SUPPLEMENT

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TEC & CGLI: GUIDANCE FOR STUDENTS

Contents

TECHNICIAN EDUCATION COUNCIL

Certificate Programme in Telecommunications

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

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

The use of calculators is permitted except where otherwise indicated.

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

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

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

TRANSMISSION SYSTEMS 2 1978–79

Students are advised to read the notes above

Q1 Insert the correct bandwidth allocated to the transmission of each type of signal

Bandwidth	*Signal*	
(a) 0–120 Hz	*Music*	**(e)**
(b) 0–300 Hz	*Commercial speech*	**(d)**
(c) 0–3·4 kHz	*Telegraphy*	**(a)**
(d) 300 Hz–3·4 kHz	*Television*	**(h)**
(e) 50 Hz–10 kHz		
(f) 50 Hz–15 kHz		
(g) 0–5 MHz		
(h) 0–5·5 MHz	*(1½ min)*	

Q2 Which of the following carrier frequencies is most suitable for the transmission of a 4 kHz bandwidth?

(a) 1 kHz *(b) 2 kHz*
(c) 4 kHz *(d) 8 kHz* *(1 min)* **(d)**

Q3 Which system of multiplexing, frequency-division or time-division, when considering the merits of bandwidth and noise, would be most appropriate in the following instances?

(a) ship–shore radio communication	**FDM**
(b) medium-wave radio broadcasting	**FDM**
(c) very-high frequency music broadcasts	**FDM**
(d) long-distance cable transmission (1½ min)	**TDM**

Q4 Which one of the following bandwidths is allotted to the 2 GHz main-band microwave system?

(a) 1800–2400 MHz
(b) 1000–2000 MHz
(c) 1700–2300 MHz
(d) 1900–2300 MHz *(1 min)* **(d)**

Q5 How many groups make up a basic supergroup?

(a) 3 *(b) 4*
(c) 5 *(d) 6* *(1 min)* **(c)**

Q6 Fig. 1 shows the stages of a single-sideband supressed-carrier amplitude-modulated signal. Enter in the table the reference of the appropriate frequency-spectrum diagram representing the signal at the points indicated by 1–4 on Fig. 1 *(1½ min)*

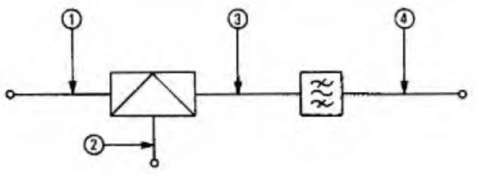
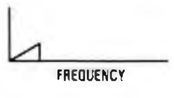
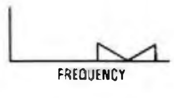


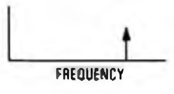
Fig. 1



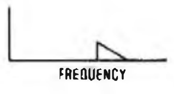
(a)



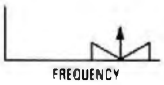
(b)



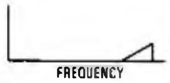
(c)



(d)



(*e*)



(*f*)

1	**(a)**
2	**(c)**
3	**(e)**
4	**(d) or (f)**

Q7 Match the descriptions of signals varying as shown in Table 1 to the type of modulation used to produce them in Table 2.

Table 1	*Table 2*	
(*a*) *both frequency and phase*	*2-level amplitude modulation*	**(f)**
(*b*) *frequency only*	*frequency-shift keying*	**(b)**
(*c*) *both amplitude and frequency*	*amplitude modulation*	**(d)**
(*d*) *amplitude only*	*phase modulation*	**(e)**
(*e*) *phase only*		
(*f*) *2 levels of amplitude*	(*1½ min*)	

Q8 Which of the following features will prevent the satisfactory transmission of digital signals over a short-distance telephone circuit switched in a public telephone exchange?

(*a*) *the exchange battery and earth*

(*b*) *the transmission bridge in the circuit at the exchange*

(*c*) *the local cable*

(*d*) *the lack of amplifiers* (*1 min*) **(b)**

Q9 Which of the changes, if applied to a frequency-modulation system, would improve its signal-to-noise ratio?

(*a*) *an increase in the modulation index*

(*b*) *a reduction in bandwidth*

(*c*) *an increase in the frequency of the carrier*

(*d*) *an increase in the amplitude of the modulating signal* (*1½ min*) **(a)**

Q10 Which of the following modulation methods, employing the same percentage modulation and the same modulating signal level, would require the smallest power amplifier for the transmission of the modulation product?

(*a*) *double-sideband amplitude modulation*

(*b*) *single-sideband amplitude modulation*

(*c*) *single-sideband suppressed-carrier amplitude modulation*

(*d*) *double-sideband suppressed-carrier amplitude modulation* (*2 min*) **(c)**

Q11 How many 4 kHz bandwidth signals can be transmitted simultaneously over a carrier system of bandwidth 48 kHz for each of the following methods of modulation?

(*a*) *double-sideband amplitude modulation* **6**

(*b*) *single-sideband amplitude modulation* **12**

(*c*) *single-sideband suppressed-carrier amplitude modulation* (*3 min*) **12**

Q12 The function of a filter is to . . . certain frequencies and attenuate unwanted frequencies.

(*a*) *amplify* (*b*) *pass*

(*c*) *select* (*d*) *trap* (*1 min*) **(b)**

Q13 Which of the following would be the correct type of cable pair to use for the transmission of a music signal?

(*a*) *lumped loaded*

(*b*) *unloaded*

(*c*) *lumped loaded and unloaded in series* (*1 min*) **(a)**

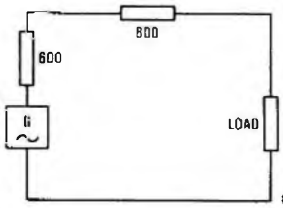
Q14 Which of the resistor values shown, when used for the load in the diagram, will allow maximum power to be transferred to the load?

(*a*) *300 Ω*

(*b*) *600 Ω*

(*c*) *900 Ω*

(*d*) *1200 Ω*



(*1½ min*) **(d)**

Q15 The function of a carrier is to provide a means of. . . .

(*a*) *increasing the amount of information carried on a cable pair*

(*b*) *changing the frequency of signals*

(*c*) *transferring information at a high frequency*

(*d*) *allowing wide-bandwidth signals to be transmitted over cable pairs* (*1 min*) **(c)**

Q16 Calculate the wavelength of a signal of frequency 1 kHz and velocity of 0·5c (where c is the speed of light). Show all working. (*2 min*)

A16 $v = f\lambda$ where v is the velocity of propagation, f is the frequency and λ is the wavelength.

$$\therefore \quad 0{\cdot}5 \times 3 \times 10^8 = 1 \times 10^3\lambda.$$

$$\therefore \quad \lambda = \frac{1{\cdot}5 \times 10^8}{1 \times 10^3}\ \text{m},$$

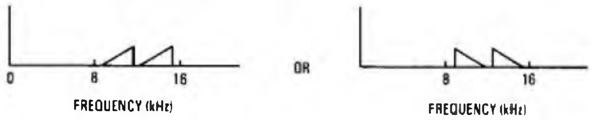
$$= \underline{150\ \text{km.}}$$

Q17 Two signals, each of bandwidth 300–3400 Hz, are to be transmitted simultaneously over the same medium, whose bandwidth is restricted to 8–16 kHz.

(*a*) *Sketch a frequency domain diagram showing approximately the position of each signal relative to zero frequency.*

(*b*) *What 2 frequencies would be suitable as carriers?* (*2½ min*)

A17 (*a*) The 2 possible diagrams are shown in the sketches



(*b*) 8 kHz and 12 kHz OR 12 kHz and 16 kHz.

Q18 Determine the practical bandwidth of a frequency modulation system whose frequency swing is 150 kHz and the modulating signal frequency is 15 kHz. Show your working. (*2 min*)

A18 Practical bandwidth $= 2(F_d + F_m)$

where F_d is the frequency deviation (that is, half of the swing) and F_m is the modulating signal frequency.

$$\therefore \quad \text{practical bandwidth} = 2\left(\frac{150}{2} + 15\right),$$

$$= \underline{180\ \text{Hz.}}$$

Q19 Calculate the number of 4 kHz bandwidth signals that may be transmitted simultaneously over a 48 kHz bandwidth circuit, using frequency modulation with a maximum frequency deviation of 8 kHz. Assume a practical bandwidth. (*4 min*)

A19 If F_d is the frequency deviation and F_m is the modulating frequency,

$$\text{bandwidth of one channel} = 2(F_d + F_m),$$

$$= 2(8 + 4) = 24\ \text{kHz.}$$

Therefore, the maximum number of signals that can be transmitted simultaneously is bandwidth available/channel bandwidth,

$$= \frac{48}{24} = \underline{2.}$$

Q20 Determine the absolute power in decibels referred to 1 mW for a signal of power 40 mW. *(3½ min)*

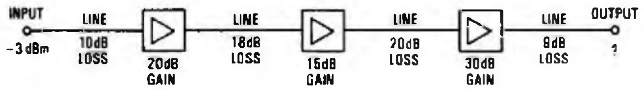
A20 Absolute power $= 10 \log_{10} \dfrac{\text{actual power}}{\text{reference power}}$,

$= 10 \log_{10} \dfrac{40}{1}$,

$= 10 \times 1{\cdot}6$,

$= \underline{+16 \text{ dBm.}}$

Q21 Determine the output power, in decibels referred to 1 mW, for the system shown in the diagram. *(4 min)*



A21 Overall line loss $= (10 + 18 + 20 + 9)$ dB $= 57$ dB.

Overall amplifier gain $= (20 + 15 + 30)$ dB $= 65$ dB.

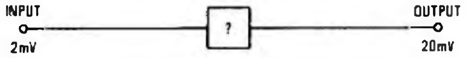
Overall gain $=$ (gain $-$ loss),

$= 65 - 57 = +8$ dB.

Output power $=$ input power $+$ overall gain,

$= -3 + 8, = \underline{+5 \text{ dBm.}}$

Q22 Determine the power gain or loss in decibels for the following circuit element. *(4 min)*



A22 Power gain $= 20 \log_{10} \dfrac{\text{output voltage}}{\text{input voltage}}$,

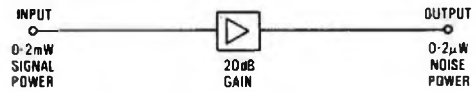
$= 20 \log_{10} \dfrac{20}{2}$,

$= 20 \log_{10} 10$,

$= \underline{20 \text{ dB.}}$

[*Tutorial note:* A negative answer would have indicated a power loss.]

Q23 Determine the signal-to-noise ratio in decibels at the output of the following circuit. *(4½ min)*



A23 If the power input is P_{in} and the power output is P_{out}, then

$$\text{power gain} = 10 \log_{10} \frac{P_{out}}{P_{in}}.$$

$$\therefore \quad P_{out} = P_{in}\left(\text{antilog}_{10} \frac{\text{power gain}}{10}\right),$$

$$= 0{\cdot}2 \times 10^{-3}\left(\text{antilog}_{10} \frac{20}{10}\right) \text{ W},$$

$$= 0{\cdot}2 \times 100 \text{ mW},$$

$$= 20 \text{ mW}.$$

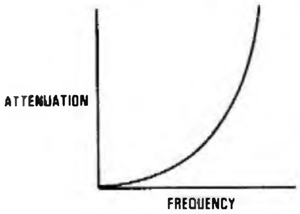
$$\text{Signal-to-noise ratio} = 10 \log_{10} \frac{\text{signal power}}{\text{noise power}},$$

$$= 10 \log_{10} \frac{20 \times 10^{-3}}{0{\cdot}2 \times 10^{-6}},$$

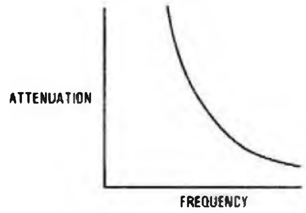
$$= 10 \log_{10} 10^5,$$

$$= \underline{50 \text{ dB.}}$$

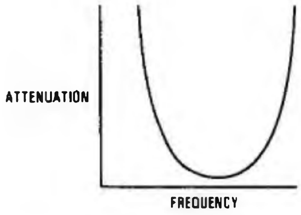
Q24 Label each of the following characteristics according to the type of filter used to produce them.



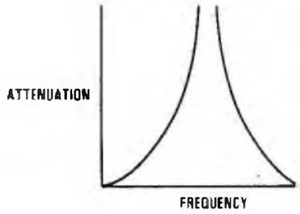
(*a*)



(*b*)



(*c*)



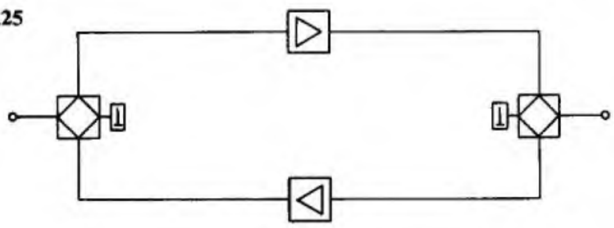
(*d*)

(1½ min)

A24 (*a*) Low pass.
(*b*) High pass.
(*c*) Band pass.
(*d*) Band stop.

Q25 Draw a block diagram of a 4-wire amplified circuit, showing both terminating units and 2 line amplifiers. *(1½ min)*

A25



Q26 Delete the incorrect items in the following statements on 2-wire–4-wire conversion units.

(*a*) *An incoming signal on the 2-wire side will lose* $\dfrac{\textit{half its}}{\textit{no}}$ *power in the balance resistor.*

(*b*) *An incoming signal on the receive side will lose* $\dfrac{\textit{half its}}{\textit{no}}$ *power in the balance resistor.* *(3 min)*

A26 (*a*) "Half its" should be deleted.
(*b*) "No" should be deleted.

Q27 Which is the most suitable circuit for conveying telephone speech signals over a cable of distance 70 km?

(*a*) *A 4-wire unamplified circuit.*
(*b*) *A 4-wire amplified circuit.*
(*c*) *A 2-wire unamplified circuit.*
(*d*) *A 2-wire amplified circuit.* *(1½ min)*

A27 (*b*) A 4-wire amplified circuit.

Q28 State whether the following statements about 4-wire amplified circuits are true or false.

(*a*) *A short-circuit across the 2-wire connexion of a terminating unit could give rise to instability.*

(*b*) *A short-circuit across one pair of wires on the 4-wire side of a terminating unit could give rise to instability.*

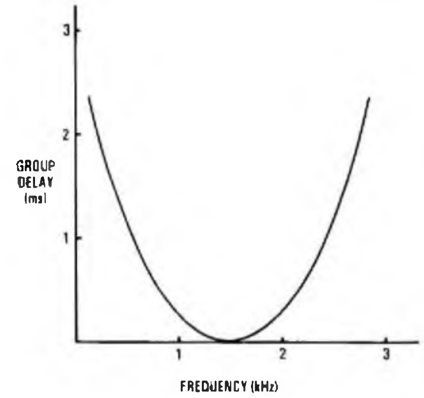
(*c*) *Replacing a section of unloaded cable with a section of the same gauge loaded cable in the 4-wire section could lead to instability.*

(*d*) *A fall in cable temperature could cause instability.* *(3 min)*

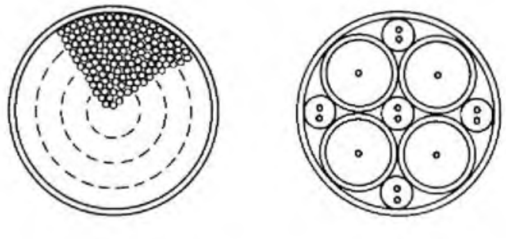
A28 (*a*) True.
(*b*) False.
(*c*) True.
(*d*) True.

Q29 *Sketch a typical group-delay response curve of a loaded cable pair.* (*1½ min*)

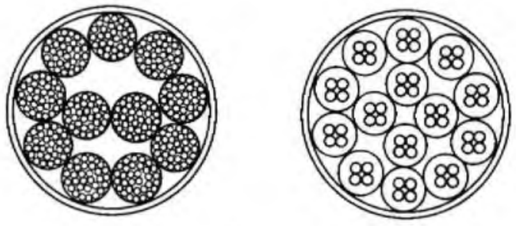
A29



Q30 *Choose from the list below the correct titles to the cables shown in cross-section in the following diagrams.*



(*a*) (*b*)



(*c*) (*d*)

(*i*) *Unit-twin external cable*
(*ii*) *Coaxial cable*
(*iii*) *Multi-pair internal cable*
(*iv*) *Multi-twin internal cable*
(*v*) *Multi-pair external cable*
(*vi*) *Multi-triple external cable*
(*vii*) *Quad external cable*
(*viii*) *Quad internal cable*

(*2 min*)

A30 (*a*) (*iii*)
(*b*) (*ii*)
(*c*) (*i*)
(*d*) (*vii*)

CITY AND GUILDS OF LONDON INSTITUTE

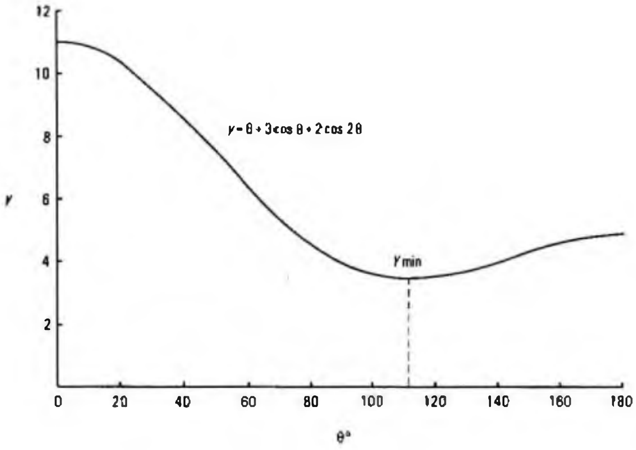
Questions and Answers

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

MATHEMATICS C 1979

Students were expected to answer any 6 questions

Q1 (*a*) *Express the function* $y = 6 + 3\cos\theta + 2\cos 2\theta$ *as a quadratic in x, where* $x = \cos\theta$.
(*b*) *Using this quadratic, or otherwise, obtain the angle* θ *between* $0°$ *and* $180°$ *for which y is a minimum. What is this minimum value?*
(*c*) *Check this minimum value by sketching the graph of* $y = 6 + 3\cos\theta + 2\cos 2\theta$ *from* $\theta = 0$ *to* $\theta = 180°$. *What is the greatest value of y?*



A1 (*a*) $y = 6 + 3\cos\theta + 2\cos 2\theta.$

$$\cos 2\theta = \cos^2\theta - \sin^2\theta,$$
$$= \cos^2\theta - (1 - \cos^2\theta),$$
$$= 2\cos^2\theta - 1.$$

Hence, the function y may be written as

$$y = 6 + 3x + 2(2x^2 - 1),$$
$$= \underline{4x^2 + 3x + 4.}$$

(*b*) $$\frac{dy}{dx} = 8x + 3 \text{ and } \frac{d^2y}{dx^2} = 8.$$

For maximum and minimum values of y, $\dfrac{dy}{dx} = 0$.

$\therefore \quad 8x + 3 = 0.$

$\therefore \quad x = -0{\cdot}375.$

Since $\dfrac{d^2y}{dx^2}$ is positive, the value of y at $x = -0{\cdot}375$ must be a minimum.

$\therefore \quad \cos\theta = -0{\cdot}375.$

$\therefore \quad \theta = \underline{112^\circ\ 1'}$ to the nearest minute.

Also $\quad y_{\min} = 4(-0{\cdot}375^2) + 3 \times -0{\cdot}375 + 4,$

$= 0{\cdot}5625 - 1{\cdot}125 + 4,$

$= \underline{3{\cdot}4375}.$

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

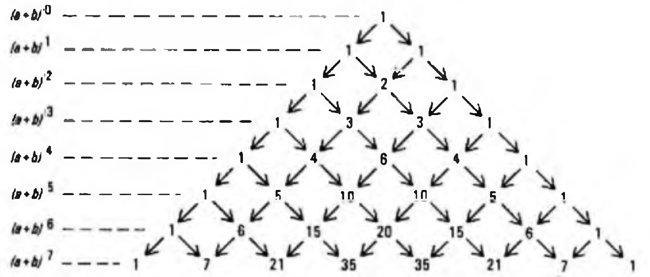
The greatest value of y within the range is $\underline{11}$.

Q2 (a) Using Pascal's triangle of coefficients, or otherwise, develop the binomial expansion of $(a + b)^7$.

(b) Using the binomial series, find to 2 significant figures the percentage error in assuming $(1{\cdot}04)^7$ *to be approximately* $1{\cdot}28$.

(c) If 7 coins are tossed simultaneously, the probability that n of them come down 'heads' is the term involving h^n *in the binomial expansion of* $(h + t)^7$, *where* $h = \frac{1}{2}$, $t = \frac{1}{2}$. *Show that the probability of 5 'heads' occurring is approximately 1 in 6.*

A2 (*a*) The coefficients of a and b in the expansion of $(a + b)^7$ are derived in the Pascal's triangle shown below.



Hence, $\quad (a + b)^7 =$

$\underline{a^7 + 7a^6b + 21a^5b^2 + 35a^4b^3 + 35a^3b^4 + 21a^2b^5 + 7ab^6 + b^7}.$

(*b*) $\quad 1{\cdot}04^7 = (1 + 0{\cdot}04)^7,$

$= 1 + 7 \times 0{\cdot}04 + 21 \times 0{\cdot}04^2 + 35 \times 0{\cdot}04^3 + 35 \times 0{\cdot}04^4 + 21 \times 0{\cdot}04^5 + 7 \times 0{\cdot}04^6 + 0{\cdot}04^7,$

$= 1 + 0{\cdot}28 + 0{\cdot}0336 + 0{\cdot}00224 + \ldots$

Since the sum of the first two terms is the approximation, the sum of all the remaining terms will be the true error. The percentage error is therefore

$$\frac{(0{\cdot}0336 + 0{\cdot}00224 + \ldots) \times 100}{1{\cdot}04^7},$$

$$\approx \frac{3{\cdot}584}{1{\cdot}04^7}.$$

It is clear that the fifth term of the expansion can only affect the fourth and higher decimal places. Since the percentage error is required to only 2 significant figures, it is reasonable to ignore the fifth and subsequent terms. Hence, the percentage error to 2 significant figures is $\underline{2{\cdot}7\%}$.

(*c*) From part (*a*), the term involving a^5 in the expansion of $(a+b)^7$ is $21a^5b^2$. Hence, the term involving h^n when $n = 5$ in the expansion of $(h + t)^7$ is $21h^5t^2$.

When $h = t = \frac{1}{2}$, this becomes

$$21(\tfrac{1}{2})^5(\tfrac{1}{2})^2 = \frac{21}{128} = \frac{1}{6{\cdot}095} \approx \frac{1}{6}.$$

Thus, the probability of 5 'heads' occurring is approximately 1 in 6.

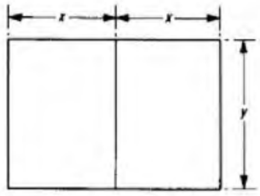
Q3 (a) A sheet of paper is so proportioned that when cut in two, each half has the same length-to-width ratio as the original sheet. Calculate the ratio.

(b) At a distance n kilometres from the sending end of a cable, the ratio of power received to the power transmitted is e^{-kn}, *where k is a constant for the cable.*

(i) Calculate k if the received power, P_n, *is 15% of the transmitted power,* P_o, *at 12 km from the sending end.*

(ii) At what distance is the power loss, $10 \log_{10}(P_o/P_n)$, *equal to 20 dB?*

A3 (*a*) Let the longer side of the sheet be $2x$ units long and the shorter side be y units long, as shown in the sketch.



The dividing line, parallel to the shorter side, then cuts the sheet into 2 halves, the shorter side of each half being x units long.

Hence, $\quad \dfrac{2x}{y} = \dfrac{y}{x}.$

$\therefore \quad x^2 = \dfrac{y^2}{2}.$

$\therefore \quad x = \dfrac{y}{\sqrt{2}},$

or $\quad \dfrac{y}{x} = 1{\cdot}4142.$

Thus, the length to width ratio is $\underline{\sqrt{2} \text{ or } 1{\cdot}414 \text{ to } 1}$.

(*b*) (*i*) $\quad \dfrac{P_n}{P_o} = e^{-kn}.$

$\therefore \quad \dfrac{15}{100} = e^{-12k}.$

Taking logarithms to base e,

$-12k = \log_e 0{\cdot}15,$

$= -1{\cdot}8971.$

$\therefore \quad k = \underline{0{\cdot}1581}.$

(*ii*) $\quad 10 \log_{10}(P_o/P_n) = 20.$

$\therefore \quad \log_{10}(P_o/P_n) = 2.$

$\therefore \quad P_o/P_n = 100.$

$\therefore \quad P_n/P_o = \dfrac{1}{100} = e^{-0{\cdot}1581n}.$

$\therefore \quad -0{\cdot}1581n = \log_e(10^{-2}),$

$= -4{\cdot}6052.$

$\therefore \quad n = \underline{29{\cdot}13 \text{ km}}.$

Q4 (a) Using the expansions for $\cos(A + B)$ *and* $\sin(A + B)$

(i) prove $\cos 2\theta = 1 - 2\sin^2\theta$,

(ii) express $\tan 2\theta$ *in terms of* $\tan\theta$, *and*

(iii) expand $\cos 4\theta$ *in powers of* $\sin\theta$.

(b) The output voltage of a modulator at a time t seconds is $18\cos 3200\pi t \cos 10^5\pi t$.

(i) Express this voltage as the sum of 2 sinusoids.

(ii) State, in kilohertz, the frequency of each sinusoid.

(iii) What is the peak voltage from the modulator?

A4 (*a*) $\quad \cos(A + B) = \cos A \cos B - \sin A \sin B$, and

$\sin(A + B) = \sin A \cos B + \cos A \sin B.$

(*i*) $\quad \cos 2\theta = \cos(\theta + \theta),$

$= \cos^2\theta - \sin^2\theta,$

$= (1 - \sin^2\theta) - \sin^2\theta,$

$= 1 - 2\sin^2\theta.$ **QED**

(*ii*) $\quad \tan 2\theta = \dfrac{\sin 2\theta}{\cos 2\theta}$

$$= \frac{2\cos\theta\cos\theta}{\cos^2\theta - \sin^2\theta},$$

$$= \frac{\dfrac{2\sin\theta\cos\theta}{\cos^2\theta}}{\dfrac{\cos^2\theta}{\cos^2\theta} - \dfrac{\sin^2\theta}{\cos^2\theta}},$$

$$\therefore \quad \tan 2\theta = \frac{2\tan\theta}{1 - \tan^2\theta}.$$

(*iii*) $\cos 4\theta = \cos(2\theta + 2\theta),$

$= \cos^2 2\theta - \sin^2 2\theta,$

$= \cos^2 2\theta - (1 - \cos^2 2\theta)$
(since $\sin^2 2\theta + \cos^2 2\theta = 1$)

$= 2\cos^2 2\theta - 1.$

But, from part (*i*)

$\cos 2\theta = 1 - 2\sin^2\theta.$

$\therefore \quad \cos^2 2\theta = (1 - 2\sin^2\theta)^2.$

Hence, $\cos 4\theta = 2(1 - 2\sin^2\theta)^2 - 1,$

$= 2(1 - 4\sin^2\theta + 4\sin^4\theta) - 1,$

$= \underline{1 - 8\sin^2\theta + 8\sin^4\theta.}$

(*b*) (*i*) Let $v = 18\cos 3200\pi t\cos 10^5\pi t,$

$= 9(2\cos 10^5\pi t\cos 3200\pi t).$

But, $2\cos A\cos B = \cos(A + B) + \cos(A - B).$

$\therefore \quad v = 9\{\cos(10^5\pi t + 3200\pi t) + \cos(10^5\pi t - 3200\pi t)\},$

$= \underline{9(\cos 103\,200\pi t + \cos 96\,800\pi t).}$

(*ii*) The general form of the equation derived in part (*i*) is $A(\cos 2\pi f_1 t + \cos 2\pi f_2 t)$ where f_1 and f_2 are the two constituent frequencies.

$\therefore \quad \underline{f_1 = 51{\cdot}6 \text{ kHz and } f_2 = 48{\cdot}4 \text{ kHz.}}$

(*iii*) The peak voltage is represented by A in the general equation and is equal to $\underline{9 \text{ V}}$.

Q5 (a) Plot the polar curve $r = 3 + 2\sin\theta$ using values of θ in steps of $\pi/6$.

(b) Show that the curve lies between two concentric circles.

(c) If the initial line $\theta = 0$ is taken as the x-axis, and the pole as the origin of cartesian co-ordinates, show that the cartesian equation of the plotted curve is $(x^2 + y^2 - 2y)^2 = 9(x^2 + y^2)$.

A5 (*a*) The values of r are derived in the table below.

θ radians	0	$\frac{\pi}{6}$	$\frac{\pi}{3}$	$\frac{\pi}{2}$	$\frac{2\pi}{3}$	$\frac{5\pi}{6}$
$\sin\theta$	0	0·5	0·866	1	0·866	0·5
$2\sin\theta$	0	1	1·732	2	1·732	1
r	3	4	4·732	5	4·732	4

θ radians	π	$\frac{7\pi}{6}$	$\frac{4\pi}{3}$	$\frac{3\pi}{2}$	$\frac{5\pi}{3}$	$\frac{11\pi}{6}$	2π
$\sin\theta$	0	−0·5	−0·866	−1	−0·866	−0·5	0
$2\sin\theta$	0	−1	−1·732	−2	−1·732	−1	0
r	3	2	1·268	1	1·268	2	3

The polar curve is shown in sketch (*a*).

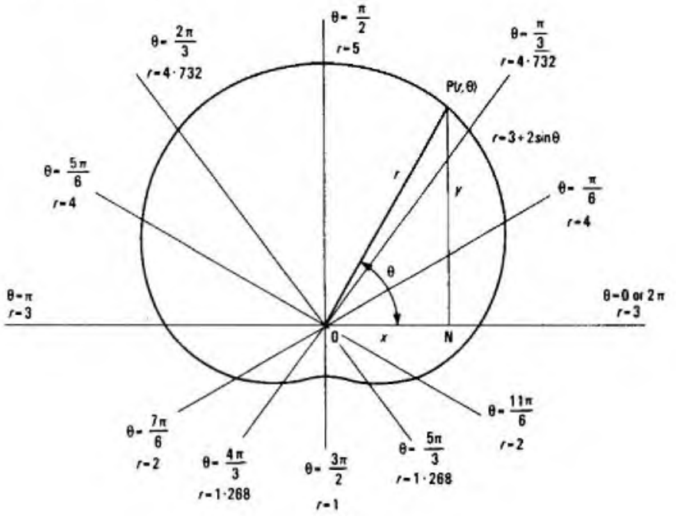
(*b*) Since $\sin\theta = \sin(\pi - \theta),$

$r_\theta = 3 + 2\sin\theta,$

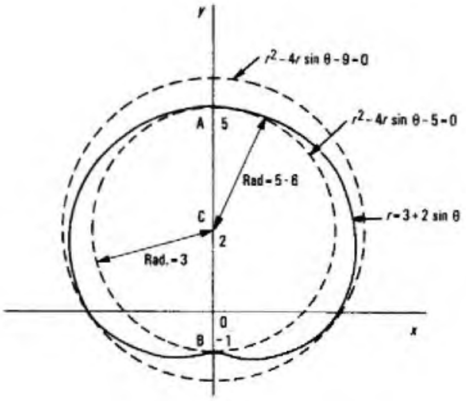
$= 3 + 2\sin(\pi - \theta) = r_{\pi-\theta}.$

Hence, the graph of $r = 3 + 2\sin\theta$ must be symmetrical about the y-axis, as is clear from sketch (*a*).

In sketch (*b*), the curve is redrawn to cut the y-axis at A and B, whose ordinates are 5 and −1 respectively. Taking C, the mid-point of AB, as centre, it is clear that concentric circles may be drawn to circumscribe and inscribe the polar curve. The limiting curves are shown in the sketch, but it is clear that any number of circles could be drawn.



(*a*)



(*b*)

(*c*) Referring to sketch (*a*), let P (r, θ) be any point on the curve. Then, if PN is the perpendicular dropped to the x-axis,

$$PN = y = r\sin\theta.$$

Also, in triangle PON,

$$r^2 = ON^2 + PN^2,$$
$$= x^2 + y^2.$$

But,

$$r = 3 + 2\sin\theta,$$
$$= 3 + 2\frac{y}{r}.$$

$\therefore \quad r^2 = 3r + 2y.$

$\therefore \quad x^2 + y^2 = 3\sqrt{(x^2 + y^2)} + 2y.$

$\therefore \quad x^2 + y^2 - 2y = 3\sqrt{(x^2 + y^2)}.$

$\therefore \quad (x^2 + y^2 - 2y)^2 = 9(x^2 + y^2).$ **QED**

Q6 (a) State and prove a formula for differentiating the quotient of two functions. State without proof the corresponding formula for differentiating the product of two functions.

(b) Differentiate with respect to x, the functions

(i) $y = x^3e^{-2x}$, and

(ii) $y = \dfrac{2x - 5}{(x - 3)^2}$.

(c) Sketch the graph of ONE *of the functions differentiated in part (b).*

Q7 (a) If $y = x^2\cos x$, show that

$$x^2\frac{d^2y}{dx^2} - 4x\frac{dy}{dx} + y(x^2 + 6) = 0.$$

(b) An object placed u centimetres from a convex lens of focal length f centimetres forms an image v centimetres beyond the lens, given by the formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$. *Express u + v in terms of u and f only, and hence prove that as u varies the minimum distance between object and image is 4f centimetres.*

A7 (*a*)

$$y = x^2 \cos x.$$

$$\frac{dy}{dx} = x^2(-\sin x) + 2x \cos x,$$

$$= x(2 \cos x - x \sin x).$$

$$\frac{d^2y}{dx^2} = x\left\{-2 \sin x - \frac{d}{dx}(x \sin x)\right\} + 2 \cos x - x \sin x,$$

$$= -2x \sin x - x(x \cos x + \sin x) + 2 \cos x - x \sin x,$$

$$= -3x \sin x - x^2 \cos x - x \sin x + 2 \cos x,$$

$$= -4x \sin x - x^2 \cos x + 2 \cos x.$$

Hence, $x^2 \frac{d^2y}{dx^2} - 4x\frac{dy}{dx} + y(x^2 + 6) =$

$$x^2(-4x \sin x - x^2 \cos x + 2 \cos x) - 4x\{x(2 \cos x - x \sin x)\} + x^2 (\cos x)(x^2 + 6),$$

$$= -4x^3 \sin x - x^4 \cos x + 2x^2 \cos x - 8x^2 \cos x + 4x^3 \sin x + x^4 \cos x + 6x^2 \cos x,$$

$$= \sin x(-4x^3 + 4x^3) + \cos x(-x^4 + x^4 + 2x^2 - 8x^2 + 6x^2),$$

$$= 0 \qquad \text{QED}$$

(*b*)

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}.$$

$$\therefore \quad \frac{1}{v} = \frac{1}{f} - \frac{1}{u},$$

$$= \frac{u - f}{uf}.$$

$$\therefore \quad v = \frac{uf}{u - f}. \qquad \ldots\ldots (1)$$

Also, $\frac{u + v}{uv} = \frac{1}{f}$.

$$\therefore \quad u + v = \frac{uv}{f}.$$

Hence, substituting for v in equation (1) gives

$$u + v = \frac{u}{f} \times \frac{uf}{u - f},$$

$$= \underline{\frac{u^2}{u - f}}.$$

Let $y = u + v$.

Then $y = \frac{u^2}{u - f}$.

$$\therefore \quad \frac{dy}{du} = \frac{(u - f)2u - u^2}{(u - f)^2},$$

$$= \frac{u^2 - 2uf}{(u - f)^2}.$$

But, for a maximum or minimum value of y, $\frac{dy}{du} = 0$.

$$\therefore \quad \frac{u^2 - 2uf}{(u - f)^2} = 0.$$

$$\therefore \quad u^2 = 2uf.$$

$$\therefore \quad u = 2f$$

$$\frac{d^2y}{du^2} = \frac{(u - f)^2(2u - 2f) - (u^2 - 2uf)2(u - f)}{(u - f)^4},$$

$$= \frac{2(u - f)^2 - 2(u^2 - 2uf)}{(u - f)^3},$$

$$= \frac{2u^2 - 4uf + 2f^2 - 2u^2 + 4uf}{(u - f)^3},$$

$$= \frac{2f^2}{(u - f)^3}.$$

When $u = 2f$, $\quad \frac{d^2y}{du^2} = \frac{2f^2}{f^3} = \frac{2}{f}$.

Since f is positive, $\frac{d^2y}{du^2}$ is positive and hence a minimum value of y obtains when $u = 2f$.

Therefore,

$$y_{\min} = \frac{u^2}{u - f},$$

$$= \frac{4f^2}{2f - f},$$

$$= 4f.$$

Therefore the minimum distance between the object and the image, $y = u + v$, is $4f$ centimetres.

Q8 (*a*) *Evaluate*

(*i*) $\int_0^{1\cdot5}(2x - 3)^2\, dx$, *and*

(*ii*) $\int_4^7 \frac{dx}{2x - 7}$.

(*b*) *Calculate the volume of revolution generated when the curve* $y = x^2$ *from* $x = 0$ *to* $x = 3$ *rotates through 360° about the y-axis.*

A8 (*a*) $\int_0^{1\cdot5}(2x - 3)^2\, dx = \int_0^{1\cdot5}(4x^2 - 12x + 9)\, dx,$

$$= \left[\frac{4x^3}{3} - 6x^2 + 9x\right]_0^{1\cdot5},$$

$$= \frac{4 \times 1\cdot5^3}{3} - 6 \times 1\cdot5^2 + 9 \times 1\cdot5,$$

$$= 4\cdot5 - 13\cdot5 + 13\cdot5,$$

$$= \underline{4\cdot5.}$$

(*ii*)

$$\int_4^7 \frac{dx}{2x - 7} = \left[\tfrac{1}{2} \log_e (2x - 7)\right]_4^7,$$

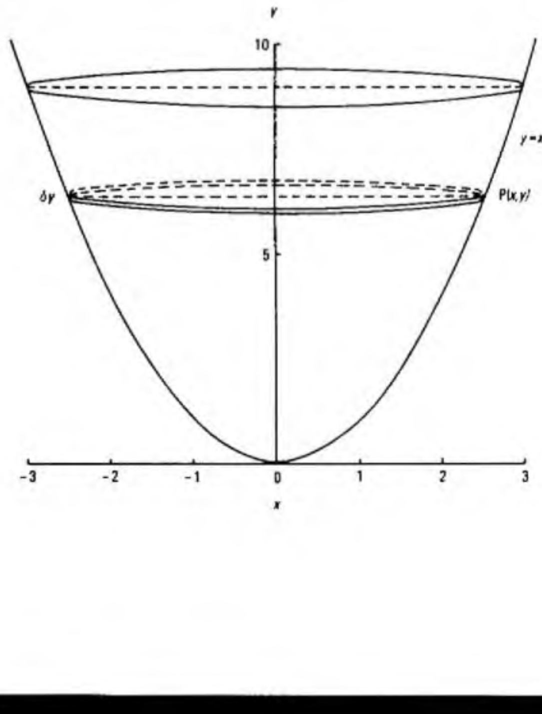
$$= \tfrac{1}{2}\{\log_e (14 - 7) - \log_e 1\},$$

$$= \tfrac{1}{2} \log_e 7,$$

$$= \tfrac{1}{2} \times 1\cdot9459.$$

$$= \underline{0\cdot97295.}$$

(*b*) The curve of $y = x^2$ plotted from $x = 0$ to $x = 3$ is shown in the sketch.



When the curve is rotated through 360° about the y-axis it will form a solid symmetrically disposed about the y-axis, of the shape depicted in the sketch.

Let $P(x, y)$ be any point on the curve between $x = 0$ and $x = 3$. As this point rotates with the curve, it traces out a circle of radius x and area πx^2. A point at a distance δy and very close to P will similarly trace out a circle so that the two circles generate a thin lamina of approximate area $\pi x^2\ \delta y$.

Hence, the total volume of the solid from $x = 0$ to $x = 3$ is given by

$$\sum_{x=0}^{x=3} \pi x^2\ \delta y = \int_{x=0}^{x=3} \pi x^2\ dy,$$

$$= \pi \int_{x=0}^{x=3} y\ dy,$$

$$= \pi \int_0^9 y\ dy,$$

$$= \pi \left[\frac{y^2}{2}\right]_0^9,$$

$$= \pi \times \frac{81}{2},$$

$$= \underline{127 \cdot 23 \text{ units}^3}.$$

Q9 (a) Use Simpson's rule with 5 ordinates to evaluate $\int_0^{1\cdot 2} 5e^{2x}\,dx$ to 3 significant figures.

(b) Calculate for the function $v = 40 \cos 100\pi t$

(i) the mean value, and
(ii) the root-mean-square value

from $t = 0$ to $t = 15 \times 10^{-3}$. You may find it useful to substitute $\theta = 100\pi t$ in the integration process.

Q10 *A circuit consists of branches A and B connected in parallel across a source of 6 V RMS and frequency 1592 Hz (10^4 rad/s).*
Branch A has an 80 Ω resistance in series with a 4 mH inductance.
Branch B has a 60 Ω resistance in parallel with a 2 μF capacitance.

(a) Express in the phasor form $a + jb$
(i) the impedance of branch A, and
(ii) the admittance of branch B
at this frequency.

(b) Calculate the total RMS current taken from the supply and its phase relative to that of the applied voltage.

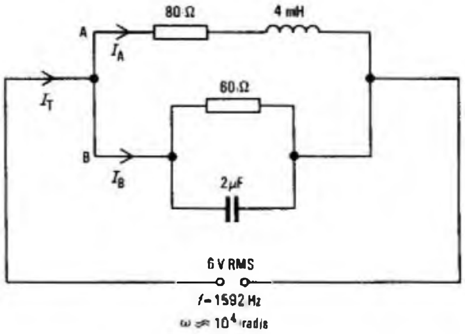
A10 The circuit diagram of the arrangement is shown in the sketch.

(*a*) (*i*) The impedance of branch A, Z_A,

$$= R + j\omega L,$$

$$= 80 + j10^4 \times 4 \times 10^{-3},$$

$$= \underline{80 + j40\ \Omega}.$$



(*ii*) The admittance of branch B, Y_B,

$$= \frac{1}{Z_B},$$

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

$$= \frac{1}{60} + j10^4 \times 2 \times 10^{-6},$$

$$= \underline{0 \cdot 01\dot{6} + j0 \cdot 02\ S}.$$

(*b*) Let V be the source RMS voltage and I_A and I_B be the respective RMS currents in branches A and B.

Then, $I_T = I_A + I_B$, where I_T is the total current,

$$= \frac{V}{Z_A} + VY_B,$$

$$= V\left(\frac{1}{80 + j40} + 0 \cdot 01\dot{6} + j0 \cdot 02\right),$$

$$= V\left(\frac{80 - j40}{80^2 + 40^2} + 0 \cdot 01\dot{6} + j\,0 \cdot 02\right),$$

$$= V(0 \cdot 01 - j0 \cdot 005 + 0 \cdot 01\dot{6} + j0 \cdot 02),$$

$$= V(0 \cdot 02\dot{6} + j0 \cdot 015).$$

But, $V = 6$ V.

$$\therefore \quad I_T = 6\sqrt{(0 \cdot 02\dot{6}^2 + 0 \cdot 015^2)}\ \angle \tan^{-1} \frac{0 \cdot 015}{0 \cdot 02\dot{6}},$$

$$= 6\sqrt{(0 \cdot 0007111 + 0 \cdot 000225)}\ \angle \tan^{-1} 0 \cdot 5625,$$

$$= 6 \times 0 \cdot 030596\ \angle 29^\circ\ 21',$$

$$= 0 \cdot 1836\ \angle 29^\circ\ 21'.$$

Thus, the total RMS current is $\underline{0 \cdot 1836\text{ A}}$ lagging the applied voltage by $\underline{29^\circ\ 21'}$.

TELEGRAPHY B 1979

Students were expected to answer any 6 questions

Q1 *Consider 2 separate circuits, one consisting of a battery, a switch and a capacitor in series with a resistor, the other consisting of a battery, a switch and an inductor in series with a resistor.*

(a) Using time constants, plot graphs to show the change in current with time in EACH circuit from the instant when the switch is closed.

(b) Explain the significance of the graphs in relation to the transmission of telegraph signals by direct current.

A1 (*a*) Sketches (*a*) and (*b*) show the 2 circuit configurations. Sketches (*c*) and (*d*) show how the current, I, changes with time for the inductive circuit and for the capacitive circuit, respectively.

If a battery is connected to a circuit containing resistance and inductance, the inductance of the circuit generates an EMF in the circuit while the current is changing. When the switch is closed current immediately begins to increase; the changing current generates a back-EMF in the inductance which, according to Lenz's law, opposes the change in current; that is, it opposes the EMF, E. The current increases gradually depending on the time-constant of the circuit; that is, the current increases to approximately 63% of its final value in a time:

$$t = \frac{L}{R},$$

where t is time in seconds, L is the inductance in henrys and R is the resistance in ohms.

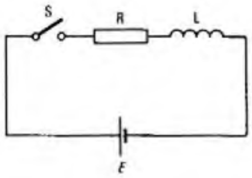
For the second period of time t the current will again increase to about 63% of the remainder; that is, to a value of $\{0 \cdot 63 + (0 \cdot 63 \times 0 \cdot 37)\}\ I = (0 \cdot 63 + 0 \cdot 23)I = 0 \cdot 86I$. The graph can be sketched for values of t, $2t$, $3t$ etc., to reach the steady value of current:

$$I = \frac{E}{R}$$

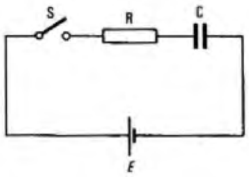
For the capacitive circuit, the current varies as the capacitor, value C farads, charges. When the switch is closed with the capacitor uncharged, the current is limited only by the resistor and has the value:

$$I = \frac{E}{R}$$

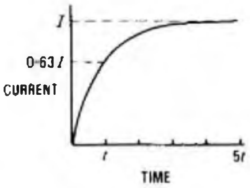
As the charge on the capacitor increases, the voltage across the



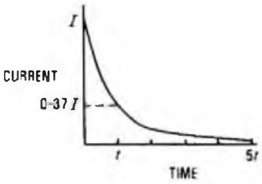
(*a*)



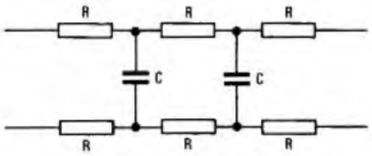
(*b*)



(*c*)



(*d*)



(*e*)

capacitor plates opposes the flow of current, causing it to decrease. The rate of decrease depends on the time-constant:

$$t = CR$$

and the current decreases to approximately 37% of its initial value in time t seconds. The graph can be sketched for values of t, $2t$ etc. to reach a steady value of zero current as the capacitor becomes fully charged.

(*b*) The significance of sketch (*c*) is that the resistor and inductor may represent the telegraph line and the teleprinter RECEIVE magnet, respectively. The inductance prevents the current in the magnet from increasing quickly, and thus affects the speed of signalling. Corrective measures, such as the use of high signalling voltages, increased resistance to improve the time-constant and the provision of a shunted-capacitor signal-shaping network, are employed to improve the circuit.

The main characteristics of underground cables which affect telegraph signals are resistance and capacitance, and a long telegraph line may be represented by a large number of π-networks connected in tandem as shown in sketch (*e*). The effect of the capacitance shown in sketch (*d*) is that, when a signal is connected to a line, the initial flow of current is large at the transmitter but, at the receiver, the growth of current is delayed by the effect of the distributed capacitance and resistance of the line. If the line is long, there is a short interval after the connexion of the signal before the received current is detectable. Double-current working enables signals to be sent more rapidly as the reversal of polarity during signalling hastens the discharge and re-charge of the line capacitance. The battery must be of low impedance to allow the high initial surge of current at the transmitter.

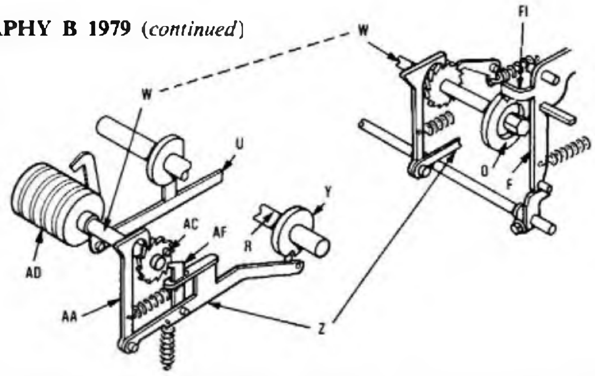
Q2 (*a*) *Explain, with the aid of sketches, the basic operation of the answerback mechanism of a teleprinter.*

(*b*) (*i*) *How does the originating operator request the distant answerback?*

(*ii*) *If the the originating teleprinter has a local record, describe how the answerback is prevented from operating to the local record signal.*

A2 (*a*) The answerback mechanism of a British Post Office Teleprinter No. 15 is shown in the sketch. The answerback drum, AD, which is detachable and can be changed, contains 20 characters, each character consisting of one row of 5 plastic teeth. Each tooth may be broken off or not, depending on whether a MARK or SPACE element is to be transmitted. In this way, the answerback code may be set up before the answerback drum is fixed to shaft W on the teleprinter.

The answerback mechanism is started on the receipt of the character 'J' when the machine is in the figure-shift mode. The detection of the character causes a release arm to release the clutch driving the cam-sleeve, R; a separate linkage moves the selecting levers clear of the sequential levers, U, to prevent keyboard operation from interfering with the answerback transmission.



As the cam-sleeve, R, rotates, feed cam, Y, moves lever Z to cause ratchet AA to move one tooth, to present the first character on the answerback drum to the sequential levers, U. Further rotation of R causes the 5 sequential levers U, (one per character element) to move forward in turn to sense the pattern of teeth across the answerback drum. The blocked and free conditions encountered control the common frame and the striker to produce the required MARK and SPACE condition and apply the signal to line from the transmitter.

Lever FI is lifted out of the cut-out on disc O at the start of the operation and rests on the disc to maintain the trip action which allows transmission to continue. As the answerback code is transmitted, disc O rotates until lever FI falls into the cut-out. This stops cam-sleeve R and unlocks the keyboard. The answerback drum takes one more step under the control of pawl AF. This action causes a row of blanks on the drum to move opposite the reading ends of sequential levers, U, so enabling the levers to come under the control of the keyboard.

(*b*) The operator requests the distant answerback by depressing the WHO ARE YOU (WRU) key. This transmits the characters FIGURE-SHIFT and J to the distant teleprinter. When the WRU key on the keyboard is operated, an extension of the key falls into a notch on a comb-bar operated by any other key, and a tooth on the WRU extension operates a comb-bar not operated by other keys. This inhibit combination operates an inhibit lever which, by linkages, pivots a pawl anticlockwise so that the movement of the release arm in response to the answerback code is ineffective.

Q3 *A private telegraph circuit, working 2-way simplex (half-duplex), is routed over a physical circuit in a telephone cable and is terminated by a teleprinter at each end. With the aid of a circuit diagram explain the need for and the operation of*

(*a*) *the spark-quench circuit in the transmit line,*

(*b*) *the filter in the send circuit, and*

(*c*) *the receive line termination.*

Q4 (*a*) *Describe, with the aid of diagrams,* THREE *tests which may be applied to an electromagnetic telegraph relay to verify that it will function satisfactorily.*

(*b*) *Describe briefly the features of a mercury-wetted telegraph relay which eliminate the disadvantages of earlier types of telegraph relay.*

(*b*) See A10, Telegraphy B 1976, *Supplement*, Vol. 70, p. 40, July 1977.

Q5 *A teleprinter message is to be transmitted simultaneously to two stations.*

(*a*) *Draw circuit diagrams and explain how this may be accomplished over*

(*i*) *a broadcast network, and*
(*ii*) *a conference network.*

(*b*) *Describe briefly the limitations of* EACH *method of working.*

Q6 (*a*) *With the aid of timing diagrams explain the meaning of the following as applied to a 75 baud, 7½ unit, start-stop telegraph signal.*

(*i*) *10% early distortion, and*
(*ii*) *30% late distortion.*

(*b*) (*i*) *Describe the difference between start-stop and isochronous (synchronous) distortion measurements.*

(*ii*) *Under what circumstances would* EACH *type of measurement be used?*

A6 (*a*) A 75 baud, 7½ unit start-stop signal consists of one start element, 5 character elements and a stop signal equal to 1½ character elements. Each character element has a duration of

$$\frac{1000}{75} = 13 \cdot 33 \text{ ms.}$$

Each character has a duration of

$$7 \cdot 5 \times 13 \cdot 33 = 100 \text{ ms.}$$

A character consisting of alternate mark and space elements is shown in sketch (*a*). A telegraph signal is a change or transition from one polarity to another, and distortion is defined as the amount by which a received signal is displaced in time as compared with an ideal signal. Sketch (*b*) shows the third transition is early as compared with the ideal instant of restitution. The distortion is calculated as a percentage of the duration of one character element and sketch (*b*) shows the third transition occurring 1·33 ms early; that is, distortion

$$= \frac{13 \cdot 33}{1 \cdot 33} \times 100 = 10\% \text{ early.}$$

Similarly sketch (*c*) shows the fifth element occurring 4 ms late; that is,

$$\text{distortion} = \frac{4}{13 \cdot 33} \times 100 = 30\% \text{ late.}$$

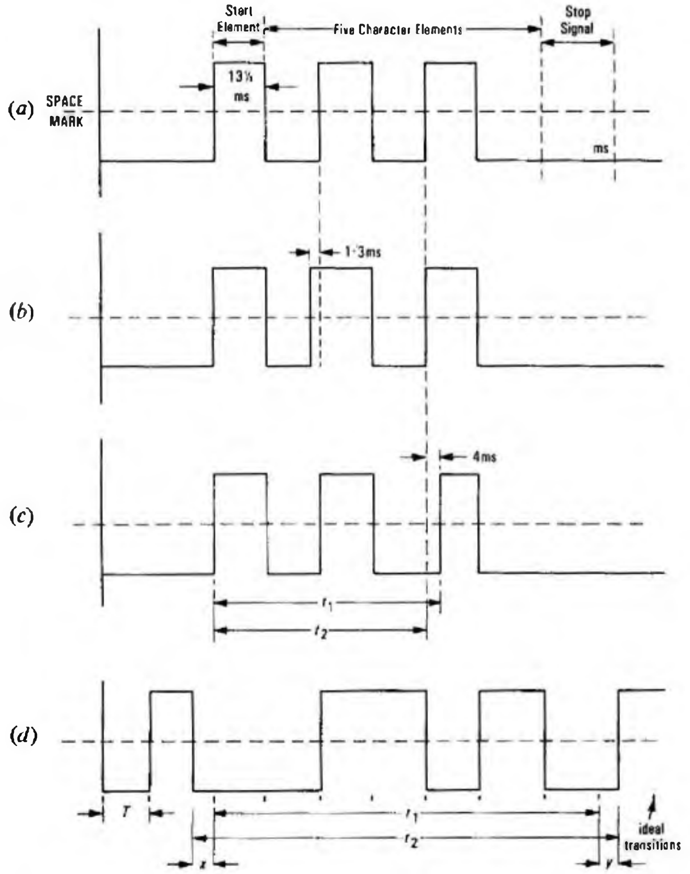
The distortion quoted for any given signal is the maximum early or late distortion displayed by that signal. For sketch (*c*) other elements could be distorted by, say 5% early and 17% early, but the distortion quoted would be the maximum of 30% early.

(*b*) (*i*) Start-stop distortion is measured from the beginning of the START element and for sketch (*c*) may be represented as $t_2 - t_1$. Start-stop distortion is defined as the ratio of the maximum measured difference between the actual and theoretical intervals separating any significant instant of modulation from the significant instant of the START element immediately preceding it to the unit interval.

Isochronous distortion measurements are made on synchronous signals and, as there is no START element to act as a datum, isochronous distortion is quoted as the sum of the maximum early and the maximum late distortion observed over any given period, expressed as a percentage of a unit element. This is illustrated in sketch (*d*), where the distortion is $x + y$. If $x = 1 \cdot 5$ ms early and $y = 2 \cdot 5$ ms late, the distortion in the case of a 75 baud signal would be:

$$\frac{1 \cdot 5 + 2 \cdot 5}{13 \cdot 3} \times 100 = 30\%.$$

Isochronous distortion is defined as the ratio to the unit interval of the maximum measured difference between the actual and theoretical intervals separating any 2 significant instants of modulation, these instants being not necessarily consecutive.



As shown in sketch (*d*), isochronous distortion

$$= \frac{t_2 - t_1}{T} \times 10\%.$$

(*ii*) Start-stop distortion measurements would be taken on a circuit carrying teleprinter signals; the signals consist of random traffic as opposed to regular 1 : 1 or 2 : 2 signals. Isochronous measurements are normally taken when testing a multi-channel voice-frequency circuit, when synchronous signals are used.

Q7 *A mains-dependent power supply is to be provided for a subscriber's teleprinter station.*

(*a*) *Draw a circuit diagram and explain the operation of the equipment providing*

(*i*) *±80 V for signalling, and*
(*ii*) *6 V for supervisory lamps.*

(*b*) *What arrangements are made to protect against faults causing damage to the unit or wiring?*

Q8 (*a*) *Describe two methods of handling and transmitting an inland telegram.*

(*b*) *Compare the advantages and disadvantages of sending a message by telegram with sending a message by Telex.*

A8 (*a*) See A3(*a*), Telegraphy B 1978, *Supplement*, Vol. 72, p. 62, Oct. 1979.

(*b*) The advantages and disadvantages of sending a message by telegram as compared with Telex are listed below.

Telegram	Telex
Advantages	
May be sent to any person whether a Telex subscriber or not.	There is direct access to all Telex users with instant assurance that the message has been received.
No skill is required by the customer.	Alarm facilities to draw attention to priority messages.
No delays due to congestion or the distant subscriber being engaged.	Operation can be in a conversational mode.
The handling Authority takes the responsibility for handling.	Messages can be transmitted when the distant office is unoccupied.
The message is paid for as required.	Multiple copies can be received.
Greetings and special deliveries may be arranged.	Economical for large numbers of messages.
Disadvantages	
High cost if many messages are sent.	High rental costs.
There is no assurance that the message has reached its destination.	Some skill required by the operator.
Slower service than Telex.	Limited access; that is, only to other Telex subscribers.
There may be errors caused by the handling Authority.	

Q9 *For a multi-channel voice-frequency telegraph system:*

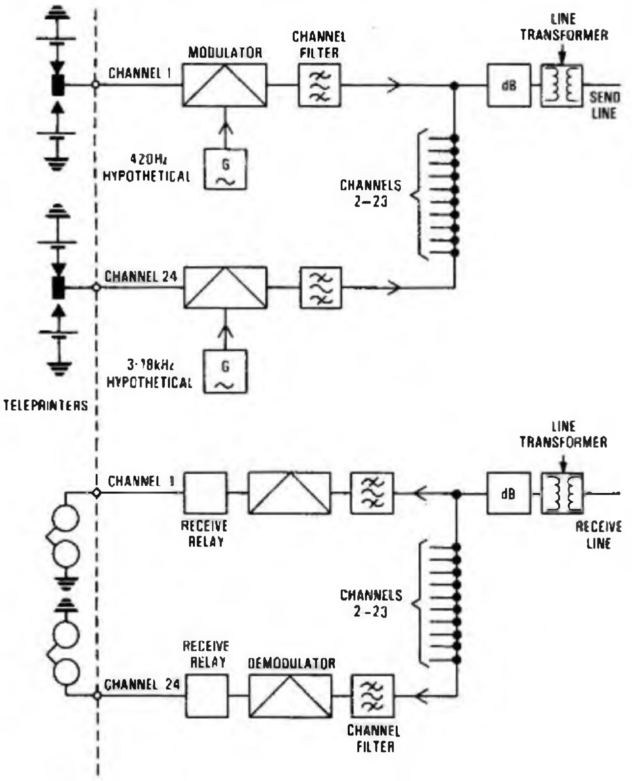
(*a*) *Explain the use and describe briefly the operation of:*

(*i*) *the transmit and receive filters,*
(*ii*) *a modulator, and*
(*iii*) *a frequency generator.*

(*b*) *What bandwidth is normally allocated to any channel on the system and why has this value been chosen?*

A9 (*a*) The basis of a multi-channel voice-frequency (MCVF) telegraph system is the division of the available frequency bandwidth of a telephone channel into a large number (up to 24) of narrow frequency bands each capable of carrying telegraph signals. A different frequency is allocated to each telegraph channel and all the frequencies generated by each channel are mixed before transmission to line; at the distant terminal the frequencies appropriate to each channel are separated and the telegraph signals detected. The sketch shows the equipment at each end of a telephone bearer circuit used for a MCVF system.

(*i*) The channels are separated electrically by the use of band-pass filters, each of which permits signals within a narrow band of frequencies to pass, whilst severely attenuating signals outside the band. Filters are provided at the output of each channel, before the channels are combined, so that only the signals of the required frequency are transmitted to line. The filter restricts the sidebands of the modulated



carrier frequency, offers high impedance to line at the operating frequencies of other channels, so that one channel does not draw appreciable energy from other channels, and prevents the transmission of unwanted harmonics which may be present. Similar filters are also provided at the RECEIVE terminal of the system to select the band of frequencies required for the particular channel.

(*ii*) Each telegraph channel must occupy a band of frequencies different from any other channel in order that the separate channels may be separated by the receive filters. Each DC input is, however, similar and, in order to give each channel its individual characteristic, the DC signal is mixed with an AC signal at the frequency appropriate to the channel. This process is known as *modulation*, whereby the DC signal modulates an AC carrier signal. The DC MARK and SPACE signals cause diodes in the modulator either to conduct or not to conduct so as to switch inductance and capacitance in parallel with a transformer to swing the oscillator frequency about the nominal value. In this way the frequency of the AC signal sent to line varies above and below the hypothetical frequency chosen for that channel.

(*iii*) Carrier frequencies are normally generated by transistor oscillators which give a sine-wave output with a frequency stability of ± 1 Hz and a frequency adjustment range of 6 Hz. The oscillator normally forms part of an oscillator-modulator and its basic, or hypothetical, frequency is not transmitted. The oscillator is always operating either at the MARK frequency or the SPACE frequency, depending on the DC input.

(*b*) The telephone bearer circuit has an available bandwidth of 300–3400 Hz which can be used to accommodate up to 24 telegraph circuits, each occupying a bandwidth of 120 Hz. A bandwidth of 420–3180 Hz is normally used to allow for the response of telephone amplifiers.

A square-wave telegraph signal may be considered as consisting of the sum of the fundamental frequency of the signal and all the odd harmonics of that frequency. When such a signal is used to modulate a carrier frequency, it is only necessary to transmit the signal resulting from the carrier frequency and the sidebands of the fundamental frequency. With a carrier frequency of, say, 900 Hz and modulating telegraph signals at a speed of 50 bauds, the products of modulation would include the 900 Hz carrier frequency and the side-frequencies 900 ± 25 Hz, 900 ± 75 Hz, 900 ± 125 Hz etc. The first side-frequencies only are required; these have a bandwidth of 50 Hz and a channel spacing of 120 Hz allows a conservative design of the system.

Q10 *For an apparatus rack suitable for carrying* ONE *type of main switching equipment in an automatic Telex exchange.*

(*a*) *Give a sketch to show the rack dimensions and the various items of equipment to be accommodated.*

(*b*) *Show how power supplies are connected and distributed.*

(*c*) *Describe the cabling to equipment* EITHER *preceding* OR *succeeding the rack in the switching sequence.*

TELEPHONY C 1979

Students were expected to answer any 6 questions

Q1 (*a*) *With reference to a national STD network, state what is meant by line signalling. Give the types of switching centres in the network between which line signalling is used in conjunction with some other type of signalling.*

(*b*) *What are the advantages and disadvantages of using 3825 Hz as a line-signalling frequency compared with 2280 Hz for long-distance signalling?*

(*c*) *State* ONE *advantage and* ONE *disadvantage of* EACH *of the following three types of signalling-system concepts:*

(*i*) TONE ON *indicating the idle condition,*

(*ii*) TONE ON *indicating the occupied or seized condition, and*

(*iii*) *continuous tone not being used, all signalling changes being conveyed in tone-pulse form.*

A1 (*a*) Line signalling is the passing of signals over a circuit between exchanges, such signals indicating, typically, circuit seizure (in the forward direction), circuit clear (in the forward direction), release guard (in the backward direction), called-subscriber answer (in the backward direction), called-subscriber clear (in the backward direction), and backward busy.

Such signals are concerned only with the seizure, release and supervisory-repetition aspects of circuits between exchanges, and not with the dialled information (whether in Strowger pulsing or multi-frequency form) that needs to be passed between exchanges. Line signalling is normally used over long-distance DC-signalling and high-frequency-carrier plant.

Line signalling is mainly used on main-network circuits between group switching centres, transit switching centres, central switching units and sector switching centres (the last two applying only to director areas). In addition, line signalling may be used on junction circuits between local exchanges and group switching centres where ordinary 2-wire loop-disconnect signalling cannot be used.

(*b*) The advantages of 3825 Hz as a line-signalling frequency are:

(*i*) the voice-frequency receiver can be simple, since voice immunity is not required,

(*ii*) signalling can take place in either direction while the circuit is being used for speech (for example, periodic metering pulses), and

(*iii*) the outgoing and incoming relay-sets can be relatively simple, as tone-recognition and timing functions are not required.

The disadvantages are:

(*i*) accurate band-pass filters are needed in the signalling terminations,

(*ii*) accurate channel spacing is necessary to ensure that the 3825 Hz signalling frequency does not interfere with the adjacent channel higher in the frequency spectrum, and

(*iii*) the signalling-system equipment is split between the line relay-sets and the signalling terminations in the repeater station, leading to less efficient use of space and possible difficulty in proving the location of faults.

(*c*) (*i*) One advantage of TONE ON IDLE signalling is that automatic backward busying is given during interruption of the transmission path. One disadvantage is that transient bursts of interference in the transmission path may give rise to false dial pulses.

(*ii*) One advantage of TONE ON OCCUPIED signalling is that short interruptions of the transmission path do not result in the seizure of idle equipment. One disadvantage is that automatic backward busying is not given during interruption of the path.

(*iii*) One advantage of tone-pulse signalling is that all the signalling-system logic is contained in one relay-set at each end, leading to reduced space requirements and easier fault-location. One disadvantage is that the voice-frequency receiver has to be more complex, as voice immunity is required.

Q2 (*a*) *Sketch a circuit, using one transistor to operate a relay, meeting the* THREE *requirements in the table.*

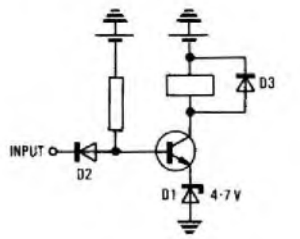
Input Relative to Earth	*Resultant Relay State*
5 V or less	*Released*
15 V or more	*Operated*
Disconnected	*Operated*

(*b*) *Explain how the circuit functions.*

(*c*) *State* ONE *reason for using a transistor in the circuit.*

(*d*) *How could the transistor be protected from damage due to a momentarily excessive input voltage?*

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



(*b*) With the input disconnected, the relay will be operated, as the transistor is turned on by virtue of the +50 V supply connected via the resistor.

If the input is connected to any potential between earth and +5 V, diode D2 will be forward-biased and, consequently, that potential will appear at the base of the transistor. The transistor will therefore be turned off and the relay released, as a potential in excess of +5 V is needed at the base to turn the transistor on. This is due to the presence of Zener diode D1, which effectively raises the base threshold voltage of the transistor to something in excess of +5 V.

If the input is connected to a potential above +15 V, the transistor will be turned on and the relay operated, as the base potential will be at approximately +5 V; diode D2 will be reverse-biased and the circuit will behave as if the input were disconnected.

(*c*) A transistor gives good sensitivity in relation to the input threshold voltages at which the relay will operate, and its release can also be set accurately. A simple relay circuit gives too wide a margin on the input voltages due to the wide tolerance of relay characteristics.

(*d*) The transistor is automatically protected against excessive input voltages by diode D2, which is reverse-baised for all input potentials above +5 V (approximately). This assumes diode D2 has a large reverse-bias breakdown voltage.

(Diode D3 protects the transistor from back-EMF produced by the relay upon its release.)

Q3 *Individually-coded calling signals from a radio-telephone system of mobile subscribers are signalled to the public-exchange control equipment via a two-channel signalling link. The calling signal from a mobile occupies either one of the channels for 330 ms. Assuming that calls originating when the signalling channels are busy are lost, how many mobile busy-hour call-attempts can the link deal with if the probability of finding both channels occupied when a random call is originated must not exceed* 4×10^{-4}*?*

A3 The probability of finding both channels occupied is the same as the grade of service, B, and

$$B = \frac{\dfrac{A^N}{N!}}{1 + A + \dfrac{A^2}{2!} + \dfrac{A^3}{3!} + \ldots \dfrac{A^N}{N!}},$$

where N is the number of circuits and A is the traffic offered.

Now $B = 0{\cdot}0004$ and $N = 2$. Therefore,

$$0{\cdot}0004 = \frac{\dfrac{A^2}{2}}{1 + A + \dfrac{A^2}{2}}.$$

$$\therefore \quad \frac{A^2}{2} = 0{\cdot}0004\left(1 + A + \frac{A^2}{2}\right).$$

$$\therefore \quad A^2 = 0{\cdot}0008\left(1 + A + \frac{A^2}{2}\right).$$

$$\therefore \quad 1250A^2 = 1 + A + \frac{A^2}{2}.$$

$$\therefore \quad 2500A^2 = 2 + 2A + A^2.$$

$$\therefore \quad 2499A^2 - 2A - 2 = 0.$$

Using the formula for solving a quadratic equation:

$$A = \frac{-(-2) \pm \sqrt{\{(-2)^2 - [4 \times 2499 \times (-2)]\}}}{2 \times 2499},$$

$$= \frac{-(-2) \pm \sqrt{19996}}{4998},$$

$$= \frac{143{\cdot}4}{4998} = 0{\cdot}0287 \text{ erlangs (negative solution ignored).}$$

If the total occupancy permitted is $0{\cdot}0287$ erlangs, then the number of calls handled in the busy hour is given by

$$\frac{0{\cdot}0287 \times 3600}{330 \times 10^{-3}} = \underline{313.}$$

Q4 (*a*) *Explain what is meant by*

(*i*) *preventive maintenance, and*
(*ii*) *corrective maintenance.*

(*b*) *What are the advantages and disadvantages of relying exclusively on either as a method of exchange maintenance?*

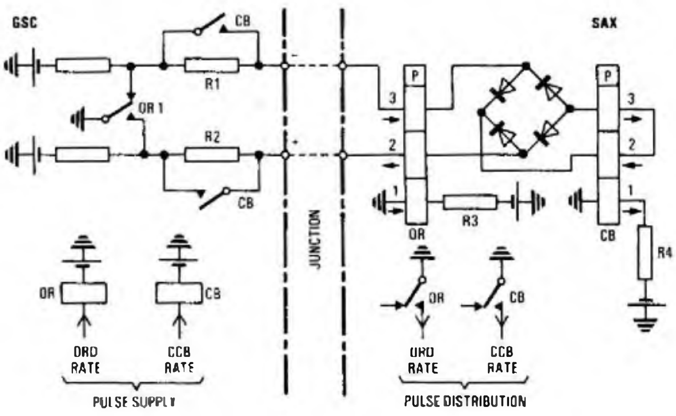
(*c*) *Describe briefly how the effectiveness of the maintenance effort can be assessed.*

Q5 (*a*) *For a small automatic exchange which does not justify provision of an accurate time-pulse generator (tariff equipment), describe how pulses can be transmitted from the parent trunk exchange for periodic-metering purposes on subscriber-dialled*

(*i*) *own-exchange calls, and*
(*ii*) *trunk calls.*

(*b*) *How can the metering pulses be extended from the exchange to operate a meter at the subscriber's premises?*

A5 (*a*) (*i*) Periodic metering pulses for own-exchange calls may be transmitted from the group switching centre (GSC) to the small automatic exchange (SAX) by the arrangement shown in the sketch.



With relays OR and CB in the GSC normal, current flows from earth at contact OR1 to battery via resistor R1, the negative wire of the junction, winding 3 of relay OR in the SAX, windings 2 and 3 of relay CB in the SAX, winding 2 of relay OR in the SAX, the positive wire of the junction and resistor R2. Relays OR and CB in the SAX are of the polarized type and are side-stable; that is, they remain operated or released until current flows through the coils in such a way that conventional current flow (earth to battery) in the direction of the arrow moves the contact to the released position. (If conventional current flow is in the opposite direction to the arrow, the contact moves to the operated position.) Hence, for the current flow described, relay OR at the SAX will be released. Relay CB at the SAX will also be released, as the current in bias winding 1 is sufficient to overcome the effect of the current in windings 2 and 3; this latter current is low due to resistors R1 and R2.

When relay OR at the GSC operates to an ORDINARY (ORD) pulse, the current flow in windings 2 and 3 of relay OR at the SAX is reversed and this relay operates to repeat the ORD pulse at the SAX. (The current in bias winding 1 of relay OR is lower than that in bias winding 1 of relay CB and is not sufficient to overcome the effect of the current in windings 2 and 3 of relay OR.) The bridge rectifier at the SAX ensures that current always flows through windings 2 and 3 of relay CB in the same direction, irrespective of whether relay OR at the GSC is operated or released.

When relay CB at the GSC operates to a COIN-COLLECTING BOX (CCB) pulse, resistors R1 and R2 are short-circuited and the current flow around the loop, and hence through windings 2 and 3 of relay CB at the SAX, is increased; this is sufficient to overcome the effect of the current in bias winding 1 of relay CB and hence this relay operates to repeat the CCB pulse at the SAX. The increase in loop current has no effect on the operation of relay OR at the SAX.

This circuit arrangement allows for ORD and CCB pulse-rates to be transmitted from a GSC to an SAX at the same time over one junction circuit, but with complete independence between the pulse rates.

(*ii*) See A8, Telephony C 1978, *Supplement*, Vol. 72, p. 26, Apr. 1979.

(*b*) See A7, Telephony C 1975, *Supplement*, Vol. 69, p. 74, Oct. 1976.

Q6 *(a) Describe the main functions of a local register in a Strowger director exchange. Give* TWO *examples of those functions which require timing in the register.*

(b) Explain, with the aid of a circuit sketch, how digit storage is achieved.

(c) List the information required to enable the quantity of local registers to be determined, and state briefly how the information is used.

Q7 *For a TXE2 exchange,*

(a) show how the reed relays are arranged to form an A-switch,

(b) show how the A-switches are interconnected to form an A-switch group, and state why this method of interconnexion is used,

(c) state the difference between A-switch groups designed to serve

(i) residential subscribers, and
(ii) business subscribers.

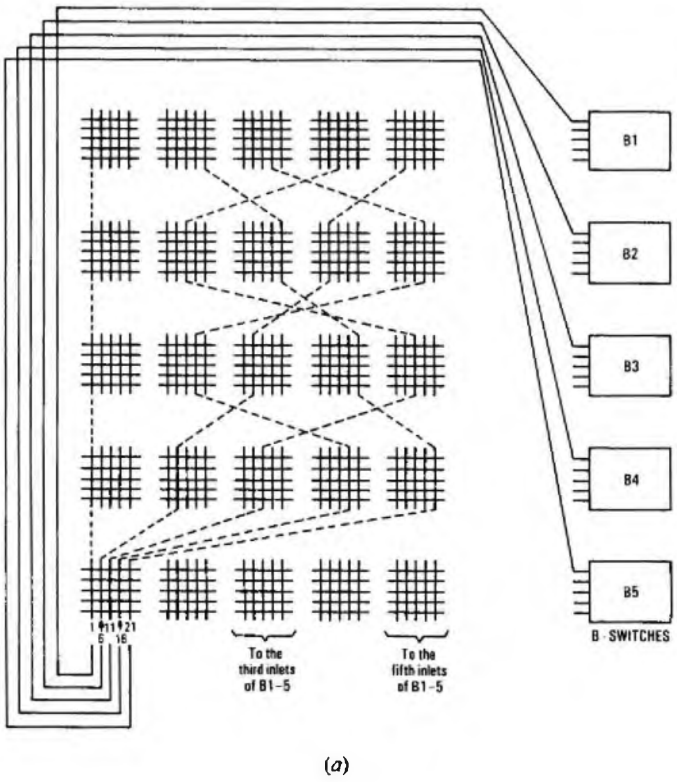
A7 (*a*) See A10, Telephony C 1975, *Supplement*, Vol. 69, p. 75, Oct. 1976.

(*b*) The arrangement is shown in sketch (*a*). This method of interconnexion in the A-switch group is used to minimize the risk of congestion if more than 4 subscribers in a 25-line group are engaged in simultaneous calls.

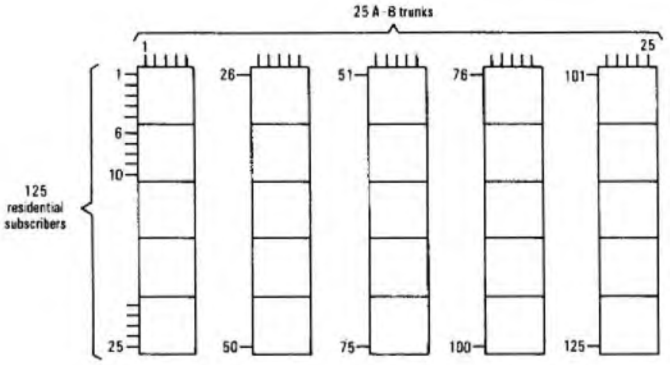
(*c*) An A-switch group for residential subscribers would comprise, typically, twenty-five basic 5 × 5 A-switches to form a 125-line A-switch group.

An A-switch group for business subscribers would comprise, typically, fifteen basic 5 × 5 A-switches to form a 75-line A-switch group.

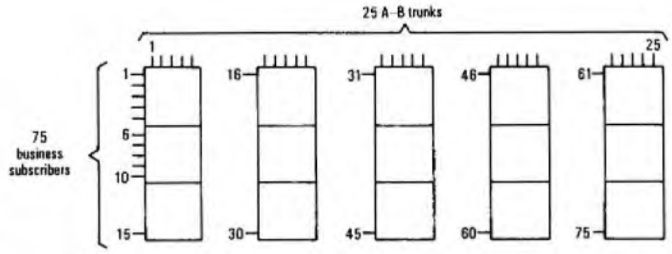
These are shown in sketches (*b*) and (*c*). Each A-switch group has access to 25 A–B trunks. The higher calling rate of the business subscriber is catered for by providing less exchange connexions per 25 A–B trunks.



(*a*)



(*b*)



(*c*)

Q8 *(a) Describe the operation of a local crossbar exchange from the instant a subscriber lifts his receiver to make a directly dialled (STD) long-distance call, until a few seconds after he has dialled the last digit.*

(b) Compare the time taken to process the call in part (a) with that necessary when the local exchange is non-director Strowger, and explain briefly any difference. (Assume that the subscriber dials without unnecessary pauses.)

(c) What would happen in (a) if too few digits were dialled for completion of the call?

Q9 *(a) Sketch and describe* THREE *ways in which STD traffic may be routed between two group switching centres (GSCs).*

(b) What factors determine the choice of routing?

(c) What sets a limit to the number of 2-wire switching centres through which a call may be routed?

A9 (*a*) and (*c*) See A6, Telephony C 1975, *Supplement*, Vol. 69, p. 74, Oct. 1976.

(*b*) The factors determining the choice of routing are:

(*i*) whether the level of traffic justifies the provision of a direct GSC–GSC route,

(*ii*) for lower levels of traffic, whether a tandem routing via an intermediate GSC is available, (*iii*) if such a tandem routing is available, whether there is sufficient equipment capacity at the intermediate GSC to cope with the expected level of tandem traffic,

(*iv*) whether there would be excessive post-dialling delays on a tandem routing,

(*v*) whether the transmission quality would be acceptable on a tandem routing,

(*vi*) whether the controlling register-translator has sufficient translation digits for a tandem routing, and

(*vii*) if a direct or tandem routing is not available (or cannot be justified), whether a transit-network routing has to be used.

Q10 (*a*) *The circuit in Fig. 1 is used to receive dial pulses from a subscriber's telephone. A and AA are reed relays. Show by waveform sketches the approximate time relationship between the line current and the output at contact AA2 during reception of a pulse.*

(*b*) *How would the performance of the circuit be affected*

(*i*) *if the 1000 Ω resistor were short-circuited, and*

(*ii*) *if the 690 Ω bias winding were disconnected?*

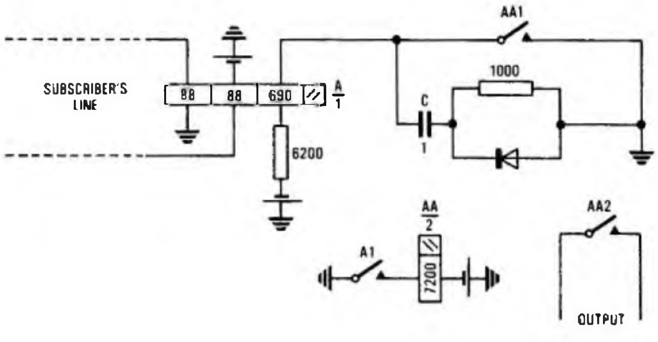
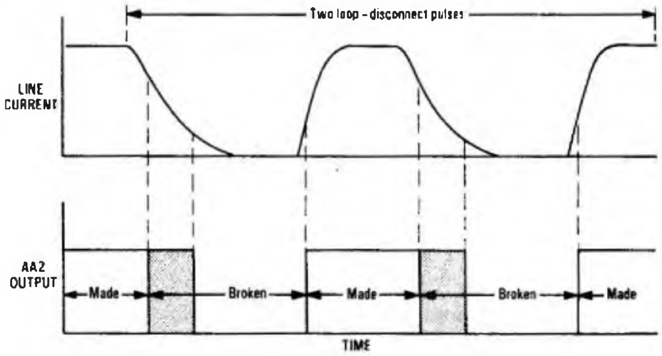


Fig. 1

A10 (*a*) The waveforms are shown in the sketch.

(*b*) (*i*) Initially, the performance of the circuit would not be affected, as the 1000 Ω resistor serves only to limit the discharge current of capacitor C upon closure of contact AA1. However, contact AA1 would be unable to carry the extremely high discharge current of capacitor C with the 1000 Ω resistor short-circuited and would probably weld and so become permanently made. Under such conditions, current would permanently flow in the 690 Ω bias winding of relay A, thus de-sensitizing it, with possible non-operation to the subscriber's line current, particularly on long local lines. Where relay A did operate, it would operate slightly later (due to the higher current required) with a small increase in negative-pulse distortion.

(*ii*) As the line current dies away exponentially at the start of each BREAK pulse (due to the effect of the dial spark-quench capacitor in the telephone instrument), relay A would take longer to release because it now releases at a lower line current, due to the absence of the de-sensitizing bias current. This gives an increase in positive-pulse distortion. The shaded areas in the sketch indicate the increase in the MAKE time.



BASIC MICROWAVE COMMUNICATION C 1979

Students were expected to answer any 6 questions

Q1 (*a*) *Give TWO reasons why a radiated power of only a few watts is sufficient for reliable point-to-point microwave communication for distances of 40 km.*

(*b*) *A laboratory microwave source uses a horn radiator.*

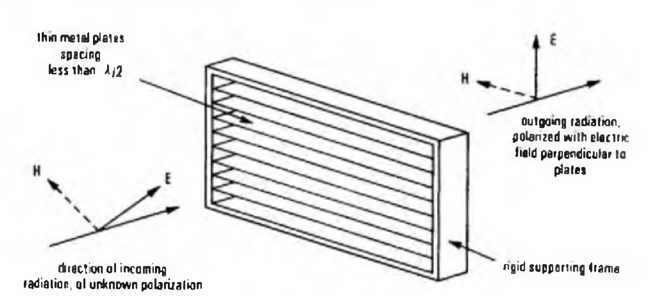
(*i*) *With the aid of a diagram describe a device for determining the polarization of the radiation.*

(*ii*) *Explain how this device is used.*

A1 (*a*) A radiated power of only a few watts is normally sufficient for reliable point-to-point microwave communication over a distance of 40 km because:

(*i*) Assuming no obstructions in the path, the loss between isotropic aerials 40 km apart is of the order of 140 dB (the exact figure depends on the frequency employed). Microwave aerials with large effective areas (that is, paraboloidal reflectors with a diameter of 60–120 wavelengths and therefore a gain of 40–50 dB) may be employed, thus giving an overall loss between transmitter and receiver of 40–60 dB. A transmitter power of a few watts is therefore sufficient to give an adequate signal-to-noise ratio at the receiver.

(*ii*) Employing the directive aerials referred to in part (*i*) provides a good measure of protection against interference from other radio links using similar frequencies. For example, the half-power beamwidth of a 3 m aperture aerial at 5 GHz is 1·4°.



(*b*) (*i*) A simple device which may be used to determine the polarization of the radiation from a microwave horn radiator is a polarization grating. The construction of a typical grating is illustrated in the sketch. The operation of the grating is such that only the component of the incident energy whose electric-field vector is aligned perpendicular to, yet in the same plane as, the thin metal plates will propagate through the grating and emerge from the other side. Such operation will only take place if the plates are spaced by less than one half-wave length, and are sufficiently long.

(*ii*) To measure the polarization of any radiated microwave field with respect to some predetermined plane, the polarization grating described in part (*b*) (*i*) may be fitted to a horn. The horn is terminated in a length of waveguide fitted with a crystal detector and probe. This assembly can then be mounted in a frame that will allow rotation about the axis of the horn, and placed in front, some distance away, and coaxial with, the radiating aperture. By rotating the grating/horn assembly and noting the angular displacement of the horn from a predetermined reference plane at which the maximum signal is produced in the detector, the polarization of the source of the radiation may be defined.

Q2 (*a*) *Explain briefly why an open-wire transmission line has a higher characteristic impedance than a coaxial cable.*

(*b*) *As represented in Fig. 1, a low-loss feeder of characteristic impedance 50 Ω is terminated in load R. The line is energized by a signal generator having an EMF of 6·0 V and internal resistance 50 Ω. The*

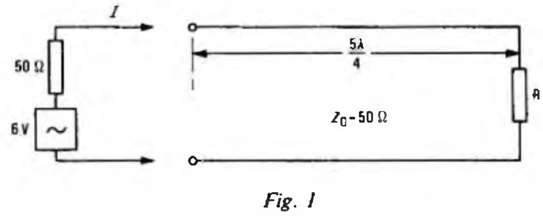


Fig. 1

source frequency makes the line exactly $5\lambda/4$. Determine the current I when R is

(*i*) *a short circuit,*
(*ii*) *an open circuit,*
(*iii*) *a 50 Ω resistor, and*
(*iv*) *a 100 Ω resistor.*

A2 (*a*) See A2, Basic Microwave Communication C 1974, *Supplement*, Vol. 68, p. 82, Jan. 1976.

(*b*) The reflection coefficient ρ due to a resistive load R ohms terminating a low-loss transmission line of characteristic impedance Z_0 ohms is given by:

$$\rho = \frac{R - Z_0}{R + Z_0}.$$

When the line is terminated by a load other than one equal to the characteristic impedance, standing waves will be present and will repeat exactly in amplitude and phase, in the loss-free line case, every one-half wavelength. Therefore the $5\lambda/4$ line is equivalent to a transmission line only $\lambda/4$ long.

(*i*) When R is a short circuit ($R = 0$), the reflection coefficient $\rho = -1$. Therefore the reflected wave has an amplitude equal to the amplitude of the incident wave, but the reflection occurs with a 180° change in phase of the voltage, with no change in phase of the current. The current at the load is therefore the sum of the incident and reflected currents, and at $\lambda/4$ towards the source the current will therefore be zero $(I = 0.)$

(*ii*) When R is an open circuit ($R = \infty$), $\rho = 1$. Therefore the reflected wave is equal in amplitude to the incident wave and the reflected and incident voltages are in phase. The current at the load is therefore the sum of two equal, but out-of-phase, contributions, and is zero. Consequently, at $\lambda/4$ towards the source the currents will be in phase; that is, twice the current flowing under matched conditions (I_m) with $R = Z_0$.

When $R = Z_0$, $I_m = V/R_{TOTAL} = 6/100$ A. Therefore when $R = \infty$, the current at the input to the line is $2 \times I_m = 12/100$ A $=$ 120 mA.

(*iii*) As calculated in part (*ii*), the current flowing in the transmission line when the line is terminated in a 50 Ω resistor, (that is, the line is matched) is $I = V/R_{TOTAL} = 6/100$ A $=$ 60 mA.

(*iv*) When R is 100 Ω, the reflection coefficient $= 1/3$. Therefore at the load the voltage is $1\frac{1}{3}$ times the incident voltage, and the current is $\frac{2}{3}$ of the current in the matched case. One quarter of a wavelength along the line towards the source the incident and reflected currents are in phase; therefore at this point the current is $1\frac{1}{3}$ times the incident current; that is $I = 60\text{ mA} \times 1\frac{1}{3} =$ 80 mA.

Q3 (*a*) *With the aid of diagrams, explain how dominant mode propagation in a rectangular waveguide differs from propagation in a higher order mode.*

(*b*) *Give* TWO *reasons why dominant mode propagation is preferred.*

Q4 (*a*) *A resonant cavity consists of an 8·0 cm length of rectangular waveguide closed at both ends. The lowest resonant frequency of this cavity is 3·125 GHz. Calculate the critical frequency for this mode of resonance.*

(*b*) *Give* THREE *reasons why LC circuits are unsuitable as microwave tuning elements.*

(*c*) *What is meant by the Q-factor of a resonant cavity.*

A4 (*a*) For rectangular waveguide,

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda_o^2} - \frac{1}{\lambda_c^2},$$

where λ_g is the guide wavelength, λ_c is the critical wavelength and λ_o is the free-space wavelength.

A cavity resonator is formed using a $\lambda_g/2$ length of waveguide. Since the cavity is 8 cm long, the guide wavelength in the cavity is 16 cm. The resonant frequency is 3·125 GHz; therefore the free-space wavelength corresponding to this frequency is given by

$$\lambda_o = \frac{3 \times 10^{10}}{3\cdot125 \times 10^9}\text{ cm} = 9\cdot6\text{ cm}.$$

Rearranging the formula for guide wavelength, the critical wavelength, λ_c, is given by

$$\lambda_c = \frac{\lambda_o \lambda_g}{\sqrt{(\lambda_g^2 - \lambda_o^2)}}\text{ cm} = 12\text{ cm}.$$

Therefore the critical frequency, below which it would not be possible to construct a cavity resonator using this waveguide, is given by

$$f_c = \frac{3 \times 10^{10}}{12}\text{ Hz} = 2\cdot5\text{ GHz}.$$

(*b*) LC circuit elements are unsuitable for microwave tuned circuits for the following reasons:

(*i*) It is very difficult to design and make LC circuit elements with values of inductance and capacitance that are needed at microwave frequencies since the element values are typically very small indeed. Physical size constraints frequently lead to instances where, for instance, a capacitor designed for microwave frequencies may have its capacitance swamped by lead inductance.

(*ii*) It is difficult to obtain high Q-factor in resonant circuits because of losses inherent in lumped-constant LC elements; that is, skin-effect losses.

(*iii*) High stability is difficult to achieve with LC circuit elements due to the temperature dependence of the circuit elements inherent in the materials used in their manufacture.

(*c*) The Q-factor of a cavity resonator is defined by

$$Q = 2\pi \frac{\text{energy stored}}{\text{energy lost per cycle}}.$$

Therefore, the Q-factor is affected significantly by the ratio of the cavity volume to its surface area and by the skin-effect losses in the cavity walls.

Q5 (*a*) *The gain of a $\frac{\lambda}{2}$ dipole is 2·16 dB. Explain precisely what is meant by this statement.*

(*b*) *An aerial has a beamwidth of 2·7° in a particular plane and a gain of 30 dB with respect to a $\frac{\lambda}{2}$ dipole. For propagation in this plane and radiated power of 1·8 W, calculate the power flux at a range of 10 km:*

(*i*) *in the direction of maximum radiation, and*
(*ii*) *at an angle of 1·35° to the direction of maximum radiation.*

A5 (*a*) The gain of a $\frac{\lambda}{2}$ dipole is the ratio of power that must be supplied to an ideal isotropic source to deliver a particular field strength in the desired direction, to the power that must be supplied to the dipole to obtain the same field strength in the same direction.

Thus, in the example given,

$$P_d \approx 0\cdot6\, P_i,$$

where P_d is the power required in the dipole and P_i is the power required in the isotropic source.

(*b*) The power flux received (P_r) at a distance R metres from a transmitting aerial with a gain of 30 dB is given by

$$P_r = \frac{P_t G}{4\pi R^2}\text{ watts/metre}^2,$$

where P_t is the transmitted power and G is the gain of the system.

(*i*) In the example, $P_t = 1\cdot8$ W, $G = 30 + 2\cdot16$ dB $=$ a power gain of 1644, $R = 10000$ m. (Note that the aerial gain has been increased by 2·16 dB so that it now refers to an isotropic source standard.)

$$\therefore \quad P_r = \frac{1\cdot8 \times 1644}{4\pi \times 10^8}\text{ W/m}^2,$$
$$= 2\cdot355\ \mu\text{W/m}^2.$$

(*ii*) The beamwidth of the aerial is 2·7°, therefore at an angle of 1·35° to the direction of maximum radiation the power will be one-half that of the maximum. Therefore the power flux will be one-half that calculated above; that is, 1·1775 μW/m².

Q6 (*a*) *Fig. 2 shows the pattern of uniform rectangular pulses which have been amplitude modulated by a sinusoidal signal.*

(*i*) *Copy this diagram on the squared paper in your answer book and reconstruct the modulating signal in appropriate time relationship.*

(*ii*) *Determine the recurrence frequency and amplitude of the modulated pulse train.*

(*iii*) *State the maximum modulating frequency that could be communicated by the pulse train.*

(*b*) *Draw the circuit of a simple device for extracting the modulation from the pulse train shown in Fig. 2. Sketch the characteristic required of this device.*

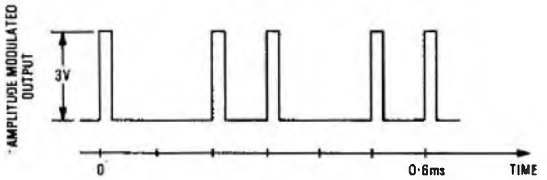


Fig. 2

A6 (*a*) (*i*) See sketch (*a*).

(*ii*) The pulse pattern repeats every 0·3 ms, and from the sketch it can be seen that the modulating sinusoidal signal has an identical period. Therefore the recurrence frequency will be the reciprocal of this period; that is, $1/0{\cdot}3 \times 10^{-3}$ Hz, = 3·33 kHz.

Examining the sketch, it can be seen that the modulating voltage, ($E = E_0 \sin \omega t$) is at a minimum at $t = 0{\cdot}1$ ms, and at a maximum at $t = 0{\cdot}25$ ms. At the sampling instant $t = 0{\cdot}2$ ms, the modulating voltage has a total amplitude of 3 V and from the sketch $\omega t = 30°$.

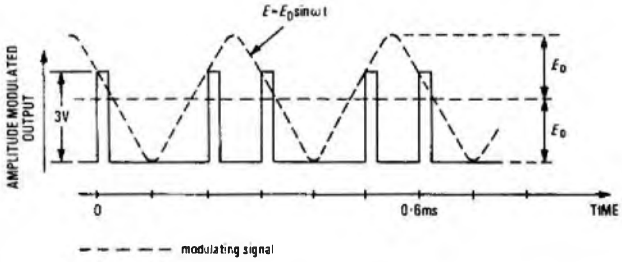
Since the modulating voltage is a sinusoid, the voltage, E, at $t = 0{\cdot}2$ ms is given by $E = E_0 + E_0 \sin 30°$. Since $E = 3$ V, $3 = E_0 + E_0/2$.

$$\therefore \quad E_0 = 2 \text{ V}.$$

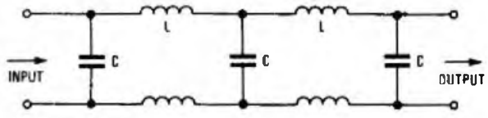
(*iii*) By the sampling theorem, the maximum modulating frequency that could be communicated by this pulse train would be one-half the pulse repetition frequency. From the sketch the pulse repetition period is 0·1 ms; that is, a pulse repetition frequency of 10 kHz. Therefore the maximum modulating frequency, f_{max}, is given by

$$f_{max} = \frac{10}{2} = 5 \text{ kHz}.$$

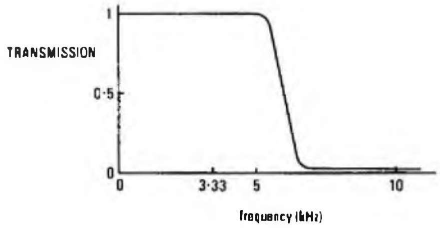
(*b*) See sketches (*b*) and (*c*).



(*a*)



(*b*)



(*c*)

Q7 (*a*) *State clearly what is meant by the following terms:*

(*i*) *white noise,*
(*ii*) *thermal agitation noise, and*
(*iii*) *shot noise.*

(*b*) *Explain the meaning of the following statements:*

(*i*) *a receiver has an input (or equivalent) noise temperature of 2100 K, and*
(*ii*) *a receiver has a noise factor of 9 dB.*

Q8 (*a*) *State properties of a p i n diode that distinguish it from an ordinary semiconductor diode at frequencies between 1 GHz and 10 GHz.*

(*b*) (*i*) *With the aid of a sketch, explain how a semiconductor can be used as the active element of a mechanically-tuned microwave oscillator.*
(*ii*) *Describe briefly the property of the semiconductor exploited in this application.*

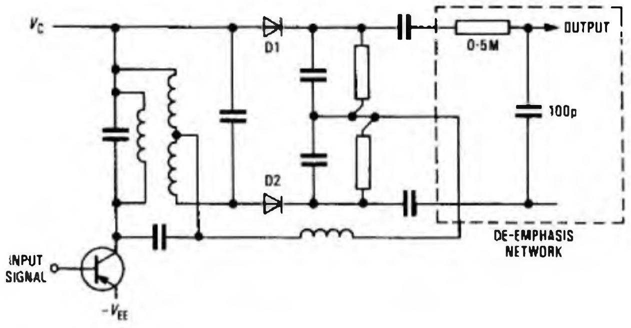
Q9 (*a*) *A frequency-modulation (FM) receiver, intended for transmissions having 60 μs pre-emphasis, uses a Foster-Seeley discriminator.*

(*i*) *Draw a circuit diagram of the discriminator, and*
(*ii*) *indicate on the diagram appropriate component values for the de-emphasis network.*

(*b*) *What will be the effect on the receiver output of omitting the de-emphasis network?*

(*c*) *State what is meant by the term linear response as applied to an FM discriminator.*

A9 (*a*) (*i*) The circuit diagram of a Foster-Seeley discriminator is shown in the sketch.



(*ii*) A de-emphasis network, calculated to provide a time constant of 50 μs, suitable for de-emphasis of FM broadcast transmissions is shown in the dotted box in the sketch with appropriate component values.

(*b*) The effect of omitting the de-emphasis network would be to unbalance the overall frequency response of the FM receiver by enhancing the high-frequency components, from about 3 kHz upwards by 6 dB/octave.

(*c*) The function of an FM discriminator is to provide an output voltage whose amplitude is dependent upon the applied frequency over a range of input frequencies. The output voltage/frequency response should be linear over the appropriate working range and departure from linearity within this range will degrade the performance of the discriminator by introducing distortion.

Q10 *The circuit shown in Fig. 3(a) is triggered by positive-going pulses of short duration applied alternately to inputs A and B.*

(*a*) *Describe briefly, with the aid of time-related diagrams, the action of the circuit showing*

(*i*) *trigger voltage at input, A,*
(*ii*) *trigger voltage at input B,*
(*iii*) *TR1 base voltage,*
(*iv*) *TR1 collector voltage,*
(*v*) *TR2 base voltage, and*
(*vi*) *TR2 collector voltage.*

(*b*) *Explain how the circuit could be modified for single input operation to trigger continuously from the leading edge of the pulses in the train shown in Fig. 3(b).*

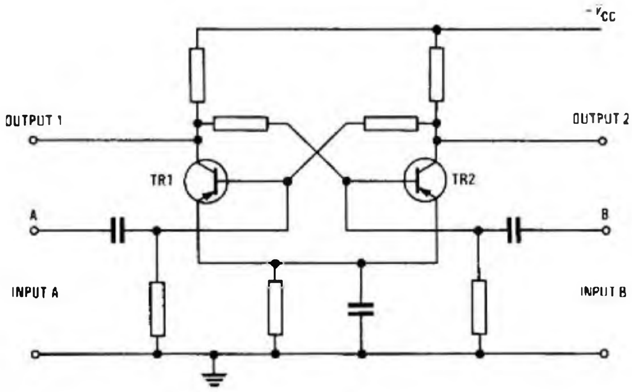


Fig. 3(a)

Fig. 3(b)

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