Problems in Electronics with Solutions

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PREFACE TO THE FIFTH EDITION

Many changes have been made in this edition, first to the nomenclature so that the book is in agreement with the International System of Units (S.I.) and secondly to the circuit diagrams so that they conform to B.S.S. 3939. The book has been enlarged and now has 546 problems. Much more emphasis has been given to semiconductor devices and transistor circuits, additional topics and references for further reading have been introduced, some of the original problems and solutions have been taken out and several minor modifications and corrections have been made. It could be argued that thermionic-valve circuits should not have been mentioned since valves are no longer considered important by most electronic designers except possibly for very high power or voltage applications. Some of the original problems on valves and valve circuits have been retained, however, for completeness because the material is still present in many syllabuses and despite the advent and prolification of solid-state devices in recent years the good old-fashioned valve looks like being in existence for a long time. There are still some topics readers may expect to find included which have had to be omitted; others have had less space devoted to them than one would have liked.

A new feature of this edition is that some problems with answers, given at the end of each chapter, are left as student exercises so the solutions are not included.

The author wishes to thank his colleagues Professor P. N. Robson, Drs. J. Allison, A. P. Anderson, K. Barker, J. C. Bennett, B. Chambers, R. Hackam and G. S. Hobson and Mr. R. W. J. Barker for providing questions and solutions on certain topics which they have produced for tutorial classes and the University of Sheffield for permission to use some of the questions set in examination papers. The author takes full responsibility, however, for any mistakes which have crept in.

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1976

PREFACE TO THE FIRST EDITION

This book is based largely on problems which the author has collected over the last ten years, many of which have been given to undergraduate engineers. The purpose of the book is to present the problems, together with their solutions, in the hope that they will prove of value to other teachers and students. It is thought that the book covers almost the complete undergraduate electronics courses in engineering at Universities, but it has not been written to match any particular syllabus, and it should also be found useful by postgraduate students and research workers as a reference source. In fact, a few questions of postgraduate standard are included.

Within the author's knowledge, there is no other problem book on electronics with solutions which covers such a wide field as the present one. The few problem books which are available, while being excellent in some ways, suffer from certain disadvantages. In some, answers are given but not solutions, in others there are no questions at all on electronics, or if there are they form only a small part of the whole. In other instances, where solutions are given, the questions and solutions are not separated. Descriptive questions are given in some problem books; and, while it may be argued that these should be included to assist readers engaged in private study, the answers to these can easily be found in standard textbooks. The purpose of a problem book should surely be the application of theory rather than the teaching of it.

Textbooks form other useful sources of problems; and in fact, most textbooks give some worked examples too, but these are generally used merely to illustrate points which have just previously been made in the text and do not encourage students to think for themselves.

The author is very much in favour of problem papers and tutorials as a method of education, because it is well known that young students encounter many difficulties when they first try to apply their theoretical knowledge to practical problems.

The 282 problems are divided up into 23 sections and the solutions are separated from the problems so that the students shall not see solutions by accident. The answer is also given, however, at the end of each problem for convenience. A thorough grasp of the principles involved in any particular problem cannot be obtained by merely reading through the solution. Students should not therefore consult the solutions until they have either repeatedly tried hard and failed to obtain the stated answer, or successfully solved the problem and wish to compare the method of solution with that given. Wherever possible the problems are based on practical data, so as to familiarize the student with practical orders of magnitude.

At first it was thought that, because of the enormous range of subjects to be included, two books might be published, one featuring the elementary topics and the other the more advanced ones. It was finally decided that one volume rather than two was much more desirable; but, to keep the price of the book at a figure reasonable for students, it was necessary to limit the number of examples to about the same as already given in the author's existing book *Electrical Engineering Problems with Solutions*. It was also obvious at the outset that, because of length limitations, it would not be possible to include step-by-step mathematics, but only the electrical steps in the solutions. It is therefore assumed that the reader knows the necessary mathematics. It has been felt desirable to include a few problems of importance which are just standard textbook material but, in such cases, the solutions simply give references to suitable textbooks. Some topics which readers may expect to find included, e.g. kinetic theory of gases, sound equipment, polyphase rectifiers, vacuum techniques, have had to be omitted, and others have had less space devoted to them than one would have liked.

The author cannot possibly claim that all the problems in the collection are original, but it is impossible to acknowledge the sources of those which are not. Most of the problems are new, however, and in many cases they have been carefully formulated to try to encourage thought and understanding; but some, which require only numerical substitutions in formulae are included, in the hope that they will develop the student's sense of magnitudes.

To avoid repetition, all the general data required have been collected together and are given at the beginning of the book.

While great care has been taken to try to eliminate errors some will inevitably have crept in, and the author will be glad to have any such brought to his notice.

The author is indebted to Dr. J. Allison, B.Sc. (Eng.) for providing some experimental figures for use in several questions on transmission lines. He also expresses appreciation to a number of his former students who have confirmed the answers to many of the problems. The encouragement given and many helpful suggestions made by Professor A. L. Cullen, B.Sc. (Eng.), Ph.D., M.I.E.E., M.I.R.E., throughout the preparation of the manuscript are also gratefully acknowledged.

Electrical Engineering Department F. A. BENSON
The University of Sheffield, 1957.

GENERAL DATA

Charge on an electron (e)	$= 1.602 \times 10^{-19}$ C
Mass of an electron (m)	$= 9.107 \times 10^{-31}$ kg
Planck's constant (h)	$= 6.624 \times 10^{-34}$ Js
Boltzmann constant (k)	$= 1.38 \times 10^{-23}$ JK^{-1}
Permittivity of free space (ϵ_0)	$= 8.855 \times 10^{-12}$ Fm^{-1}
Excitation potential of argon	= 11.6 V
Ionization potential of mercury	= 10.4 V
Ionization potential of neon	= 21.5 V
Resistivity of copper	$= 1.7 \times 10^{-8}$ Ωm
Resistivity of nickel	$= 9.39 \times 10^{-8}$ Ωm

CONTENTS

Section 1

PROBLEMS

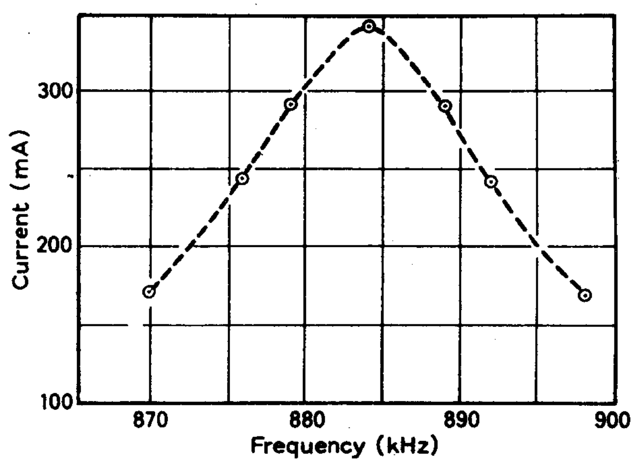
CHAPTER ONE

CIRCUIT ANALYSIS

1. A series L, C, R circuit, with $R = 4\ \Omega, L = 100\ \mu$H and $C = 200\ \mu\mu$F is connected to a constant-voltage generator of variable frequency. Calculate the resonant frequency, the value of 'Q' and the frequencies at which half the maximum power is delivered.

[*Ans.* 1126 kHz; 177; 1129 kHz; 1122 kHz]

2. The graph shows the variation of current through a series L, C, R circuit when connected to a 5-V constant-voltage generator of variable frequency. Find the values of 'Q', R, L and C.

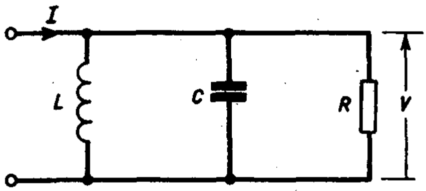


[*Ans.* 55.25; 14.53 Ω; 144.5 μH; 224 $\mu\mu$F]

3. A coil of inductance 88 μH is placed in series with a 4.8-Ω resistor. The combination is connected in parallel with a 375-$\mu\mu$F capacitor. Calculate the frequency of the circuit for which the effective impedance is a pure resistance.

[*Ans.* 876.4 kHz]

4. Determine the 'Q' factor of the parallel damped circuit shown below.



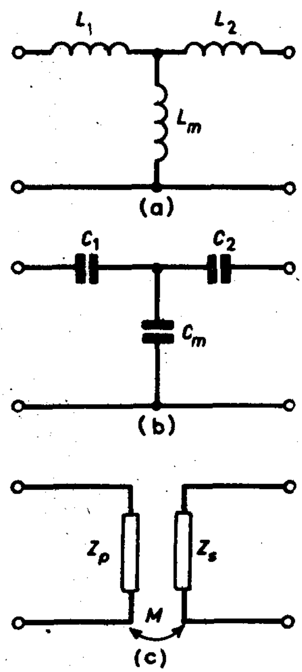
[*Ans.* $R/\omega_r L$]

5. A parallel resonant circuit is tuned to a frequency of 1 MHz and contains a 200-$\mu\mu$F capacitor. When a source of constant voltage is injected in series with the circuit the current falls to 0.707 of its resonant value, for a frequency deviation of 5 kHz from the resonant frequency. Calculate the circuit 'Q' and the parallel resonant impedance.

[*Ans.* 100; 79.6 kΩ]

6. A parallel resonant circuit employs a 50-$\mu\mu$F capacitor and has a bandwidth of 250 kHz. Calculate the maximum impedance of the circuit.

[*Ans.* 12 740 Ω]



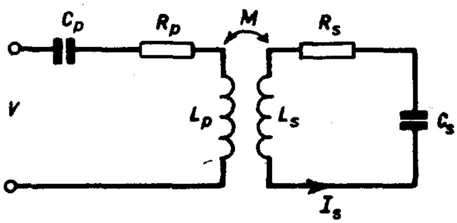
7. Reduce the two circuits shown at (a) and (b) to the simple coupled circuit of (c) by assigning suitable values to Z_p, Z_s and M.

What are the coefficients of coupling for the circuits (a) and (b)?

[*Ans.* (a) $Z_p = j\omega(L_1 + L_m)$,
$Z_s = j\omega(L_2 + L_m), M = L_m$;
(b) $Z_p = (C_1 + C_m)/\omega C_1 C_m$,
$Z_s = (C_2 + C_m)/\omega C_2 C_m$,
$M = 1/\omega^2 C_m$; coefficients of coupling are
$L_m/\sqrt{[(L_1 + L_m)(L_2 + L_m)]}$ for (a) and
$\sqrt{[C_1 C_2/(C_1 + C_m)(C_2 + C_m)]}$ for (b)]

8. The two resonant circuits shown are tuned to the same frequency $\omega_r/2\pi$ and coupled together. Obtain an expression for the secondary current I_s in terms of the voltage V, the circuit Q's, Q_p and Q_s, the coefficient of coupling k and the ratio of the actual frequency to the resonant frequency, α.

Show that I_s reaches its maximum value when the circuits are in resonance and when $\omega_r M = \sqrt{(R_p R_s)}$ and that the value of k for critical coupling is $1/\sqrt{(Q_p Q_s)}$.

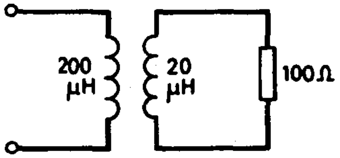


[*Ans.* $I_s = -jVk/\alpha\omega_r\sqrt{(L_p L_s)}\{k^2 + 1/Q_p Q_s - (1-1/\alpha^2)^2 + j(1-1/\alpha^2)(1/Q_p + 1/Q_s)\}$]

9. Two series circuits, each consisting of a 300-μH inductor and a 1000-$\mu\mu$F capacitor, are magnetically coupled so as to have a mutual inductance of 60μH. A voltage of 10 V having a frequency of $1/\pi$ MHz is injected into one circuit. Determine the current in the other circuit and the coefficient of coupling (k).

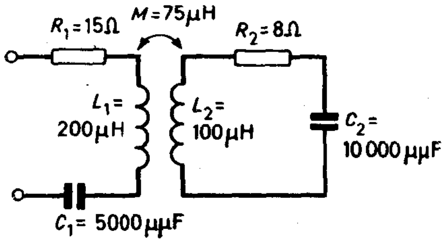
[*Ans.* $-j0.273$ A; 0.2]

10. Evaluate the input impedance of the circuit shown, at a frequency of 1 MHz. The coefficient of coupling is 0.1.



[*Ans.* $(6.1 + j1249.1)\ \Omega$]

11. A voltage of 100 V at a frequency of $[10^6/2\pi]$ Hz is applied to the primary of the coupled circuit illustrated. Calculate the total effective resistance and reactance referred to the primary.



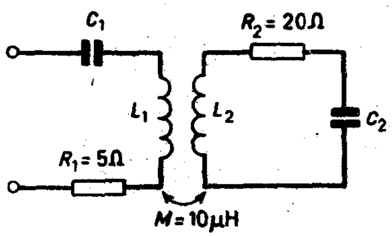
Determine also the primary and secondary currents.

[*Ans.* 718 Ω; 0; 0.139 A; 1.306 A]

12. A transformer has a tuned primary winding and an untuned secondary. The inductance of each winding is 1 mH and the mutual inductance between them is 0.5 mH. The primary winding is tuned with the secondary open-circuited, and resonates at a frequency of 500 kHz. If the secondary circuit is now short-circuited find the change of tuning capacitance required to keep the same resonant frequency. Neglect the resistances of the windings.

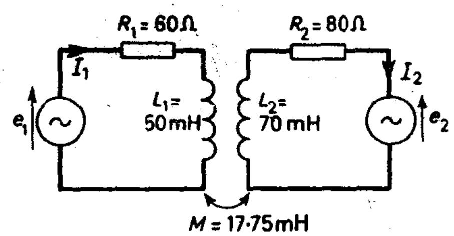
[*Ans.* 34 μμF]

13. In the circuit illustrated $\omega L_2 = 1/\omega C_2$. Determine the value of the input impedance, if C_1 is chosen to make it purely resistive. The frequency is 1 MHz.



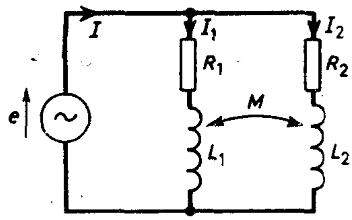
[*Ans.* 202.4 Ω]

14. In the circuit illustrated $e_1 = 169.7 \sin 1885t$ volts and $e_2 = 141.4 \sin (1885t + 45°)$ volts. Calculate the primary and secondary currents and draw a complete phasor diagram for the circuit.



[*Ans.* $I_1 = 1.168 \angle -45.6°$ A; $I_2 = 0.903 \angle -13.6°$ A]

15. Determine the equivalent impedance of the two magnetically-coupled parallel circuits illustrated.



[*Ans.* $(Z_1Z_2 - Z_m^2)/(Z_1 + Z_2 - 2Z_m)$

where $Z_1 = R_1 + j\omega L_1$

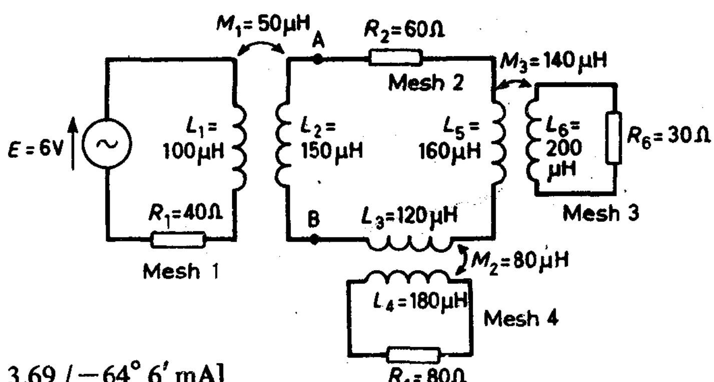
$Z_2 = R_2 + j\omega L_2$

and $Z_m = \pm\, j\omega M$]

16. Experiments carried out on a variometer, whose two coils were series-connected, showed that the inductance values obtainable varied from 40 mH to 360 mH. Assuming that the self-inductances of the two coils are equal, determine the range of inductance values obtainable if the coils are reconnected in parallel. Neglect resistances.

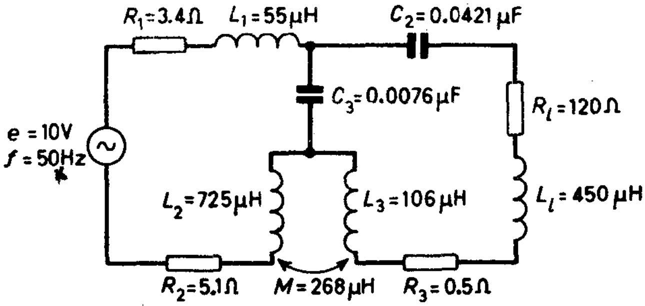
[*Ans.* 10 to 90 mH]

17. Calculate the current flowing in resistor R_6 of the network, involving several coupled circuits, as shown. The angular frequency $\omega = 2 \times 10^6$ rad s^{-1}.



[*Ans.* 3.69 $\angle -64^\circ\, 6'$ mA]

18. For the circuit shown, calculate the total loop impedances, the mutual impedance, the apparent impedance of the primary loop and the currents in the two loops.



[*Ans.* $(8.5 - j174)\ \Omega$; $(120.5 - j320)\ \Omega$;
$j503\ \Omega$; $(271 + j522)\ \Omega$;
$0.017 \angle -62.6^\circ$ A; $0.0251 \angle -83.2^\circ$ A]

19. A wavemeter consists of a variable capacitor, having a range of 50 to 1000 μμF, and two coils of inductances 300 and 100 μH respectively. If the coils are fixed so that their mutual inductance is 25 μH, what range will the wavemeter have when the coils are used (*a*) in series aiding (*b*) in series opposing, (*c*) in parallel aiding and (*d*) in parallel opposing?

[*Ans.* (*a*) 283 to 1265 m; (*b*) 249 to 1115 m;
(*c*) 122 to 546 m; (*d*) 107 to 481 m]

20. A coil has an inductance of 5 mH, a self-capacitance of 5 μμF and a high-frequency resistance of 100 Ω. Determine the effective resistance and inductance of the coil at a frequency of 500 kHz.

[*Ans.* 177 Ω; 6.67 mH]

21. A coil is tuned to a certain frequency by a 250-μμF capacitor. To tune the coil to the second harmonic of this frequency a capacitance of 55 μμF is required. Determine the self-capacitance of the coil.

[*Ans.* 10 μμF]