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TECHNICIAN EDUCATION COUNCIL

Certificate Programme in Telecommunications

The following tables of references list the topic areas of standard level-2 units, and give references to model answers to past City and Guilds of London Institute examination questions that most closely match the TEC syllabi. Back numbers of the *POEEJ* and *Supplement*, and the various model-answer books, can be ordered using the form on p. 139 of the *Journal*. The order form shows in which issues the references made below appear.

The topic areas are in accordance with the codes allocated in the TEC's standard units.

TELEPHONE SWITCHING SYSTEMS 2

Topic Areas (TEC Standard Unit U76/005)	<i>Supplement</i> References	Model-Answer Book References
A Erlangs. Traffic-intensity/time graphs for telephone and telegraph traffic. Busy hour; relation to provision of equipment and plant; grade of service (with typical values). Multiplied outlets; grading; limited and full availability; grading charts (4 and 6-group gradings); need for smooth grading	ETP: A1(a)(b) 1972, A4(b)(c) 1973, A5(a)(i)-(iii)(b) 1976, A3(b) 1977 TTA: A3 1969 (second part), A4 1972, A9 1973, A4(b) 1975, A9 1976	TTA: Q9.1(a), Q9.4, Q9.5 (except final part), Q10.6(a), Q10.7 (first part), Q10.8
B Block diagrams and outline operation of Strowger non-director and director exchanges. Hunters and finders Some flexibility of treatment is permitted, depending on local requirements. Therefore, the references given have been chosen to give broad coverage.	TTA: A3 1969 (first part), A7 1973, A8(a)(b) 1974, A4(a)(c) 1975 TpB: A7 1969, A4 1971, A4 1972	TTA: Q10.1 (except final part), Q10.2, Q10.3, Q10.4 (except final part), Q10.5
C3 Block diagrams and outline operation of TXK1, TXK3 and TXE2 exchanges (for own-exchange calls)	TpB: A4 1973, A9 1975, A8(a) 1976 TpC: A6(a) 1974	—
C4 Crossbar switch: construction and operation	TTA: A8 1973	TTA: Q8.1
C5 Principle of matrix switch. Link trunking. Internal blocking	TTA: A8(c) 1976 TpB: A9 1974	—
D6 Principles and relative advantages of single-current, double-current, loop-disconnect, single-frequency and multi-frequency signalling	ETP: A8(a)(b)(c) 1972, A7 1973, A3 1974, A9 1975, A3(b) 1976, A6(b) 1977 TTA: A2(a)(b) 1975 TgB: A1 1974	ETP: Q50 (first and second parts), Q51 TTA: Q3.1, Q3.3, Q4.1, Q4.2
D7 Transmitting and receiving circuit elements of modern telephone. Sidetone. Regulator. Calling signal, dial pulses, ringing, called-subscriber-answer signal and clear-down signal	ETP: A6(a) 1977 TTA: A2 1972, A3 1972, A4(a)(i) 1973, A1 1974, A1(a)(b)(i) 1976	TTA: Q1.2, Q1.3, Q1.5, Q3.4(a)(f), Q7.3, Q7.4 (first part)
D8 Provision and detection of signals for establishing and clearing a Telex call	TTA: A4(a)(ii)(b) 1973, A1(b)(ii) 1976 TgC: A6(a) 1972	TTA: Q3.4(a)(ii)

TRANSMISSION SYSTEMS 2

Topic Areas (TEC Standard Unit U76/006)	References (Upper box contains <i>Supplement</i> references; lower contains model-answer book references. Where only one box is shown, it contains only <i>Supplement</i> references)*
A Frequency bands for line and radio systems. Velocity, frequency and wavelength. Bandwidths of common signals. Baseband signals and carriers	RLTA: A8(c) 1973, A2(a)(ii) 1976, A5(d) 1976, A8(a)(b) 1977 TPC: A7 1973, A10 1975 RLTA: Q4.2(c), Q4.3
B Space division, frequency-division multiplexing and time-division multiplexing. CCITT 12-channel group. Supergroups and hypergroups. Sampling and digital transmission of analogue waveform	RLTB: A9(a)(b) 1972, A2(b) 1974 TgB: A9(a)(b) 1974, A6 1975 TPC: A4(a)(b) 1976 BMCC: A7(b) 1973, A9(a) 1974 LTC: A8(a) 1972, A8(a)(b) 1975, A4(a)(b) 1976 TPB: Q9.1 (first part)
C Gain and attenuation. Logarithmic units; decibels; power levels relative to 1 mW. Cascaded systems. Maximum power transfer. Logarithmic expression of voltage and current gain or loss. Signal-to-noise ratio	RLTA: A4 1973, A6 1974, A4(a)(b) 1975, A1 1976, A1 1977 TPB: A8 1973, A2 1975 LPPB: A10(b) 1973 LTC: A4 1969, A6(a) 1972, A4(a)(b)(c) 1974, A6(a)(b)(c) 1976 RLTA: Q2.1, Q2.3-2.7 TPB: Q6.1, Q6.2
D Types and frequency plots of filters; symbols	RLTB: A2(d) 1974 TgC: A2(a) 1969 LTC: A8(b)(c) 1972, A4(c)(d) 1976
E Function of carrier. Double and single-sideband amplitude-modulated signals; power and bandwidth; over-modulation; bandwidth and signal-to-noise ratio. Frequency modulation; frequency deviation, frequency swing, modulation index and bandwidth. Modulation methods for data transmission over linear systems	RLTA: A1(a) 1973, A1 1974, A5(a)(b)(c) 1976, A6(b) 1976, A4(a)(b) 1977 RLTB: A2(a)(b)(i) 1972, A9(c) 1972, A2(a)(c) 1974, A1(a) 1977 TPB: A9 1975 TgB: A5(b) 1969, A3(b) 1975 TPC: A7(b) 1975, A9(a) 1975 CRC: A7 1969 (first and second parts), A5(a) 1972, A8(a) 1972 RLTA: Q3.1-3.5 TPB: Q9.1 (except first part)
F Pair and triple-type internal cables. Multi-pair coaxial cables. Twin and quad-type external cables. Attenuation/frequency and group-delay/frequency curves for unloaded, loaded and coaxial cables	ETP: A5(b)(i) 1972, A8(b) 1976 LPPB: A2(a) 1972 LPPA: A8(a) 1976 RLTB: A3(a) 1974, A3(a)(i) 1975 ETP: Q32, Q33, Q34(b) TPB: Q9.2 (last part)
G Unidirectional transmission and reception paths. Two-wire-to-four-wire conversion units. Stability	RLTA: A6(b)(d) 1973, A2(a)(i) 1976, A3(a) 1977 LTC: A4(a)(b) 1973, A6(a)(b) 1975 RLTA: Q1.1(b), Q1.3 (first part), Q1.4, Q1.5(b)

RADIO SYSTEMS 2

Topic Areas (TEC Standard Unit U76/013)	References (Upper box contains <i>Supplement</i> references; lower contains model-answer book references. Where only one box is shown, it contains only <i>Supplement</i> references)*
A1 Loss-free lines and wave progression	LPPB: A10(a) 1973
A2 Principle of radiation. Polarization. Ground and sky waves. Ionospheric refraction. Skip distance, critical frequency, maximum usable frequency and optimum traffic frequency. Fading. Transmission frequencies. Use of VHF bands	RLTA: A2(c) 1976, A3(c) 1977 RLTB: A4(b) 1972, A6 1973, A9(b) 1974, A3(d) 1977 CRC: A1(a)(c) 1973, A1(b)(i) 1974 RLTA: Q1.2 (last part), Q4.2(b)
A3 Field strength and radiation resistance. Half-wavelength dipole. Reflectors and directors. Aerial gain and effective radiated power. Marconi unipole; earth plane. Tuning and practical forms of vertical aerial. Effective height	RLTB: A1 1973, A5(a)(c) 1975, A3(a)(b) 1977 CRC: A9(a)(b) 1975

B Block diagram of simple receiver for amplitude-modulated radio signals. Simple radio-frequency variable-tuning amplifier. Diode demodulator. Simple audio-frequency amplifier. Ganging, screening and decoupling difficulties in tuned radio-frequency receivers. Selectivity and bandwidth for high-frequency double-sideband reception. Principle of superheterodyne receiver; advantages and choice of intermediate frequency. Intermediate-frequency amplifier. Local-oscillator frequency range. Radio-frequency selection. Image-channel interference

RLTA: A2(c)(d) 1974, A10(a) 1974, A5(a)(b) 1975, A8(b) 1975, A6(a) 1976, A9(b) 1976, A4(c) 1977
 TPA: A9(a) 1974
 RLTB: A2 1973, A5(a) 1974, A10 1974, A1(a)(b) 1975, A2(a) 1975, A9(a) 1975, A6 1977, A10(a)(i)(ii) 1977
 CRC: A2(a) 1972

RLTA: Q7.1 (first part), Q11.1 (second part), Q11.2(b), Q11.3(b)(c), Q11.5

C Transmitters (block diagrams). Frequency stability. Crystal and variable-frequency oscillators. Keying. Frequency multiplication. Driver; power amplifier; aerial coupling. High-level amplitude modulation. Aerial matching

RLTA: A7(a) 1974, A9(a)(b)(c) 1975, A10(b) 1977
 RLTB: A8(a) 1973, A5(b) 1975

* For each topic area, the upper box contains references to model answers published in the *Supplement*, and the lower box contains references to the *POEEJ*'s series of model-answer books. Where only one box is shown against a topic area, all the references in it are to model answers published in the *Supplement*

ABBREVIATIONS

BMCC: Basic Microwave Communication C
 CRC: Communication Radio C
 ETP: Elementary Telecommunication Practice
 LPPA, LPPB: Line Plant Practice A, B
 LTC: Line Transmission C

RLTA, RLTB: Radio and Line Transmission A, B
 TgB, TgC: Telegraphy B, C
 TpB, TpC: Telephony B, C
 TPA, TPB, TPC: Telecommunication Principles A, B, C
 TTA: Telephony and Telegraphy A

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.

RADIO AND LINE TRANSMISSION B 1976

Students were expected to answer any 6 questions

Q1 (a) (i) Sketch and describe the construction of a coaxial cable for use in multi-channel-telephony transmission systems.

(ii) Give suitable dimensions on your sketch.

(b) Compare the main transmission characteristics of a coaxial cable with those of an open-wire line.

(c) A section of a coaxial cable has a transmission loss of 10 dB at 200 kHz.

(i) Calculate the loss at 4 MHz if the dielectric loss is negligible, and (ii) Sketch the loss/frequency characteristic of the cable.

(c) (i) Loss of coaxial cable = $k F^{1/2}$

where k is a constant of proportionality, and F is the frequency.

Substituting values give $10 = k 0.2^{1/2}$ (maintaining consistency of units).

$$\therefore k = 10/0.2^{1/2} = 22.36.$$

At 4 MHz

$$\text{Loss} = 22.36 \times 4^{1/2} = 44.7 \text{ dB}$$

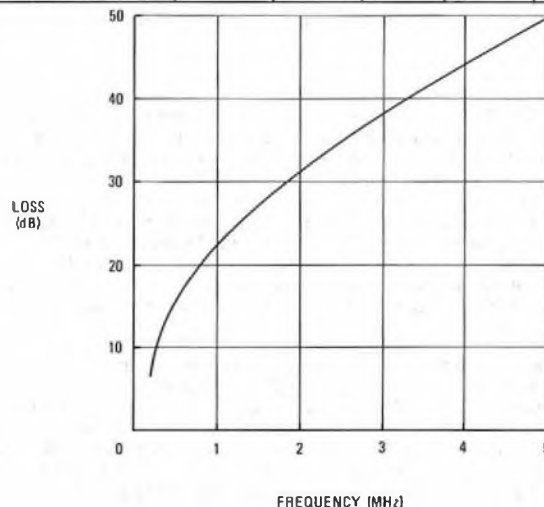
(ii) The loss/frequency characteristic is shown in the sketch.

A1 (a) See A3(a), Radio and Line Transmission B 1974, *Supplement*, Vol. 68, p. 50, Oct. 1975.

(b) The characteristics are compared in the table.

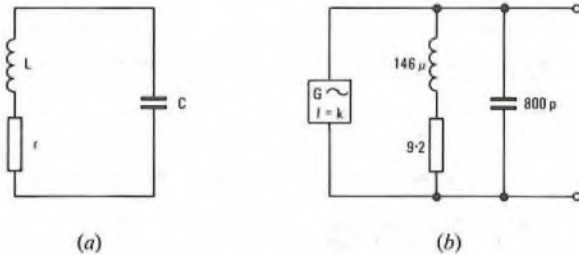
Characteristic	Coaxial Cable	Open-Wire Line
Impedance	50–100 Ω	200–600 Ω
Configuration	Unbalanced; earthed outer conductor	Balanced
Frequency Range	Up to 100 MHz; exceptionally in microwave region	Normally low-frequency (audio); exceptionally in very high frequency range
Security	Self-screening; this factor is particularly good with steel cladding	Subject to interference and crosstalk
Environmental Sensitivity	Rugged; can be used for either aerial or buried installations	Suitable only for aerial installations; susceptible to weather and interference

Frequency (MHz)	1	2	3	4	5
Loss (dB)	22.36	31.6	38.7	44.7	50



- Q2 (a) Calculate the component values of a parallel resonant circuit in the output of a constant-current amplifying device required to give a bandwidth of 10 kHz at a frequency of 465 kHz. A fixed capacitance of 800 pF is used.
 (b) The mutual conductance of the device is 1 mA/V. What is the gain of the stage at 465 kHz?
 (c) Draw the equivalent circuit of the stage and insert component values.

A2 (a) The circuit is shown in sketch (a).



Parallel resonance occurs at the frequency (f_0) at which the reactances are equal.

Writing ω_0 for $2\pi f_0$,

$$\omega_0 L = \frac{1}{\omega_0 C} = \frac{1}{2 \times \pi \times 465 \times 10^3 \times 800 \times 10^{-12}}$$

$$= \frac{10^5}{2 \times \pi \times 4.65 \times 8} = 428 \Omega$$

$$Q = \frac{\omega_0 L}{r} = \frac{f_0}{B} = \frac{465}{10} = 46.5$$

where Q is the Q -factor and r is the resistance (ohms) of the coil, and B is the bandwidth.

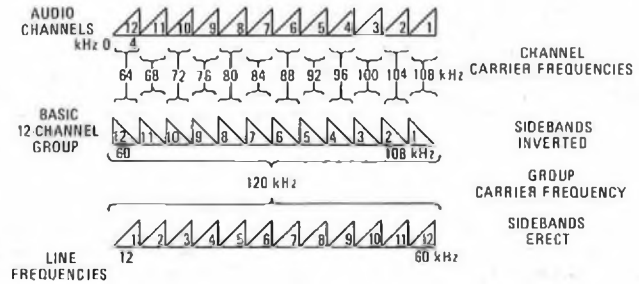
$$\therefore r = \frac{\omega_0 L}{Q} = 9.2 \Omega$$

$$L = \frac{428}{\omega_0} = \frac{428}{2 \times \pi \times 465 \times 10^3} \text{ H} = 146.5 \mu\text{H}$$

- (b) The dynamic impedance, $Z = Q\omega_0 L = 46.5 \times 428 = 19\,900 \Omega$
 \therefore the stage gain at 465 kHz = $1 \times 10^{-3} \times 19\,900 = 19.9$.
 (c) The equivalent circuit is shown in sketch (b).

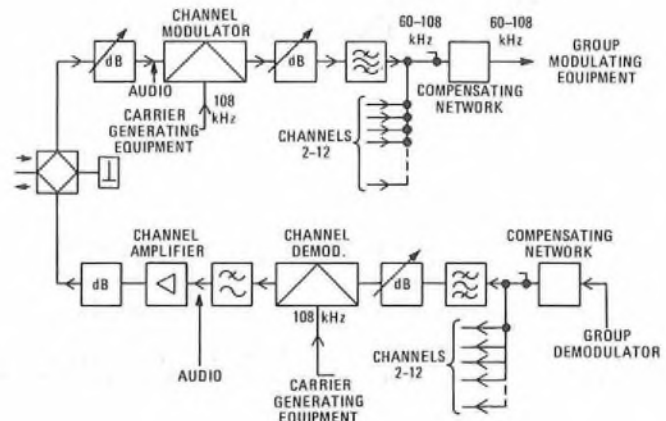
- Q3 (a) Explain why single-sideband operation is normally used in multi-channel-telephony systems.
 (b) Show, by means of a frequency diagram, the allocation of the channels in a 12-channel telephony group.
 (c) With the aid of a block diagram, trace the connexion of a 2-wire audio circuit through the GO-and-RETURN 12-channel equipments to the high-frequency line.

- A3 (a) Single-sideband operation requires approximately half the bandwidth of a double-sideband system, so that, in a strictly limited spectrum, nearly twice the number of channels can be accommodated giving proportionately more revenue.
 The assembly of a single-sideband signal, or a number of signals, involves the removal of one sideband and the reduction in level of the carrier component. Thus, for the same effective transmitted power, only about one-quarter of the available power is required in the send unit, or, with a given available power, repeater spacings can be increased. Either of these effects results in greater economy of operation.
 (b) Each channel (see sketch (a)) modulates a separate carrier frequency, and the lower sideband of each modulated carrier is combined with the others to form a basic group in the 60–108 kHz frequency band. The 12 channels are then translated into their final frequency band by modulating a carrier at 120 kHz and selecting the lower sideband in the frequency range 12–60 kHz. The sidebands are erect and are in the same form as the original channels.



(a)

(c) The block diagram is shown in sketch (b).

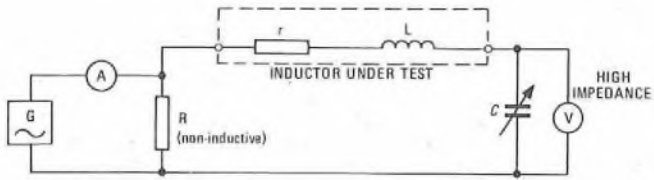


(b)

Starting at the left of sketch (b), the 2-wire audio circuit is converted to a 4-wire configuration by a hybrid transformer. The transmitted channel is adjusted to the correct level and applied to a Cowan type modulator where it is translated to one of 12 channels in the 60–108 kHz band. The band-pass filter selects the lower sideband and the channel is then combined with the other 11 channels. The compensating network is used primarily to provide correct terminations for channels 1 and 12. The group of channels is translated to the band 12–60 kHz by the group modulating equipment (not shown on the diagram).
 In the reverse direction, the channel demodulating equipment is very similar to the modulating equipment. After translation by the group demodulator, the channels are selected by their respective filters and then demodulated. Up to this stage, the modulation and demodulation equipments are identical. Following the demodulator, the audio channel is selected and amplified to a level which allows for losses through the hybrid transformer, through which the received signal passes to the 2-wire line.

- Q4 (a) Explain the term effective series resistance of an inductor and give TWO factors which contribute to this resistance.
 (b) Describe, with the aid of a circuit diagram, ONE method of measuring the effective series resistance of an inductor.
 (c) State precautions to be taken during the measurement.

- A4 (a) An inductor is usually a coiled wire having resistance distributed throughout its length. The magnitude of the resistance depends upon
 (i) the resistivity of the metal used for the wire, and
 (ii) the frequency of operation, since, at high frequencies, the current tends to travel along the surface of the wire, a phenomenon known as skin effect.
 For circuit evaluation, it is normal practice to represent the resistance through the wire by a separate lumped component in series with the pure inductance of the coil. This resistance is known as the effective series resistance.



(b) The effective series resistance of an inductor can be measured by the use of a Q -meter (see sketch). This instrument has a variable-frequency oscillator which can operate normally over the high-frequency band and which is coupled across a low-value non-inductive resistor. The output level of the oscillator can be adjusted to provide a set voltage across the resistor, measured by a thermocouple type of ammeter. The inductor to be measured is connected in series with a high-grade calibrated capacitor having a maximum value of about 500 pF. A high-impedance voltmeter indicates the voltage developed across the capacitor.

To measure the series resistance of the inductor, the frequency of the oscillator is set to the required value, and the variable capacitor is adjusted for maximum deflexion of the voltmeter. The oscillator output level is adjusted to provide a set deflexion of the ammeter, under which condition the voltmeter is calibrated to read the Q -factor directly.

Since the circuit is at resonance, the effective series resistance of the inductor can be obtained from the formula

$$Q = \frac{\omega_0 L}{r} = \frac{1}{\omega_0 C r}$$

where ω_0 is 2π times the resonant frequency, C is the capacitance (farads) and r is the effective series resistance (ohms).

Hence $r = 1/Q\omega_0 C$ ohms.

The frequency, Q -factor and capacitance are all read from the Q -meter, so that the effective series resistance can be readily calculated.

(c) The resistance due to skin effect is frequency-dependent, so that the frequency during a measurement must be observed. The DC value of resistance alone is insufficient.

The oscillator output level must be set to the correct value otherwise the Q -factor cannot be measured.

Q5 (a) (i) State what is the function of the time-base of an oscilloscope and explain how the trace is formed.

(ii) Explain how a waveform is displayed on the tube.

(iii) Describe the action of the brilliance and focus controls.

(b) Describe a method of measuring the modulation factor of an amplitude-modulated signal by means of an oscilloscope.

(c) If in (b) the maximum and minimum vertical deflexions as displayed on the oscilloscope are 6 and 4 cm respectively, what is the modulation factor of the signal?

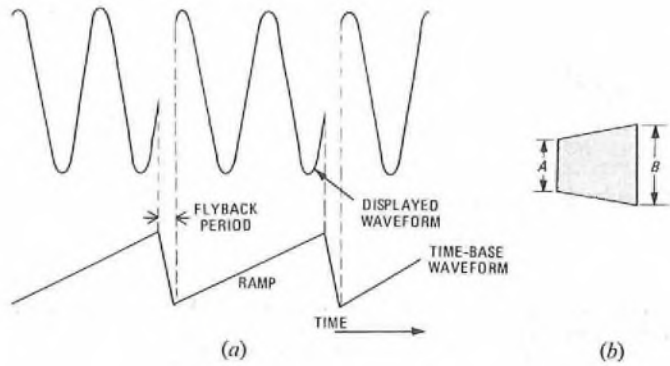
A5 (a) (i) The time-base of an oscilloscope is the basic waveform which provides, usually on the horizontal axis, a deflexion which is a function of time.

The time-base is applied to the horizontal deflexion plates of the oscilloscope tube as a sawtooth waveform, providing a linear deflexion with time of the electron beam within the period of the waveform ramp. On completion of deflexion, the trace returns rapidly to the starting point. During this *flyback* period the trace is extinguished by a blanking pulse applied to the grid of the oscilloscope tube. Provided the time-base is synchronized to the waveform under examination, a clear stationary trace can be observed.

(ii) The waveform to be examined is applied through amplifiers to the vertical deflexion plates, whilst the time-base (normally internally generated) is applied to the horizontal deflexion plates. The time-base is synchronized by feeding a sample of the applied signal to the time-base generator, and, provided the time-base frequency is within adequate locking range, it is controlled by the applied signal, giving a stable trace, as illustrated in sketch (a).

(iii) The brilliance control provides a means of adjusting the gun voltage which, under normal conditions, is negative with respect to the cathode potential. Using this control the density of the electron stream is adjusted to give the required trace brightness.

The focus control adjusts the potential of the second anode; this potential is higher than that of the first and third anodes. The electron beam is thereby dilated and converges through the aperture of the third anode to focus on the fluorescent screen. Variation of the focus control provides adjustment of the convergence of the electron beam and gives the required focusing action.



(b) A sample of the modulating signal is connected to the horizontal deflexion amplifiers, the normal time-base having been removed. After adjustment of amplitudes, the modulation envelope obtained is in the form of a trapezium (see sketch (b)).

In sketch (b), B corresponds to the peak-to-peak value of the envelope peaks and A the value of the troughs.

The modulation factor is then given by $\frac{B-A}{B+A}$.
When $A = 0$, a modulation factor of unity is obtained.

(c) When $B = 6$ cm, $A = 4$ cm, the modulation factor = $\frac{6-4}{6+4} = 0.2$

Q6 (a) With the aid of sketches, describe the THREE main regions of the ionosphere and the causes of their formation.

(b) Explain any variations that normally occur and how propagation via the ionosphere is affected.

(c) (i) State the frequencies used for long distance communication via the ionosphere.

(ii) Explain the terms maximum usable frequency and critical frequency at vertical incidence.

A6 (a) and (c)(ii) See A4, Radio and Line Transmission B 1972, Supplement, Vol. 66, p. 88, Jan. 1974.

(b) As described in (a), there are 3 main ionized layers, E, F₁ and F₂ at heights of approximately 100, 200 and 350 km respectively during daylight hours. Whilst the E layer remains fairly constant at night, the F₂-layer descends to merge with the F₁-layer to give maximum electron density at about 250 km. This layer is referred to as the F-layer.

(i) Attenuation increases with electron density.

(ii) Attenuation is inversely proportional to frequency.

(iii) Refraction reduces with frequency.

Thus, at any time, the highest frequency consistent with reliable propagation is used. It follows that the optimum frequency of operation has to be continuously adjusted, varying from the highest frequencies being used during the day and the lowest frequencies at night. Since the electron density varies also with the seasons, being greater during the summer months, the daily pattern for optimum frequency of operation is not constant for a particular transmission path. It also varies with locality. Monthly prediction charts for optimum traffic frequencies are produced for the different route paths.

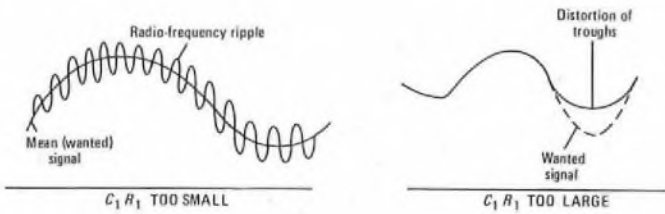
(c) For daytime conditions, frequencies in the range 12–25 MHz are used whilst at night the optimum band of operation is 4–12 MHz.

Q7 (a) With the aid of a circuit diagram and waveform sketches describe the operation of a diode detector for amplitude-modulated signals.

(b) State suitable values of load resistor and capacitor in the detector circuit of a broadcast receiver having an intermediate frequency of 465 kHz.

(c) Explain THREE principal effects if the components in (b) are incorrect.

A7 (a) and (b) See A2, Radio and Line Transmission B 1975, Supplement, Vol. 69, p. 37, July 1976.



(c) The diode load resistor (R_1) and capacitor (C_1) determine the detector time constant.

The principal requirements for these components are:

- (i) the load resistor must be large compared with the diode forward resistance, otherwise the detector efficiency is adversely affected,
- (ii) the load capacitor must have a low reactance at carrier frequencies and high reactance in the modulation frequency range and
- (iii) the time constant, C_1R_1 , must be large compared with the period of the carrier frequency, and small compared with the highest modulating frequency.

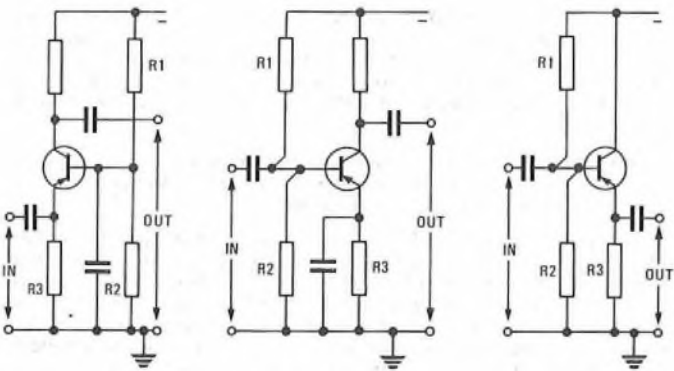
If the time constant is too low the capacitor discharges too rapidly through R_1 allowing carrier-frequency variations to be superimposed on the detected modulating frequency which is then effectively reduced in amplitude as shown in the sketch. If the time constant is too large, C_1 cannot discharge rapidly enough to follow the modulation content and distortion occurs.

Q8 (a) Sketch and describe the basic circuits of audio-frequency transistor amplifiers in the following configurations, showing typical bias arrangements

- (i) common base,
- (ii) common emitter, and
- (iii) common collector (emitter follower).

(b) (i) Draw the circuit diagram of a tuned 2-stage r.f. amplifier using transistors in common-emitter configuration.
 (ii) Briefly describe the operation of the amplifier.

A8 (a) The circuit diagrams are shown in the sketches.



(i) Common base (ii) Common emitter (iii) Common collector

(i) In the common-base circuit, the input signal is applied across the emitter and base, and the output taken from the collector (between the collector and base). The base is thus common to input and output. With this configuration the current gain is always less than unity. Base bias is maintained through the potential divider, R_1 , R_2 , and the emitter current is stabilized by the inclusion of emitter resistor R_3 .

(ii) In the common-emitter circuit, the input is applied across the base and emitter, whilst the output is taken from the collector (between collector and emitter). In this case, therefore, the emitter is common to input and output. The current gain is greater than unity, typically greater than 50, so that this configuration is suitable for resistance-capacitance coupling in audio-frequency amplifiers. The bias circuit is essentially the same as that used for the common-base circuit except that the decoupling capacitor is connected to the emitter.

(iii) The common-collector circuit is analogous to the cathode-follower circuit in valve amplifiers and is sometimes referred to as the emitter follower. The input is connected across the base and collector, and the output across the emitter and collector. The voltage gain in this circuit is less than unity but, since it provides both current and power gain, it is used for coupling to a low-impedance load. Again the bias circuit is similar to that used in other configurations. The emitter is not decoupled and sometimes resistor R_2 is omitted to take advantage of the high input impedance of the common-collector configuration.

(b) See A1, Radio and Line Transmission B 1975, Supplement, Vol. 69, p. 37, July 1976.

Q9 (a) Explain the term 'noise' as applied to communication systems and outline the essential difference between impulse noise and random noise.

(b) (i) Give TWO possible causes of impulse noise and describe means of reducing their effects.

(ii) Explain why impulse noise causes interference over a wide frequency spectrum.

(c) State the main source of noise in a superheterodyne receiver and describe steps which can be taken to reduce it.

A9 (a) Noise is an unwanted signal received or amplified along with the wanted signal, thereby reducing the intelligibility of the wanted signal. Noise may be already present within the receiver or amplifier. On the other hand, it may be an external signal received in addition to the wanted signal or it may be generated through crosstalk from other signals as a result of non-linearity in the amplifier. The noise may arise through atmospheric conditions (for example, lightning discharges) or it may be of cosmic origin. Discharges developed in machinery or power lines (corona discharges) are common causes.

Impulse noise is created by a discharge mechanism. Examples are lightning, corona discharge and arcing across circuit breakers. In the latter example, domestic electrical appliances, unless correctly suppressed, are liable to create interference because of the many switching functions that may take place. A well-known potential source of interference is the ignition system of the internal combustion engine. An impulse creates interference because it contains a very large range of frequencies. In practice this is a function of pulse width and shape. Thus a single discharge can cause momentary interference over a large range of frequencies.

Random noise may be due to thermal agitation of electrons in a conductor or shot noise in a thermionic or semi-conductor device. Other forms of random noise are partition and induced grid noise in thermionic valves. Random noise becomes significant in high-gain receivers capable of amplifying low-level signals. The absolute sensitivity of a receiver is determined by the level of noise present in the first stages of the equipment. Random noise has a uniform power/frequency spectrum, so that the effective level is determined by the bandwidth of the receiver. Its level is also determined by the absolute temperature of the component creating the noise.

(b) Impulse noise may be reduced by screening the source to restrict radiation. On the other hand, if the interference is transmitted along, for example, power lines, the interference may be suppressed by the use of a filter placed across the terminals of the incoming power feed. This filter may be in the form of capacitors shunting the feed to earth or more effectively through a filter designed to prevent the transmission of frequencies covering the radio spectrum.

(c) The frequency-changer in a superheterodyne receiver has a conversion conductance which is generally lower than the mutual conductance of a normal amplifier. If a frequency-changer is used as the first stage, the sensitivity of a receiver is therefore liable to suffer. Also, a multi-electrode frequency-changer, such as the triode hexode, produces partition noise in addition to the normal noise sources. Under the above circumstances a superheterodyne receiver has less sensitivity than a "straight" receiver. The superheterodyne receiver is also liable to image channel interference if the stages prior to the frequency-changer have inadequate selectivity.

The inclusion of a low-noise radio-frequency (RF) amplifier increases the sensitivity of the receiver, since the signal is amplified before the frequency-change. At the same time the RF amplifier improves image channel rejection by the inclusion of an additional RF coupling stage.

Q10 (a) The gain of an amplifier without feedback is 80 dB. Calculate the gain in decibels of the amplifier if 2% of the output voltage is fed back in antiphase with the input signal.

(b) The gain of the amplifier without feedback then increases to 90 dB. What is the new gain when the feedback is applied?

(c) Describe FOUR effects of negative feedback on the characteristics of such an amplifier.

(d) Give TWO reasons for using negative feedback in repeaters for coaxial line systems carrying multi-channel telephony signals.

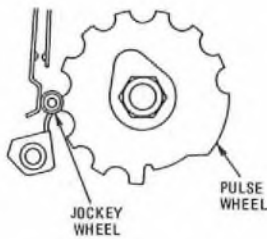
Students were expected to answer any 6 questions

Q1 (a) With the aid of sketches of parts of a dial mechanism, describe those features and actions that

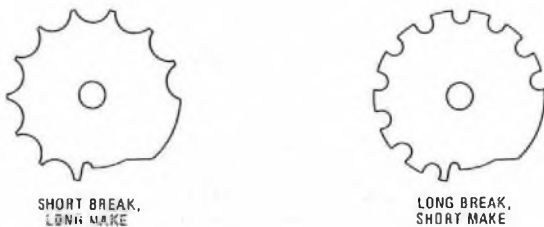
- (i) determine the break-to-make ratio of the pulses, and
- (ii) control the speed at which the pulses are generated.

(b) Explain why a spark-quench is included in the telephone circuit while pulses are being transmitted.

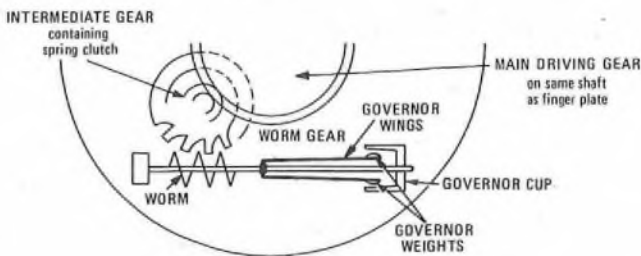
A1 (a) (i) Sketch (a) show those parts of the dial mechanism which determine the break-to-make ratio of the pulses. The principal item which determines the ratio is the shape of the teeth on the pulse wheel. Sketch (b) shows the effect of varying the relative size of each tooth on the pulse wheel. Other factors which affect the ratio are the clearance between the jockey wheel and springset in the MAKE position and the amount of follow which takes place before the contacts separate.



(a)



(b)



(c)

(ii) Sketch (c) shows the governor assembly which controls the speed of the dial. The governor is driven by step-up gearing from the main spindle of the dial. As the dial restores the governor rotates causing the wings to move outwards under centrifugal force and so to rub against the inside of the cup. This rubbing provides a braking force and so stabilizes the speed at which the dial returns.

(b) Dial pulses result in the release and re-operation of the pulsing relay in the exchange. Making and breaking such a highly inductive circuit would lead to arcing at the dial-pulsing contacts and this would cause rapid erosion of the contacts. The provision of a spark-quench prevents arcing and hence prolongs the life of the pulsing contacts.

Q2 (a) For a single-contact high-speed telephone relay,

- (i) sketch a plan view, and
- (ii) state the approximate operate and release times.

(b) State THREE features of the relay that contribute to its fast operation and fast release.

(c) Briefly explain why a high-speed relay is used for repeating dial pulses in a transformer-type transmission bridge.

A2 (a) See A2, Telephony and Telegraphy A 1973, Supplement, Vol. 67, p. 31, July 1974.

(c) Any relay used for repeating dial pulses must be fast to operate and to release. For good pulsing performance over long circuits a relay also requires approximately equal operate and release times so as to minimize distortion. The high-speed relay possesses these characteristics and is used in junction relay-sets as a pulsing relay.

Q3 (a) From the equipment at his premises a subscriber connected to an automatic exchange is able to call the exchange to originate a call, send trains of dial pulses to the exchange and clear the connexion at the end of the call.

With the aid of simple circuit sketches explain how the above signals are generated and signalled from

- (i) a telephone station, and
- (ii) a Telex station.

(b) Explain

(i) why there needs to be a pause between the vertical and rotary actions of a group selector, and

(ii) how the pause is controlled by a slow-to-release relay.

Q4 (a) Describe the structure and use of

- (i) the Morse code, and
- (ii) the Murray (5-unit) code.

(b) With the aid of a sketch show the sequence and relative timing of the signal elements comprising a character from a teleprinter.

(c) (i) Describe in outline the mechanical response of a teleprinter when receiving start and stop elements.

(ii) Briefly explain why these elements are necessary.

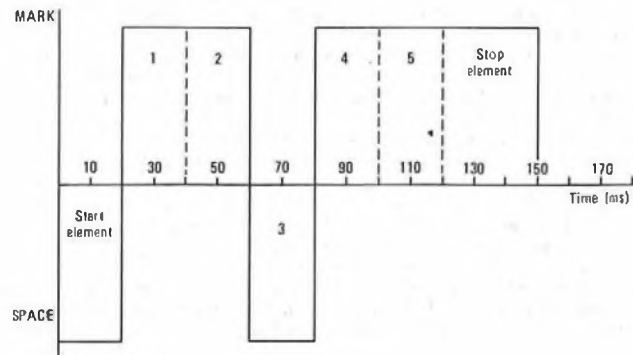
A4 (a)(i) The Morse code is a hand-signalling telegraph code. Its primary use today is in ship-to-shore high-frequency radio-telegraphy. The code consists of 2 elements, the dot of 1 unit duration and the dash of 3 units. Each letter and figure is allocated a unique combination of dots and dashes to represent it. The elements themselves are separated by a space of 1 unit, letters are separated by a 3-unit space and words by a 7-unit space.

(ii) The Murray code is a machine telegraph code used extensively in machine-printing telegraphy (such as in Telex). The code consists of 2 elements, known as the MARK and SPACE. They are of equal duration and are distinguished by using different circuit conditions; for example +80 V and -80 V, or TONE ON and TONE OFF (depending on the signalling system). Each character consists of a combination of 5 MARK and SPACE elements. START and STOP elements are usually added to each 5-unit character for synchronization purposes.

(b) A typical teleprinter character is shown in the sketch.

(c) (i) The START element unlatches the drive pawl and engages the receive mechanism to the teleprinter motor. The STOP element performs the converse, it latches the drive pawl and declutches the receive mechanism from the motor.

(ii) The purpose of engaging and declutching the receive mechanism, and of the START and STOP elements required to perform it, is to resynchronize the sending and receiving mechanisms at the start of every



character. Thus, any difference in motor speeds only accumulates over the time of one character and minor speed variations do not affect the receiving mechanisms.

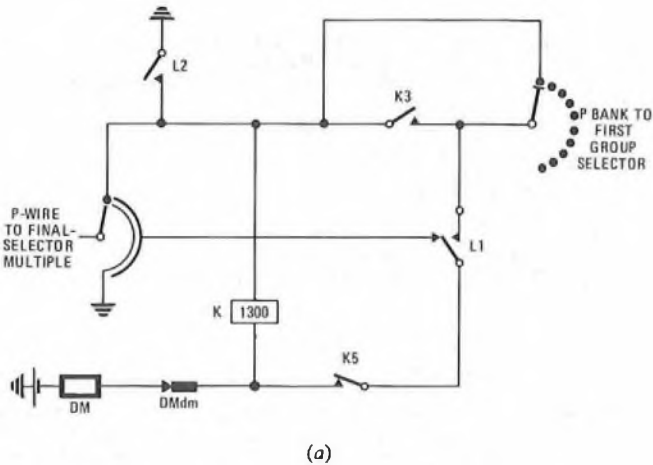
Q5 (a) Sketch rotary-hunting and testing circuit elements for

- (i) a uniselector, and
- (ii) a 2-motion group selector.

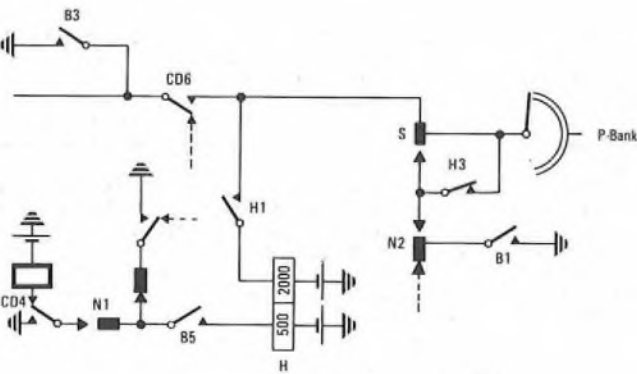
(b) Explain why the circuit elements are different.

(c) For EACH circuit explain how an immediate guarding condition is applied when switching to an outlet that has been tested and found to be free.

A5 (a) The rotary and testing circuit elements of a uniselector are shown in sketch (a), and those of a group selector are shown in sketch (b).



(a)



(b)

(b) One essential difference between the 2 circuits is the manner in which the drive is disconnected. In the uniselector case, the absence of a busying earth allows testing relay, K, to operate whilst in the group selector, testing relay H is pre-operated, and the absence of a busying earth causes it to release.

Another major difference concerns the mechanisms which the circuits control. A uniselector is a reverse-acting mechanism and the interrupters thus close when wipers step on to a contact to be tested. A group-selector rotary drive is, however, a forward-acting device and the rotary interrupters are therefore open during testing.

(c) In the uniselector circuit an immediate guarding earth is placed on the P-wire by contact K3 from the L2 earth. This guard condition is maintained during the slow release of relay L and allows time for the guarding earth to be returned from the first selector.

In the group selector circuit, the release of relay H applies an immediate guarding earth to the P-wire via contact B1, contact N2 and contact H3. This immediate guard is maintained during the re-operation of relay CD and until relay H subsequently re-operates, by which time a guarding earth will have been returned from the following selector.

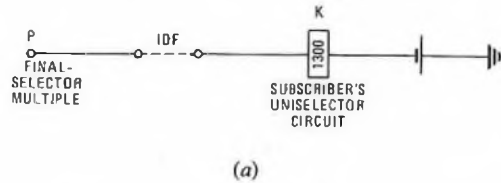
Q6 (a) The following electrical conditions appear on the P-wire of a subscriber's multiple at an automatic exchange: battery, earth and disconnection.

- (i) State ONE reason why EACH appears.
- (ii) Draw simple sketches to show how EACH is applied.

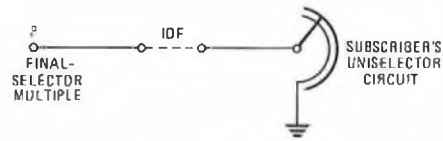
(b) With the aid of a sketch of the circuit elements concerned, describe the circuit operation when a final selector tests the line of a busy subscriber.

A6 (a) (i) A battery on the P-wire is the normal free condition, an earth is the normal engaged condition, a disconnection indicates that the line is not in use.

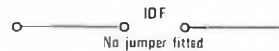
(ii) The circuit elements concerned are shown in sketches (a), (b) and (c).



(a)



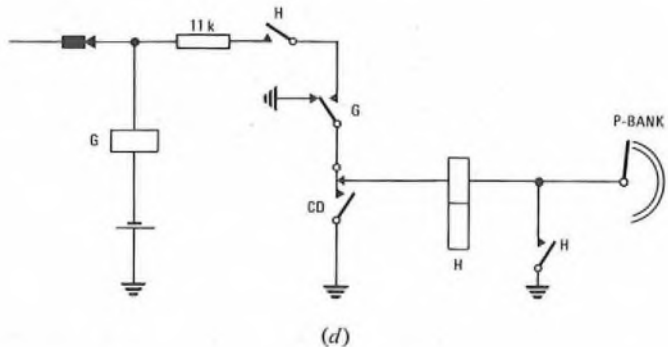
(b)



(c)

(b) The testing elements of a final selector are shown in sketch (d). Relay G is pre-operated. At the end of vertical stepping, on the re-operation of relay CD, relay G holds over its own contact via the 11 kΩ resistor to the contact CD earth.

At the end of rotary stepping, relay CD releases and offers the pre-operated relay G to the P-wire via the 11 kΩ resistor and relay H. A busy subscriber's line has an earth on the P-wire, and relay G holds to this earth. The current flowing is however limited by the 11 kΩ resistor and relay H does not operate. On the slow release of relay E, with relay G held, busy tone is returned to the calling subscriber.



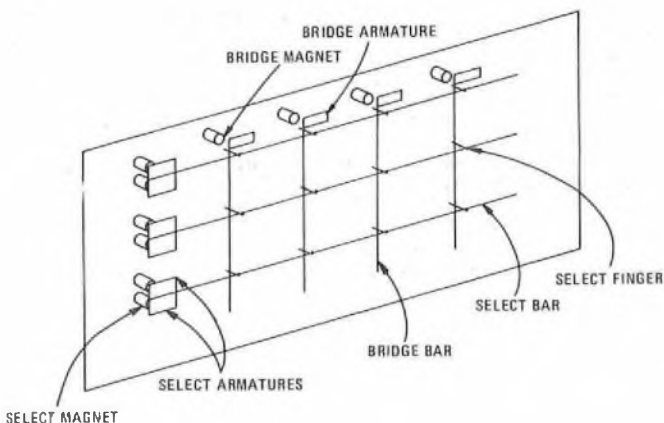
(d)

Q7 (a) With the aid of sketches, explain how EACH of the following mechanical operations is performed in a crossbar switch,

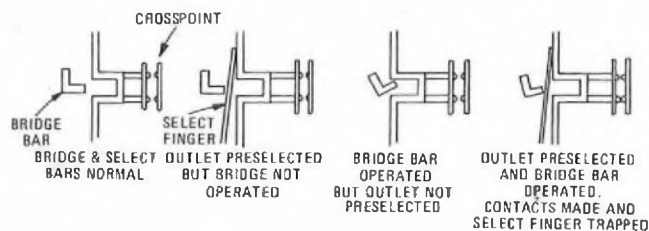
- (i) preselecting a crosspoint,
- (ii) operating a crosspoint,
- (iii) holding a crosspoint, and
- (iv) releasing a crosspoint.

(b) Which of the above mechanical operations would you expect to be made under the direction of a common control and which not? Give reasons for your answers.

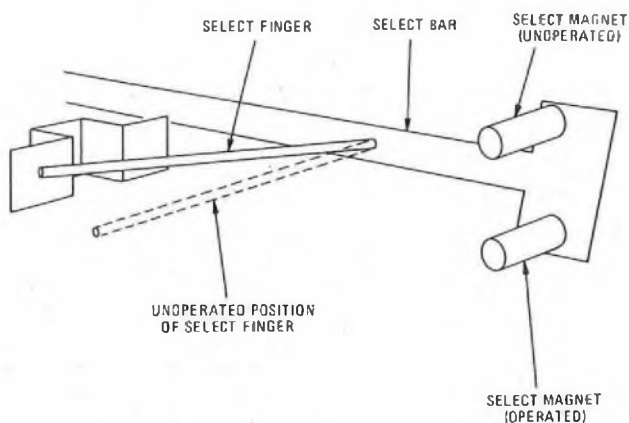
A7 (a) (i) A crossbar switch is arranged as a matrix of horizontal select bars and vertical bridge bars as shown in sketch (a). A path through the switch is provided by operating a crosspoint at the intersection of a horizontal and a vertical, thus connecting those 2 circuits together. Pre-selection is the first stage in operating a crosspoint. A select magnet is energized, thus attracting a select-bar armature and rotating a select bar so as to position all the select fingers on that bar either up or down. In this position a complete horizontal row of crosspoints is primed, as shown in sketch (b) the select fingers lie across the recess in the operating bar of each springset. Thus any bridge magnet will operate a springset at its junction with the primed select bar.



(a)



(b)



(c)

(ii) Operating the crosspoint is performed by a bridge magnet which, in operating, rotates the bridge bar. As shown in sketch (c) the rotation of a bridge bar performs no action on the crosspoints unless a select bar has been operated. Thus all crosspoints associated with the bridge remain unoperated except for the crosspoint in the row primed by the select bar. In this case, the bridge bar is not free to rotate into the recess since this is blocked by the select finger. In rotating the bridge bar bears on the operate bar with the select finger trapped and thus operates that crosspoint.

(iii) A crosspoint having been operated, it is not necessary to keep both select and bridge magnets energized in order to hold it. The select magnet is released, the select bar rotates to normal but the select finger remains trapped by the bridge bar. The finger is mounted flexibly to permit this.

(iv) The release of a crosspoint is carried out by releasing the bridge magnet. The bridge bar in releasing allows the crosspoint to restore and the select finger, no longer trapped, restores under its own spring tension.

(b) Preselection and operation of a crosspoint is normally performed under common control since the primary common control function is to steer calls from the calling number via appropriate crosspoints to the called number.

Holding and releasing is not normally carried out by common control; these functions are normally carried out by a transmission bridge and supervisory circuit, known as a transmission relay group or as a junctor.

Q8 The table below gives the traffic offered in the busy-hour to each outlet of a group of trunks served from a group-selector level.

Trunk number	1	2	3	4	5	6
Traffic offered (erlangs)	3.00	2.25	1.60	1.05	0.62	0.34

If the average duration of a call is 3 min and the grade of service given by the group is 0.05.

(a) Determine

- (i) the total number of calls,
- (ii) the traffic lost when all outlets are busy, and
- (iii) the traffic carried by each trunk.

(b) Explain why

- (i) an early-choice outlet does not normally carry 1 erlang of traffic, and
- (ii) a late-choice outlet normally carries less traffic than an early-choice outlet.

A8 (a) (i) No. of calls = $\frac{\text{traffic in erlangs}}{\text{average call duration in hours}}$

\therefore No. of calls offered = $\frac{3.0}{3/60} = 60$ calls

(ii) Traffic lost = traffic offered \times grade of service
 $= 3.0 \times 0.05 = 0.15$ erlangs

(iii) Traffic carried by any trunk = $\frac{\text{traffic offered to that trunk}}{\text{to the following trunk}}$

\therefore traffic carried by:

- trunk 1 = $3.0 - 2.25 = 0.75$ erlangs
- trunk 2 = $2.25 - 1.60 = 0.65$ erlangs
- trunk 3 = $1.60 - 1.05 = 0.55$ erlangs
- trunk 4 = $1.05 - 0.62 = 0.43$ erlangs
- trunk 5 = $0.62 - 0.34 = 0.28$ erlangs
- trunk 6 = $0.34 - 0.15^* = 0.19$ erlangs.

* For the last trunk the traffic offered to the following trunk is taken to be the lost traffic.

(b) (i) An erlang is defined as one circuit continuously occupied for 1 h, thus for any outlet to carry one erlang it must be occupied continuously for 1 h, either by a single call or by a succession of calls without any gaps between them. Single calls of an hour or more duration are rare, and the random nature of call arrivals makes a sequence of shorter calls, arriving at the precise moment that the circuit is freed from an earlier call, equally rare. Thus, although an early-choice outlet, or indeed any outlet, can occasionally carry 1 erlang they do not normally do so.

(ii) Outlets are normally tested sequentially and, only when an early-choice is engaged, is traffic offered to a later choice. Thus a late-choice outlet is offered less traffic than an early choice and so carries less traffic.

TELEPHONY AND TELEGRAPHY A 1977 (continued)

Q9 (a) For a non-director exchange having a multiple of 4000 lines, draw a trunking diagram to show how a call is routed through the selectors and the various connexions at the intermediate distribution frame (IDF).

(b) From which switching stages, and under what circumstances, might busy tone be returned?

(c) State THREE important functions of the main distribution frame and TWO important functions of the intermediate distribution frame.

A9 (a) The trunking diagram requested is shown in the sketch.

(b) Busy tone can be returned only from the final selector if the required number is busy.

A similar tone, equipment engaged tone, can be returned from either the first or second group selector stages if all outlets to the next switching stage are engaged.

(c) Three important functions of the main distribution frame (MDF) are:

(i) to provide flexibility between cable pairs and subscribers' numbers,

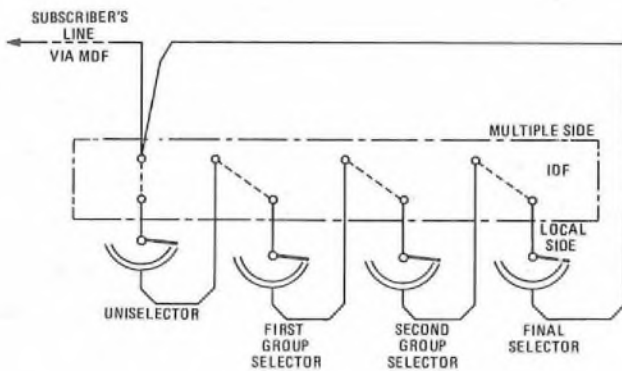
(ii) to provide a convenient test-access point, and

(iii) to provide a suitable point to mount protection devices, such as protectors, fuses and heat coils.

Two important functions of the intermediate distribution frame are:

(i) to provide flexibility between calling equipment and the subscribers' numbers, and

(ii) to provide flexibility in the allocation of equipment between switching stages.



Q10 (a) Draw a circuit diagram to show the essential features of a charge-discharge power plant for a telephone exchange and describe a procedure for recharging the batteries.

(b) Explain

(i) why the battery should not be overcharged,

(ii) how overcharging is avoided in a charge-discharge system, and

(iii) how overcharging is prevented in a floated battery system.

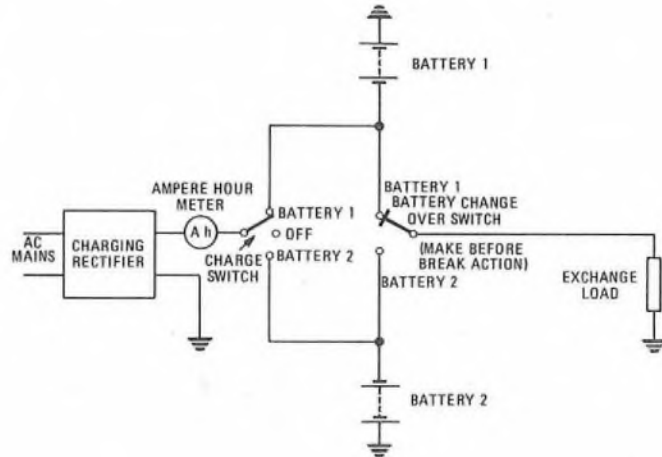
A10 (a) The essential features of a charge-discharge power plant are shown in the sketch.

To recharge the battery supplying the exchange load, the charging rectifier is first disconnected from the idle battery. The idle battery is then connected in parallel with the partially-discharged one, which is then disconnected from the exchange load. Finally the charging rectifier is connected to the discharged battery.

(b) (i) Overcharging is undesirable on a number of grounds. It causes excessive gassing of the electrolyte which loosens the active material of the plates and so shortens the life of the battery. It can also remove an excessive amount of acid from the battery in the form of spray, as well as being a waste of power.

(ii) Overcharging is avoided by the use of an ampere-hour meter which reduces the charge rate to a trickle charge when the battery is close to being fully-charged.

(iii) In the floated-battery system, the battery is connected to both the rectifier and the load at all times. During periods of light load the rectifier supplies more current than the load draws and thus charges the battery. As the battery is charged, the battery voltage rises; when this exceeds a preset level an automatic device reduces the charging voltage from the rectifier and so reduces the charging rate.



TELEPHONY B 1977

Students were expected to answer any 6 questions

Q1 A trunk (STD) call is dialled from a coin-box telephone connected to a non-director satellite exchange.

(a) (i) Draw a trunking diagram of the connexion as far as the first trunk selector at the main exchange (group switching centre).

(ii) Which item of equipment determines the charge rate for the call? On what information is the decision based?

(b) Briefly describe the signalling methods used to inform the coin-and-fee-checking relay-set of

- (i) the value of coins deposited by the caller, and
- (ii) the units of call charge while the call proceeds.

A1 See A2, Telephony B 1974, Supplement, Vol. 68, p. 37, July 1975.

Q2 A small PABX has only one switching stage of 2-motion selectors and an operator's cordless switchboard with digit keys.

(a) Draw a trunking diagram of the PABX.

(b) Describe the sequence of operations when a subscriber from the public exchange calls and asks to be connected to a particular extension.

(c) What advantages are gained by

(i) serving the extensions by line finders instead of selector hunters, and

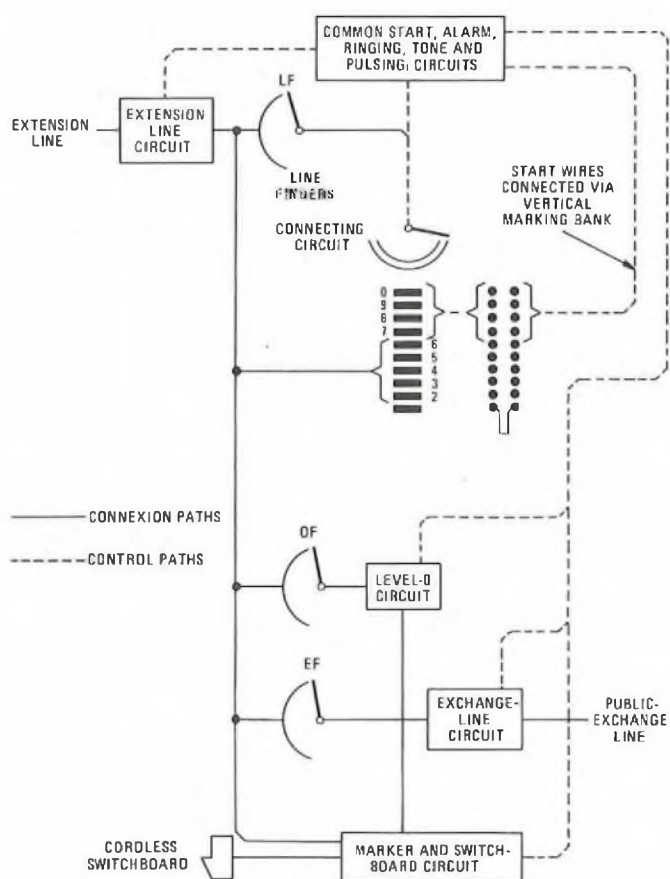
(ii) directly associating an additional line-finder with each exchange line relay-set?

A2 (a) The trunking diagram shows the main features of a PABX of the type described.

(b) A relay in the exchange-line relay-set responds to the ringing current from the public exchange and causes the associated exchange-line lamp on the cordless switchboard to flicker. Manual operation of the associated exchange-line key connects the PBX operator's telephone to the exchange line, and the ringing is tripped.

After speaking to the caller, the PBX operator selects the required extension by keying a 2-digit number. The first depression of a digit key operates a tens marking relay, and the second operates a units marking relay. The line finder EF then searches to find the extension that has been marked on its bank by the marking relays.

When the marked extension has been located, it is tested by the exchange-line relay-set and, if free, is rung automatically. Meanwhile, the exchange-line relay-set lamp glows and the PBX operator should restore the exchange-line key, leaving the exchange-line relay-set to trip the PBX ringing and extend the exchange line to the required extension as soon as the call is answered.



If the extension line tests busy, the exchange-line lamp flashes at the periodicity of busy tone. The ring-when-free facility ensures that a caller, who continues to hold the call, is connected when the extension becomes free.

(c) (i) A very small number of 2-motion selectors is sufficient to carry the dialled extension-to-extension traffic. Only one uniselector line finder LF is associated with each 2-motion selector. On the other hand, if selector hunters were used, then one such uniselector would be required for each extension. The use of line finders, therefore, permits an overall saving in uniselectors.

(ii) In addition to its use on calls incoming from the public exchange, the line finder EF is used to complete outgoing calls to the public exchange. Although a 2-motion selector is used during the initial stages of setting-up such an outgoing call, it is quickly released and made available for use by other extensions. These additional line finders EF, which are provided on the basis of one per exchange-line relay-set, therefore carry the traffic to and from the public exchange. A greater number of the more expensive 2-motion selectors would be required if they were used for carrying the traffic to and from the public exchange.

Q3 (a) Draw a trunking diagram to show the equipment involved in routing a call from one director exchange to another at the opposite side of a large director area.

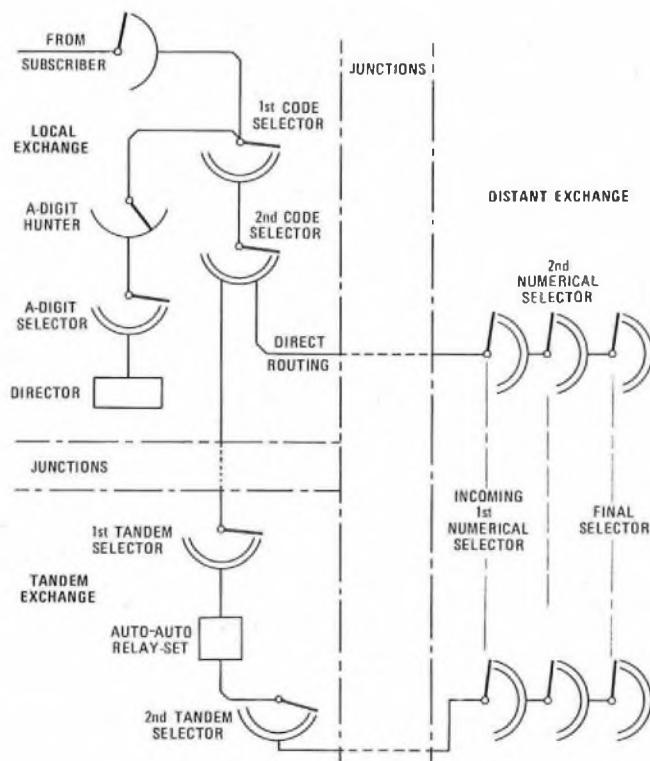
(b) Describe the sequence of operations within the common equipment while the call is being set up.

(c) What advantage is taken of the translation facilities when dealing with

- (i) own-exchange calls,
- (ii) calls to other exchanges, as in (a), and
- (iii) calls to operator services such as assistance and directory enquiries?

A3 (a) The required diagram is shown in the sketch.

(b) When a caller has been connected to a first code selector the associated A-digit-selector hunter (ADH) seizes a free A-digit selector (ADS), from which dial tone is returned. The first of the code digits dialled by the caller steps the ADS, which then hunts for a free director. The next 2 code digits step a 2-motion selector (BC-switch) within the



director. The banks of the BC-switch carry the locally-wired translations for up to 100 codes having a common A-digit. One of these translations is selected by the 6 wipers of the BC-switch. As each of the 6 wipers is marked in turn, the wiring of the translation field determines the sequence of routing digits that is pulsed out by the director and used to step the first and subsequent code selectors. If less than 6 routing digits are required, not all of the BC-switch wipers are marked.

While the translated routing digits are being pulsed out, the director receives and stores the 4 numerical digits denoting the called subscriber's number. After the last routing digit has been pulsed out, the subscriber's number is pulsed out in the form it was received. As soon as the director has finished pulsing-out the units digit of the subscriber's number it releases the connexion via the ADS to the ADH, thereby making the common equipment available to set up calls from other subscribers.

(c) (i) For own-exchange calls, the director normally translates the 3-digit exchange code to a single routing digit, the local first numerical selectors being trunked from a level of the first code selector. This has the advantage of avoiding unnecessary provision of second and third code selectors for a significant volume of traffic. It also reduces the setting-up time.

(ii) The routing digits of each translation can be chosen to give the best routing. Calls to a number of the more distant exchanges in the director area can be routed in a common group of junctions to a tandem switching centre. This permits the provision of a smaller overall number of junctions compared with the provision of separate small junction groups to serve the individual distant exchanges.

(iii) One large auto-manual switchboard serving a group of exchanges permits financial savings compared with the location of separate switchboards at each exchange. These savings are realized through the translation facility of the director, which permits the operator-service calls from a group of local exchanges to be concentrated onto a remote switchboard.

Q4 (a) With the aid of a sketch of the circuit elements concerned, describe the circuit operation of a 2-10 line PBX final selector when testing the lines of a 4-line PBX group in the following situations:

- (i) first line busy, second line free, and
- (ii) all lines busy.

(b) Explain how the same selector can deal with calls to direct exchange lines.

A4 See A5, Telephony B 1974, Supplement, Vol. 68, p. 38, July 1975.

Q5 (a) Design and sketch the best 4-group grading for 24 trunks from a level of 100-outlet first group selectors to second group selectors.
 (b) If the 24 second group selectors are accommodated on 3 shelves of one rack, show how they could be allocated to the grading.
 (c) Explain why the grade of service given by the 24 trunks would be worse if they were arranged as 4 separate groups of 6 trunks each.

A5 (a) The 4 groups of the grading should be arranged as singles, pairs and full commons. If these are represented by a , b and c respectively then their sum is equal to the availability of the level,

$$a + b + c = 10, \quad \dots\dots (1)$$

and $4a + 2b + c = 24. \quad \dots\dots (2)$

Subtracting equation (1) from equation (2),
 $3a + b = 14 \quad \dots\dots (3)$

The possible values of a that satisfy equation (3), and give practical values for b , are 4, 3 or 2.

If $a = 4$, then $b = 2$ and $c = 4 \quad \dots\dots (4)$

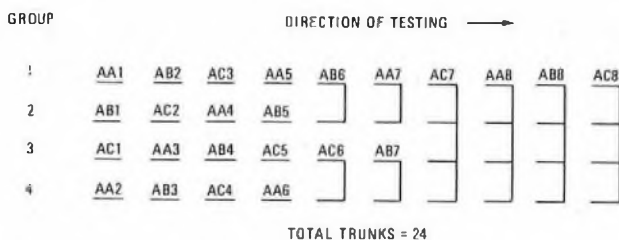
If $a = 3$, $b = 5$, $c = 2 \quad \dots\dots (5)$

If $a = 2$, $b = 8$, $c = 0 \quad \dots\dots (6)$

A practical grading cannot have a zero value for c and expression (6) must, therefore, be disregarded. This leaves the choice of grading between those represented by expressions (4) and (5).

	a	b	c	Sum of successive differences
Expression (4)	4	2	4	4
Expression (5)	3	5	2	5

The best grading is that which has the smoothest progression from singles to pairs, and from pairs to full commons. This is found from the table by choosing the grading which has the lowest sum of successive differences, that is 4 singles, 2 pairs and 4 full commons. This grading is shown in the sketch.

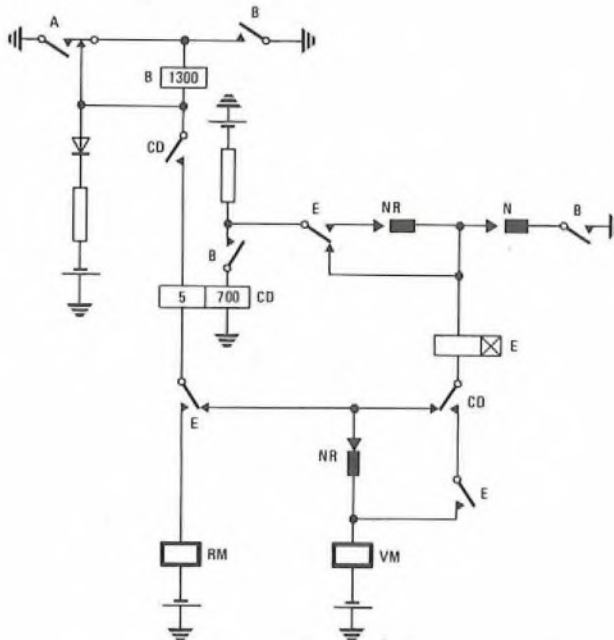


(b) The 24 second selectors should be accommodated on 3 shelves, each carrying 8 selectors. They should be identified as AA1 to AA8, AB1 to AB8 and AC1 to AC8, and should be allocated to the grading in a manner which gives to each shelf one third of the traffic carried by the grading. The second selectors available from each of the 4 grading groups should also be spread over the 3 shelves so that, if a fuse serving a shelf of second selectors were to rupture, the resultant lost calls would be spread over the 4 grading groups instead of being concentrated in one or two groups. A systematic method of allocation, which comes close to satisfying these requirements, is shown in the sketch.

(c) Since calls arrive in a random manner, it is highly probable that, when a short peak of traffic occurs in one first-selector group the others will be carrying relatively less traffic. If the 4-group grading is used, then the group which has a peak of traffic can pass the extra calls to those late choices which are common to all the groups. But, if 4 separate groups of 6 trunks were used, congestion would occur in any group that is offered extra calls when the 6 trunks are already busy. More calls would, therefore, be lost, and a worse grade of service would result.

Q6 (a) Sketch those circuit elements of a final selector that control vertical and rotary stepping.
 (b) Why is a make-before-break action used for the pulsing relay contact?
 (c) For a call routed via one intermediate switching centre in a non-director area, identify the equipments at which the dialled pulses would suffer some distortion of the break period.
 (d) To what approximate extent could the break and make pulses be distorted without affecting the performance of the final selector?

A6 (a) The sketch shows those circuit elements of an ordinary final selector that control vertical and rotary stepping.



(b) The make-before-break (K) action of contact A ensures that relay B is short-circuited immediately after it is energized but, if a break-before-make (C) action were used, relay B would be subjected to a short disconnection while the moving (lever) spring was in transit. This would shorten relay B release time by permitting some of the flux to collapse quickly while the winding remained open-circuited. The selector might then release prematurely during vertical, or rotary, stepping.

Not all selector circuits use short-circuiting of relay B and there is a more general reason for the use of the K action. This concerns its beneficial effect on the energization times of the vertical and rotary magnets. These magnets are highly inductive and, when they are energized, the build-up of current and flux is relatively slow. If prior pulse distortion has caused severe shortening of the BREAK period, the time for which the magnet is energized may be insufficient to allow the flux to rise to a value that is adequate to attract the armature and step the wiper carriage. The magnet energization period is the interval between the closing of the BREAK contact and its subsequent re-opening. Compared with a C action, the K action closes the BREAK contact earlier and breaks it later. Hence it produces a longer magnet energization period than would a C action. Thus, when the pulse distortion introduced by preceding equipment and line conditions causes the final selector to receive shortened BREAK pulses, the selector is less likely to misoperate during vertical or rotary stepping.

(c) For a call routed via an intermediate switching centre in a non-director area, the auto-auto relay-set at that centre introduces some degree of pulse distortion due to repetition of the pulses by relay A. Relay A of the final selector introduces additional distortion when it repeats the pulses to the selector magnets. In each case the amount and sign of the distortion depends very much on the type and length of line which precedes the pulse-repeating relay.

(d) The time required to operate, or to release, a final-selector magnet depends on a number of variables such as type and manufacture, the adjustment, the wear, and the battery voltage. The circuit configuration also has an effect. Typically, if the energization period is reduced below about 30 ms, there is a risk of failure during operation due to the magnet armature and pawl not moving the ratchet sufficiently to engage the forward stop and latch the detent. Since the nominal BREAK pulse from the dial is 66½ ms, the limiting distortion

(shortening) of the BREAK pulse is approximately 37 ms. Similarly, the time required to release the selector magnet is typically about 12 ms. This represents a limiting shortening of the MAKE pulse of approximately 21 ms.

Q7 At a sleeve-control auto-manual switchboard a relay-set gives access to a loop-disconnect-dialling junction.

(a) With the aid of a sketch of the principal circuit elements, describe the circuit operation of the relay-set.

(b) Explain why this relay-set

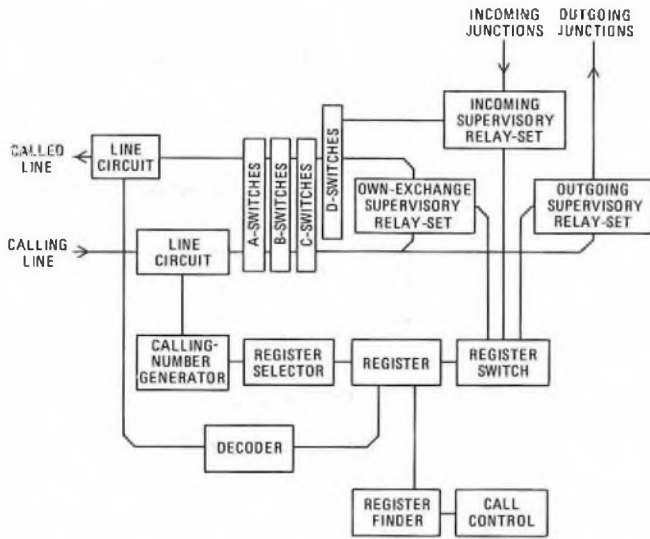
- (i) provides a flicker signal on the sleeve conductor, and
- (ii) applies a called-subscriber-answer signal to the ring as well as to the sleeve conductor.

Q8 (a) Draw a block diagram of a small reed-relay electronic exchange (TXE2).

(b) Describe the important functions performed by

- (i) the calling-number generator, and
 - (ii) the register.
- (c) What is the purpose of the D-switch?

A8 (a) The sketch shows the principal blocks of equipment which form a TXE2 exchange.



(b) (i) When a subscriber calls the exchange, his line circuit sends a pulse to the calling-number generator (CNG), where this pulse passes over a wire that identifies the calling line. The CNG then has 2 important functions:

- (1) reading and storing the identity (directory number) of the calling line, and
 - (2) encoding the calling number in 2 out of 5 form and passing it to a free register in a register selector.
- (ii) The important functions performed by the register are:
- (1) receiving and storing the calling number,
 - (2) passing the calling number to the decoder for marking the calling line,
 - (3) passing a request to the call control for allocation of a free supervisory relay-set which can then be connected via C, B and A-switches to the calling line, and via the register switch to the register,

- (4) returning dial tone to the caller,
- (5) receiving and storing the digits dialled by the caller,
- (6) encoding the number called within the TXE2 exchange, and passing it to the decoder so that the called line may be marked,
- (7) releasing itself from an effective call when the supervisory relay-set extends ringing current to the called line, and
- (8) for an ineffective call, returning busy tone, or number unobtainable tone, to the caller as appropriate.

(c) The D-switch improves the grade of service for incoming calls by increasing the number of paths available between the supervisory relay-set in use and the called line unit. If the supervisory relay-set were connected directly to a C-switch, then that switch would limit the choice of possible paths to a total of 5.

Q9 (a) Draw the circuit of a mains power unit for supplying power to a mains-dependent cordless PMBX switchboard.

(b) Explain the functions of the various components of the power unit, including the protective devices.

- (c) Briefly explain why the output voltage varies with the load.
- (d) Which PMBX facilities remain available in the event of mains failure?

A9 (a) See A9, Telephony B 1976, Supplement, Vol 70, p. 36, July 1977.

(b) The functions of the various components are,

- (i) The transformer steps-down the 240 V AC mains to a lower voltage.
- (ii) The bridge rectifier converts the low-voltage AC supply to a DC supply which pulsates at twice the mains frequency.
- (iii) The inductor acts as a smoothing device by impeding the AC components of the pulsating DC supply.
- (iv) The electrolytic capacitor further smooths the DC supply by offering a low-impedance shunt path for the residual AC components.
- (v) The mains input fuse (FS1) protects the transformer windings against overheating caused by the excess current which would flow in the event of a short-circuit within the windings, or of a mains over-voltage.
- (vi) The output fuse (FS2) protects the transformer and rectifier elements against the excess current that would flow in the event of a short-circuit, or similar fault, on the main power-supply leads serving the PBX.

(c) As the PBX load rises, the current drawn from the power-supply unit increases. This current flows in the transformer windings, the bridge rectifier elements, and the inductor, each of which possesses some internal resistance that causes a drop in voltage. The resistance of the fuses also makes a contribution to this internal voltage drop. The voltage of the AC mains input does not vary significantly and any increase in the voltage drop within the power supply unit reduces the voltage available to supply the PBX.

(d) In the event of a mains failure, the PBX loses all local power and the only facilities that remain available at the PBX are similar to those given by the normal night-service arrangements. If the operator's telephone, or any extension telephone, is left switched through to an exchange line, it can originate or receive calls in the same manner as a direct exchange line.

Q10 (a) For a public automatic exchange, what are the characteristics of

- (i) ringing current, and
 - (ii) ringing tone?
- (b) With the aid of sketches, explain how ringing current is
- (i) generated,
 - (ii) interrupted in a periodic manner, and
 - (iii) distributed to final-selector racks.

MATHEMATICS C 1977

Students were expected to answer any 6 questions. The use of electronic pocket calculators was permitted where appropriate

Q1 A circuit consists of a capacitor (C farads) in parallel with an inductor (L henrys). Its resonant frequency (f hertz) is given by

$$4\pi^2 f^2 = \frac{1}{L(C + C')}$$

where C' is the self-capacitance of the inductor.

The circuit resonates at 1 MHz when $C = 18 \times 10^{-12}$ and at 0.8 MHz when $C = 30 \times 10^{-12}$. Calculate the self-capacitance and the inductance of the inductor.

$$A1 \quad 4\pi^2 f^2 = \frac{1}{L(C + C')}$$

Substituting the given values of f and C:

$$4\pi^2 \times 10^{12} = \frac{1}{L(18 \times 10^{-12} + C')}, \quad \dots (1)$$

and $4\pi^2 \times 0.64 \times 10^{12} = \frac{1}{L(30 \times 10^{-12} + C')}, \quad \dots (2)$

Dividing equation (1) by equation (2) gives

$$\frac{1}{0.64} = \frac{30 \times 10^{-12} + C'}{18 \times 10^{-12} + C'}$$

$$\therefore 18 \times 10^{-12} + C' = 19.2 \times 10^{-12} + 0.64C'$$

$$\therefore 0.36C' = 1.2 \times 10^{-12},$$

or $C' = 3.3 \text{ pF.}$

Substituting the value of C' into equation (1) gives

$$4\pi^2 \times 10^{12} = \frac{1}{L(18 \times 10^{-12} + 3.3 \times 10^{-12})}$$

or $L = \frac{1}{21.3 \times 10^{-12} \times 4\pi^2 \times 10^{12}}$

$$= \frac{1}{21.3 \times 4\pi^2}$$

$$= \underline{1.187 \text{ mH.}}$$

Q2 (a) Express $(1+x)^{-1/2}$ in a series of ascending powers of x as far as the term in x^4 , and write down a general term in this series.

(b) The frequency f hertz of an oscillator with variable capacitance is given by

$$f = \frac{1}{2\pi\sqrt{L(C+C_v)}}$$

where C farads is the mean capacitance of the capacitor and C_v farads the variation from this mean due to a fluctuating voltage v .

When $C_v = 0$, and the capacitance is 100 pF , the frequency is 1 MHz . If the maximum variation in capacitance is $\pm 2 \text{ pF}$, use a binomial approximation to calculate to the nearest kilohertz the corresponding range of frequency of the oscillator.

A2 (a) See A2, Mathematics C 1975, Supplement, Vol. 69, p. 60, Oct. 1976.

$$\text{Now } (1+x)^{-1/2} = 1 - \frac{x}{2} + \frac{3x^2}{8} - \frac{5x^3}{16} + \frac{35x^4}{128} \dots$$

The term involving x^r can be written as

$$\frac{(-1)^r \times 1 \times 3 \times 5 \dots \times (2r-1) \times x^r}{2^r \times r!}$$

(b) Now $f^2 = \frac{1}{4\pi^2 L(C+C_v)}$

When $C_v = 0$ and $C = 100 \text{ pF}$,

$$L = \frac{1}{10^{12} \times 4\pi^2 \times 10^{-10}} = \frac{1}{400\pi^2}$$

Thus, when the capacitance is varying, the frequency is given by

$$f = \frac{1}{2\pi\sqrt{\left\{ \frac{1}{400\pi^2} (100 \times 10^{-12} \pm 2 \times 10^{-12}) \right\}}}$$

$$= \frac{1}{10^{-5} \sqrt{1 \pm 0.02}}$$

$$= 10^6 (1 \pm 0.02)^{-1/2}$$

From part (a) and when $C_v = +2 \text{ pF}$

$$(1 + 0.02)^{-1/2} = 1 - \frac{0.02}{2} + \frac{3}{8} \times 0.0004 - \frac{5}{16} \times 0.000008 + \dots$$

$$= 1 - 0.01 + 0.00015 - 0.0000025 + \dots$$

As the frequency in hertz is 10^6 times the numerical value of the expansion and as the variation is required to the nearest kilohertz, it is unnecessary to consider further terms.

Hence, $f \approx 10^6 (1.00015 - 0.0100025) \text{ Hz} \approx 990 \text{ kHz}$

When $C_v = -2 \text{ pF}$

$$(1 - 0.02)^{-1/2} \approx 1 + 0.01 + 0.00015 + 0.0000025 + \dots$$

and $f \approx 10^6 \times 1.010153 \text{ Hz} \approx 1010 \text{ kHz.}$

Thus, the corresponding frequency range of the oscillator is 990 to 1010 kHz or a variation of $\pm 10 \text{ kHz}$ to the nearest kilohertz.

Q3 (a) The cost of each floor in an office building is 8% greater than that of the floor below. If the ground floor costs £40 000, calculate the total cost of an 8-floor building to 2 significant figures.

(b) Use the exponential series to calculate the value of the voltage

$$v = 40(1 - e^{-kt})$$

to 3 significant figures when $t = 0.03$ and $k = 4$.

A3 (a) Assuming that the 8-floor building is inclusive of the ground floor the total cost, C , in pounds, is given by

$$C = 40 \times 10^3 + 1.08 \times 40 \times 10^3 + 1.08^2 \times 40 \times 10^3 + \dots + 1.08^7 \times 40 \times 10^3$$

$$= 40 \times 10^3 (1 + 1.08 \dots + 1.08^7)$$

The bracketed expression is a geometric progression of 8 terms the sum of which is given by

$$S_n = \frac{a(r^n - 1)}{r - 1}$$

where a is the first term (equal to 1), r is the common ratio (equal to 1.08), n is the number of terms (equal to 8).

$$\therefore S_8 = \frac{1(1.08^8 - 1)}{1.08 - 1} = \frac{1.8509 - 1}{0.08}$$

$$= \frac{0.8509}{0.08} = 10.636$$

$$\therefore C = £40 \times 10^3 \times 10.636$$

$$= \underline{£430\,000} \text{ to 2 significant figures}$$

(b) $e^{-x} = 1 - x + \frac{x^2}{2!} - \frac{x^3}{3!} + \frac{x^4}{4!} \dots$

When $t = 0.03$ and $k = 4$, $x = 0.03 \times 4 = 0.12$.

$$e^{-0.12} = 1 - 0.12 + \frac{0.0144}{2} - \frac{0.001728}{6} + \dots$$

$$= 1 - 0.12 + 0.0072 - 0.000288 + \dots$$

$$\therefore v \approx 40(1 - (1 - 0.12 + 0.0072 - 0.000288))$$

$$= 40(0.120288 - 0.0072)$$

$$= \underline{4.52} \text{ to 3 significant figures.}$$

Q4 (a) From first principles derive $\frac{d}{d\theta}(\cos \theta)$.

(b) Sketch the waveform $q = 8 \cos \omega t - 3 \cos 2\omega t$ from $t = 0$ to $\frac{2\pi}{\omega}$ seconds.

(c) If $\omega = 10^4 \text{ rad/s}$ find when q has its first maximum within this range of t . What is this maximum value?

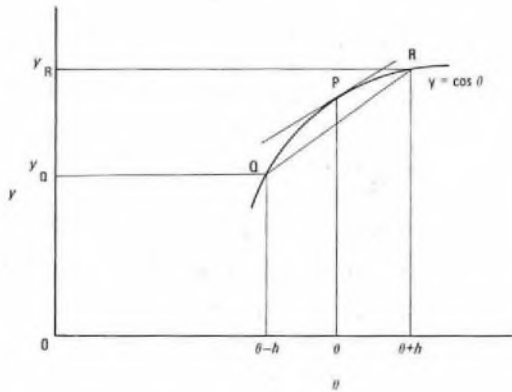
A4 (a) In the sketch, let P, Q and R be neighbouring points on the curve of $y = \cos \theta$ and let their abscissae be θ , $(\theta - h)$ and $(\theta + h)$ respectively. If P is fixed and the points Q and R move gradually towards it, the gradient of the chord QR becomes more nearly equal to that of the tangent at P. Thus, in the limit as Q and R merge with P,

$$\frac{\delta y}{\delta \theta} = \text{gradient of chord QR} = \frac{y_R - y_Q}{z_h}$$

$$\begin{aligned} &= \frac{\cos(\theta + h) - \cos(\theta - h)}{2h} \\ &= \frac{(\cos\theta \cos h - \sin\theta \sin h) - (\cos\theta \cos h + \sin\theta \sin h)}{2h} \\ &= -\sin\theta \frac{\sin h}{h} \end{aligned}$$

Now $\lim_{h \rightarrow 0} \frac{\delta y}{\delta \theta} = \frac{dy}{d\theta}$

$$= -\sin\theta \quad (\text{since } \lim_{h \rightarrow 0} \frac{\sin h}{h} = 1)$$



(b) For the answer to a similar question see A4, Mathematics C 1971, Supplement, Vol. 65, p. 73, Jan. 1973.

Q5 (a) Prove the trigonometrical identity

$$\tan\theta + \cot\theta = 2 \operatorname{cosec} 2\theta.$$

(b) Plot the polar curve $r = 5 \sin\left(\theta + \frac{\pi}{3}\right)$ from $\theta = 0$ to $\theta = 2\pi$.

Mark on the curve points A, B, C and D at which $\pi = 0, \frac{\pi}{2}, \frac{2\pi}{3}$ and $\frac{5\pi}{6}$ respectively.

(c) Show that the Cartesian equation of the curve plotted in (b) is of the form $x^2 + y^2 = ax + by$, where a and b are constants. Take the pole of the polar system as the origin, and the line $\theta = 0$ as the x -axis.

A5 (a)

$$\begin{aligned} \tan\theta + \cot\theta &= \frac{\sin\theta}{\cos\theta} + \frac{\cos\theta}{\sin\theta} \\ &= \frac{\sin^2\theta + \cos^2\theta}{\cos\theta \sin\theta} \end{aligned}$$

Since $\sin 2\theta = 2 \sin\theta \cos\theta$ and $\sin^2\theta + \cos^2\theta = 1$,

$$\begin{aligned} \tan\theta + \cot\theta &= \frac{1}{\frac{\sin 2\theta}{2}} \\ &= \underline{2 \operatorname{cosec} 2\theta} \end{aligned}$$

QED.

(b) For the answer to a similar question see A6, Mathematics C 1975, Supplement, Vol. 69, p. 62, Oct. 1976.

Q6 (a) If $y = \log_e(1 - \cos 2x)$,

(i) prove that $\frac{dy}{dx} = 2 \cot x$, and

(ii) sketch the graph of y for values of x from $x = 0$ to $x = 2\pi$.

(b) If $x = e^{-3t} \cos 4t$, show that

$$\frac{d^2x}{dt^2} + 6 \frac{dx}{dt} + 25x = 0.$$

Q7 (a) Derive from first principles the rule for differentiating the product of 2 functions of x . State without proof, the corresponding formula for differentiating a quotient.

(b) Find the maximum and/or minimum values of

$$y = \frac{2x - 1}{(x + 2)^2}$$

and sketch the graph of y , indicating any asymptotes.

Q8 (a) Evaluate

(i) $\int_0^1 (x^2 + 4)^3 dx$, and (ii) $\int_1^4 \frac{dx}{3x - 2}$.

(b) Derive, using integration, the mean value of the function $4 \cos 3x$ from $x = 0$ to $x = \frac{3\pi}{4}$.

A8 (a) (i) $\int_0^1 (x^2 + 4)^3 dx$

$$= \int_0^1 (x^6 + 12x^4 + 48x^2 + 64) dx$$

$$= \left[\frac{x^7}{7} + \frac{12x^5}{5} + 16x^3 + 64x \right]_0^1$$

$$= \frac{1}{7} + \frac{12}{5} + 16 + 64 = \underline{82.5429}.$$

(ii) $\int_1^4 \frac{dx}{3x - 2} = \left[\frac{1}{3} \log_e(3x - 2) \right]_1^4$

$$= \frac{1}{3} (\log_e 10 - \log_e 1) = \frac{1}{3} \times 2.3026 = \underline{0.7675}.$$

(b) The mean value of $4 \cos 3x$ is given by

$$\frac{\int_0^{3\pi/4} 4 \cos 3x dx}{\frac{3\pi}{4}} = \frac{16}{3\pi} \int_0^{3\pi/4} \cos 3x dx$$

$$= \frac{16}{3\pi} \left[\frac{\sin 3x}{3} \right]_0^{3\pi/4} = \frac{16}{9\pi} \left(\sin \frac{9\pi}{4} - \sin 0 \right)$$

$$= \frac{16}{9\pi} \times 0.7071 = \underline{0.4001}.$$

Q9 (a) Develop an exponential series for the function e^{-x^2} and then integrate this series term by term to evaluate to 3 significant figures the integral

$$\int_{\frac{1}{2}}^{0.6} e^{-x^2} dx.$$

(b) Use Simpson's rule with 7 ordinates to check the result obtained in (a).

A9 (a) Let $y = e^{-x^2}$.

Now
$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

Writing $-x^2$ for x gives

$$y = 1 + (-x^2) + \frac{(-x^2)^2}{2!} + \frac{(-x^2)^3}{3!} + \frac{(-x^2)^4}{4!} + \dots$$

$$= 1 - x^2 + \frac{x^4}{2!} - \frac{x^6}{3!} + \frac{x^8}{4!} - \dots$$

Hence
$$\int_0^{0.6} e^{-x^2} dx = \int_0^{0.6} \left(1 - x^2 + \frac{x^4}{2!} - \frac{x^6}{3!} + \frac{x^8}{4!} - \dots\right) dx$$

$$= \left[x - \frac{x^3}{3} + \frac{x^5}{10} - \frac{x^7}{42} + \frac{x^9}{216} - \dots \right]_0^{0.6}$$

$$= 0.6 - \frac{0.6^3}{3} + \frac{0.6^5}{10} - \frac{0.6^7}{42} + \frac{0.6^9}{216} - \dots$$

$$= 0.6 - 0.072 + 0.007776 - 0.0006665 + 0.0000466 - \dots$$

$$= 0.6078226 - 0.0726665 = 0.5351561$$

It is clear that the terms are decreasing in an approximate ratio of 10 and hence the term in 0.6^{11} and all subsequent terms could not affect the fourth decimal place.

Hence, to 3 significant figures

$$\int_0^{0.6} e^{-x^2} dx = 0.535$$

(b) The values of e^{-x^2} , using the seven values of x from 0 to 0.6 at intervals of 0.1, are obtained in the following table.

x	0	0.1	0.2	0.3	0.4	0.5	0.6
$-x^2$	0	-0.01	-0.04	-0.09	-0.16	-0.25	-0.36
e^{-x^2}	1	0.9900	0.9608	0.9139	0.8521	0.7788	0.6977

Using Simpson's rule, the area under the curve of $y = e^{-x^2}$ from $x = 0$ to $x = 0.6$ is given by

$$\frac{1}{3} \times \text{width of a strip} \times (\text{sum of first and last ordinates} + 2 \times \text{sum of other odd ordinates} + 4 \times \text{sum of even ordinates}),$$

$$= \frac{1}{3} \times 0.1 \{1 + 0.6977 + 2(0.9608 + 0.8521) + 4(0.9900 + 0.9139 + 0.7788)\}$$

$$= \frac{1}{30} (1.6977 + 2 \times 1.8129 + 4 \times 2.6827)$$

$$= \frac{1}{30} \times 16.0543 = 0.5351.$$

To 3 significant figures, the result obtained by Simpson's rule agrees exactly with that of the series integral.

Q10 (a) If $Z = -5 + j2$, express

$$\frac{1}{Z} + \frac{1}{Z + 14}$$

in the polar form $r \angle \theta$.

(b) The impedance Z of a circuit is given by

$$\frac{1}{Z} = \frac{1}{R} + j\omega C.$$

Calculate the magnitude and phase angle of Z when $R = 330$, $C = 0.42 \times 10^{-6}$, $\omega = 5000$.

A10 (a)
$$\frac{1}{Z} + \frac{1}{Z + 14} = \frac{1}{-5 + j2} + \frac{1}{9 + j2}$$

$$= \frac{-5 - j2}{(-5 + j2)(-5 - j2)} + \frac{9 - j2}{(9 + j2)(9 - j2)}$$

$$= \frac{-5 - j2}{25 + 4} + \frac{9 - j2}{81 + 4}$$

$$= \frac{85(-5 - j2) + 29(9 - j2)}{29 \times 85}$$

$$= \frac{-164 - j228}{29 \times 85}$$

$$= 0.06653 - j0.09249$$

$$= \sqrt{(-0.06653)^2 + (-0.09249)^2} \angle \tan^{-1} \frac{-0.09249}{-0.06653}$$

$$= 0.1139 \angle \tan^{-1} 1.390$$

$$\approx 0.114 \angle 234^\circ 16'.$$

(b)
$$\frac{1}{Z} = \frac{1}{R} + j\omega C$$

$$= \frac{1 + j\omega CR}{R}$$

$$\therefore Z = \frac{R}{1 + j\omega CR}$$

$$= \frac{R(1 - j\omega CR)}{1 + \omega^2 C^2 R^2}$$

Now, $\omega CR = 5 \times 10^3 \times 0.42 \times 10^{-6} \times 0.33 \times 10^3$
 $= 0.693$

and $\omega^2 C^2 R^2 = 0.48025$

$$\therefore Z = \frac{330(1 - j0.693)}{1.48025}$$

$$= 222.9 - j154.5$$

$$= \sqrt{222.9^2 + (-154.5)^2} \angle \tan^{-1} \frac{-154.5}{222.9}$$

$$= 271.2 \angle 325^\circ 16'.$$

Thus, the magnitude of Z is 271.2 and its phase angle is $-34^\circ 44'$.