*)	√		
(*c*)		√	
(*d*)		√	
(*e*)	√		√
(*f*)	√		

Q19 *The oscillator shown in Fig. 12 operates under small signal linear (Class A) conditions.*

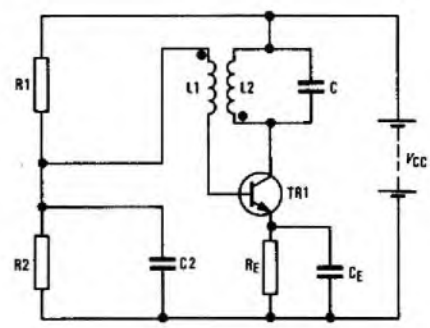


Fig. 12

(*a*) *Sketch the waveform of the steady-state output voltage.*

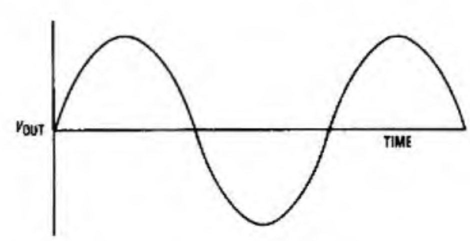
(*b*) *Name the type of feedback employed.*

(*c*) *State the functions of*

(*i*) *L and C,*
(*ii*) *L1,*
(*iii*) *R1, R2 and R_E,*
(*iv*) *C2 and C_E, and*
(*v*) *Transistor TR1.*

(*d*) *State the relationship which gives the approximate frequency of oscillation of the circuit.* (*15 min*)

A19 (*a*)



(*b*) Positive feedback.

(*c*) (*i*) To determine the frequency of oscillation of the circuit.

(*ii*) It inductively couples energy from the L-C frequency-determining circuit back into the base circuit.

(*iii*) They provide automatic DC bias for the transistor to ensure that it operates over the linear part of its characteristic.

(*iv*) They are by-pass capacitors providing an effective short circuit in the base input circuit and the emitter lead for alternating currents at the oscillation frequency.

(*v*) It provides sufficient gain to maintain oscillation.

(*d*) $$f_o = \frac{1}{2\pi \sqrt{(LC)}}.$$

Q20 *Which of the following is an example of a two-state device?*

(*a*) *A television aerial*

(*b*) *A record-player stylus*

(*c*) *A microphone*

(*d*) *A sparking plug* (*2 min*)

A20 (*d*)

Q21 (*a*) *Using 3 inputs, A, B and C, and one output, F, construct the truth table and state the Boolean expression for*

(*i*) *an AND gate, and*

(*ii*) *an OR gate.*

(*b*) *Using one input, A, and one output, F, construct the truth table and state the Boolean expression for a NOT gate.* (*10 min*)

A21 (*a*) (*i*)

Inputs			Output
A	*B*	*C*	*F*
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

Boolean expression: $F = A.B.C$

(*ii*)

Inputs			Output
A	*B*	*C*	*F*
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

Boolean expression: $F = A + B + C$

(*b*)

Input	Output
A	*F*
0	1
1	0

Boolean expression: $F = \overline{A}$

Q22 *If the waveforms shown in Fig. 13 are applied to the input terminals A, B and C of the logic circuit shown in Fig. 14, sketch the resultant output waveform.* (*5 min*)

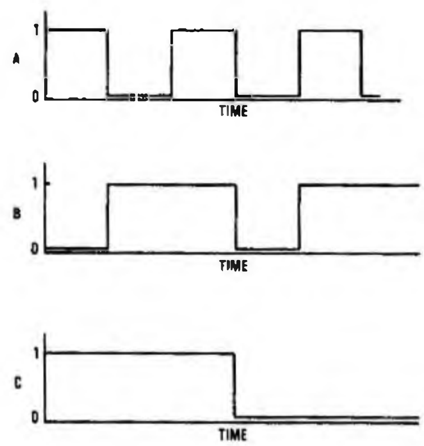


Fig. 13

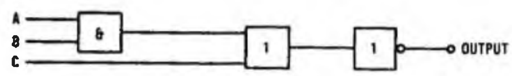
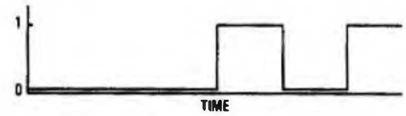


Fig. 14

A22



Q23 (*a*) *If a +10 V level represents a LOGIC 1 state and 0 V represents a LOGIC 0 state, explain the operation of the transistor gate shown in Fig. 15 when*

(*i*) *a +10 V level is applied to the input, and*

(*ii*) *a 0 V level is applied to the input.*

(*b*) *State the logic function of the gate.* (*10 min*)

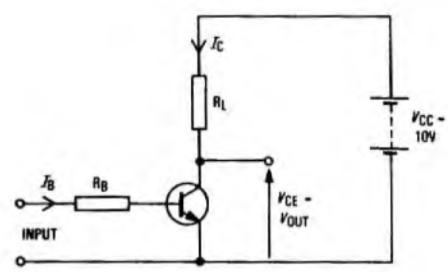


Fig. 15

A23 (*a*) (*i*) When a +10 V level (LOGIC 1) is applied to the input, the base-emitter junction of the transistor is forward biased. The base resistor, R_B, is selected so that the base current, I_B, is sufficient to drive the transistor into saturation and switch the transistor fully on. Under these conditions, the collector-emitter terminals of the transistor are effectively short-circuited, so that the collector-emitter voltage, V_{CE}, is zero and therefore the output voltage is zero (LOGIC 0).

(*ii*) When a 0 V level (LOGIC 0) is applied to the input there is no potential difference across the base-emitter junction of the transistor, which is therefore cut off. Under these conditions there is effectively an open circuit between the collector and emitter terminals of the transistor and the collector current is zero. Hence there is no voltage drop across R_L and the output voltage is +10 V (LOGIC 1).

(*b*) The logic function of the gate is NOT.

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