



SECTION 2

**ADVANCED
PRACTICAL
RADIO ENGINEERING**

FINAL EXAMINATION

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Washington, D. C.

DISCUSSION OF FINAL EXAMINATION

The Final Examination contains fifty problems of a practical nature based on the principles covered throughout the home-study course. There are ten sections of five questions each.

Since considerable time will be required to complete the examination, it is recommended that the student forward each section immediately upon completion. It will be graded and returned promptly, and thus a possible duplication of errors may be avoided.

The student can expect no help from the instructor on any part of the examination until after a passing grade has been obtained. However, the instructor will be glad to clarify any questions that appear obscure.

These examinations are to be handled with all possible aid from review of the assignments. Thus, while working the problems you are encouraged to make extensive reference to the material in your course. This is one of the reasons why the home-study method is effective. Reading is not study, so examinations must provide the automatic disciplinary measures to compel study. The examinations thus perform two functions:

1. To provide exercise in application of theory.
2. To give evidence that the student has sufficient knowledge of the theory studied.

Many problems in the Final Examination are of a type which have not been given in prior examinations. However, all can be worked by application of the principles explained in the foregoing assignment. A *methodical* application of fundamental principles will often easily solve a problem which at first appears confusing. However, many students will have forgotten theory which was once well understood. Therefore, it is earnestly recommended that the student thoroughly restudy any subject which seems unfamiliar.

The minimum *average* passing grade on the total final examination is 70%. The minimum passing grade on each section is 60%, providing that the average grade up to that point is 70% or better. Examinations not meeting this requirement will be returned for reworking. The maximum grade on a reworked examination is 80%.

It is essential that sufficient work be shown on each problem for the instructor to check the method otherwise an incorrect answer will carry the full penalty of 20 per cent. Problems should be submitted in equation form, the actual "scratch" work being omitted from the examination paper.

In working design problems the answer to a problem should show practical values actually to be used. Values must be selected on a basis of economy and the ease with which they may be obtained commercially. For example, if a resistor must dissipate 18 watts continuously, state the actual wattage rating you would specify. If a resistor works out to 34,575 ohms. state the actual value you would specify in ordering the resistor.

DISCUSSION OF FINAL EXAMINATION

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A Note of Warning: The problems of the final examination are not difficult, but many of them have a seeming simplicity which misleads many students. Consider the given information carefully and avoid jumping to unwarranted conclusions. Wherever possible, prove your work by some *independent* method. Always check every mathematical calculation you have performed before forwarding each section to the Institute.

Many mistakes will be detected by the continual application of the question "*Are my results reasonable?*" The problems in the Final Examination are practical applications of theory, so an unreasonable answer will be evidence that something is wrong with the solution.

The Final Examination is considered one of the most important parts of the CREI course. Here the fundamental principles studied in various assignments of the course are correlated and applied to practical problems. Many graduates have remarked that not until the final examination had been completed did they realize how much had been covered in the course and what a powerful tool they had acquired for solving practical problems. The completion of the Final Examination represents the first milestone of your engineering career, and the importance of your work in this examination can be inferred from the fact that your grade on this examination counts one-half in determining your final average for the course. GIVE IT YOUR BEST!

FINAL EXAMINATION

SECTION I

Page 1.

1. (A) A generator with an internal resistance of 10 ohms has an open circuit EMF of 100 volts. A variable resistance, range 0 to 30 ohms, is connected as a load across the generator. Plot a graph of power output against load resistance in 3 ohm steps over the full range of load resistance. Tabulate your results.

(B) What two important principles does this graph illustrate?

(C) Plot a graph of generator internal dissipation over the same range of load resistance.

(D) Plot a graph of generator efficiency over the same range of load resistance.
2. At the respective points of maximum energy product, the following two permanent magnet steels have the following characteristics.

MATERIAL	ENERGY PRODUCT	FLUX DENSITY
Alnico V	4.5×10^6	11,000 gauss
Cobalt	$.92 \times 10^6$	18,000 gauss

- (A) How much longer must the cobalt steel magnet be than the Alnico V magnet for the same flux density, the same area, and the same air gap as in the Alnico V magnet?
 - (B) How much larger must the Alnico V magnet be in cross section than the cobalt steel magnet for the same *total* flux?
3. What resistance must be connected in series with a storage battery having an open circuit EMF of 22 volts and an internal resistance of .24 ohm so that the charging current is limited to 5 amperes? The charging source is rated at 35 volts D.C. What power is dissipated in this resistance and what rating would you suggest be used?

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4. A shell type transformer core is to be used as the core of a choke coil, the winding being mounted on the center leg. The reluctance of the core is .00165 reluctance unit (formerly oersted). It is desired to increase the total reluctance by means of equal air gaps in the outer legs to .00565 reluctance unit (formerly oersted) to prevent core saturation under normal D.C. load. If the cross-section area of each outside leg is 4 square inches, calculate the length of the air gap required in each leg. (The center leg has an area of 8 square inches).

5. A Weston 5 M.A. D'Arsonval type D.C. meter ($R_m = 12$ ohms) is to be employed for the measurement of currents in the ranges 0 to 5A and 0 to 500 MA.
 - (A) Calculate the resistances of two suitable shunts for use with the meter to give the above mentioned ranges.

 - (B) Could the above meter movement be employed in conjunction with a suitable shunt to read 0-50 μ amperes? Explain why and discuss effect of the shunt for this purpose.

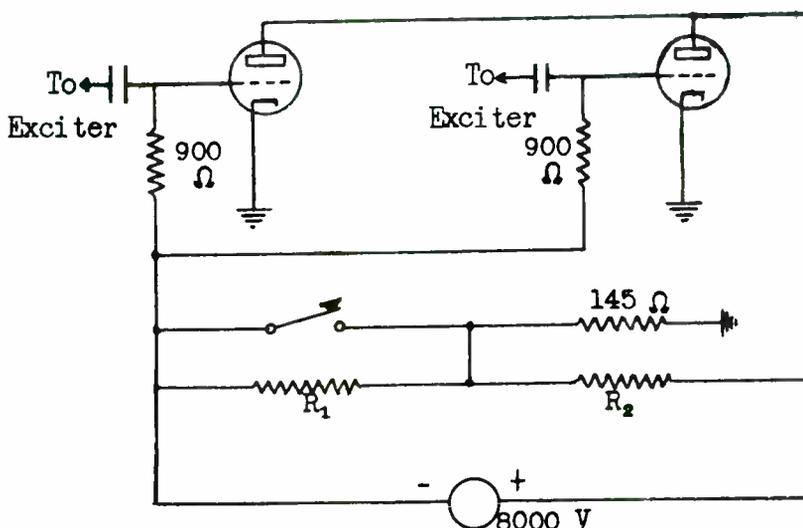
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SECTION II

Page 1.

1. The following diagram shows the bias circuits of the power amplifier stage of a radio-telegraph transmitter. Current, voltage, and tube data are as follows: Class B operation.

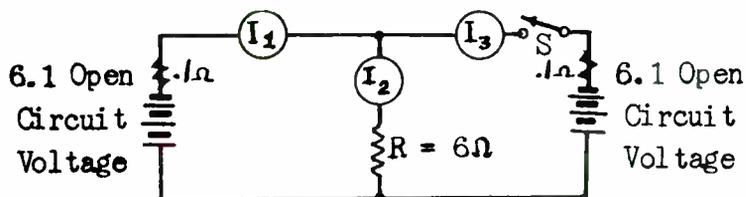
peak excitation voltage	= 200 volts
I_p each tube (key down)	= .45 ampere
I_g each tube (key down)	= .037 ampere
Bleeder current (key up)	= .01 ampere
Tube amplification factor	= 40



(A) What is the normal operating bias voltage based on circuit and tube ratings given? (Key closed.)

(B) What values and power ratings of R_1 and R_2 would you select to completely block the tubes when the key is open including the excitation given above?

2. In the following circuit, the batteries each have a no-load voltage of 6.1 volts and an internal resistance of .1 ohm.

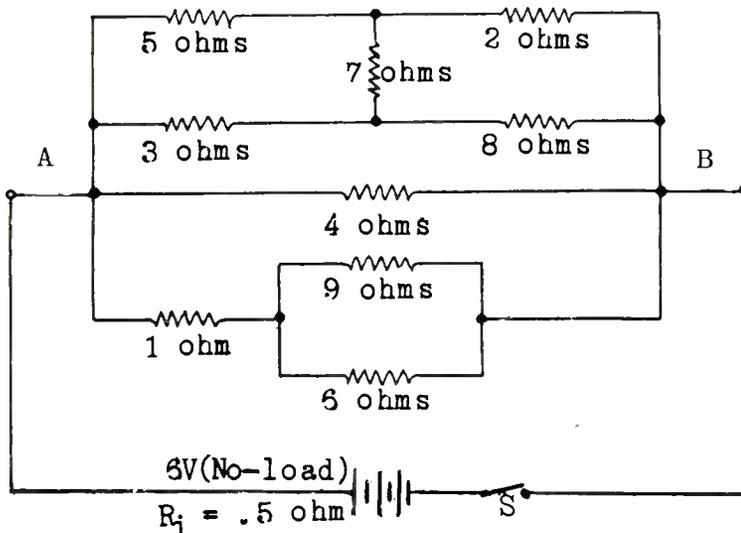


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2. (A) What are the values of I_1 , I_2 , and I_3 with S open?
 (B) What are the values of I_1 , I_2 , and I_3 with S closed?
 Show your work.
 (C) What are the battery terminal voltages in both case (A) and case (B)?
 (D) What is the effective resistance facing 'each' battery under the conditions of case (A) and case (B)?
 (E) To what value must the load resistor be reduced to obtain 6 ohms 'effective' resistance facing each battery with S closed?
3. In the following circuit, the battery no-load voltage is 6 volts and its internal resistance is .5 ohm.



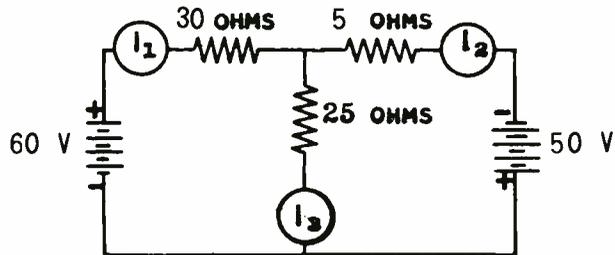
- (A) Find the total network resistance between A and B.
 (B) What current will flow through the battery when switch S is closed?
 (C) What is the battery terminal voltage under this condition?

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4. (A) In the following circuit, determine the values of I_1 , I_2 , and I_3 .
- (B) Indicate the directions of electron flow in each resistor.



5. (A) Given a tuned primary coil with an inductance of $40 \mu\text{H}$ and a tuned secondary coil with an inductance of $250 \mu\text{H}$, with both circuits resonant at 1000 kc/s . If the primary coil has a resistance of 3Ω and the secondary has a resistance of 13Ω , find the value of M to give a maximum transfer of power at a frequency of 1000 kc/s .
- (B) In part (A) what resistance will be coupled or reflected into the primary using the value of M calculated? Show your work.
- (C) Given: $L_p = 40 \mu\text{H}$; $L_s = 200 \mu\text{H}$; and $M = 10 \mu\text{H}$. Calculate the value of the coefficient of coupling k .

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1.

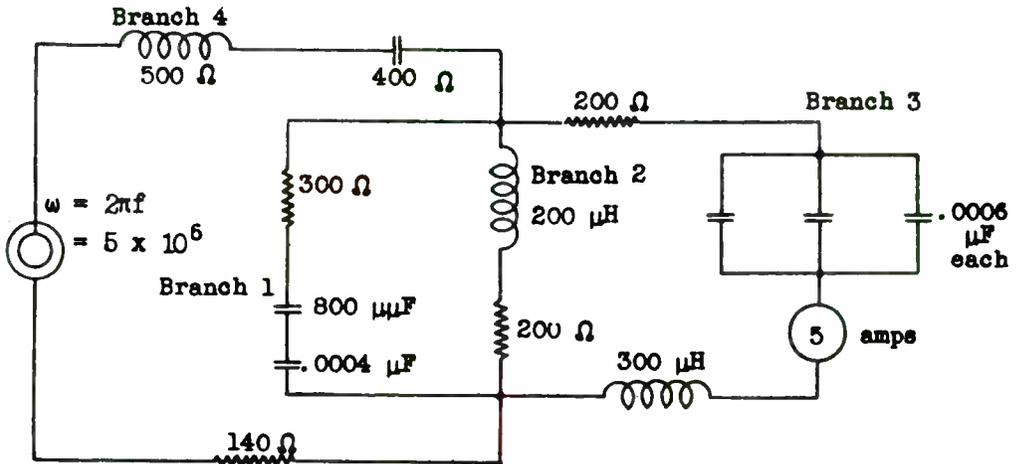


Fig. 1.

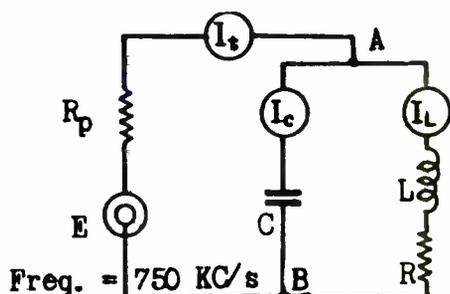
Find the total impedance.

2. Reference Fig. 1. If each capacitor in Branch 3 has a series R of 4 ohms, how much power is dissipated in the capacitor combination? What is the p.f. of each capacitor?
3. Reference Fig. 1. What inductance or capacity inserted in series with the generator (Branch 4) would be necessary to resonate the entire circuit? What would be the nature and value of the impedance at resonant frequency?
4. The measured Q of a coil is 86.6. The coil is to be used in a parallel tuned circuit so that at 600 kc the resonant impedance of the parallel circuit is 75,000 ohms. What is the coil value and what is the capacity required to tune the coil to resonance?
5. A certain capacitor when measured at 1000 cycles shows a value of $10 \mu f$. At 200 mc/s its apparent capacity is $20 \mu f$. What is its residual inductance?

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$E = 750$ volts r.m.s. at 750 kc/s
 $R_p = 1,200$ ohms
 $R = 28$ ohms
 $L = 38.5$ μ h
 $C = 1,144$ μ mf

1. (A) What are the impedances of the C and L branches and the total impedance of the parallel tank circuit between points A and B?

(B) What is the total impedance in series with E?

(C) What is the total circuit current I_t ?

(D) What is the actual voltage across the parallel combination L-C-R?

2. Reference Problem 1.

(A) What is the L branch current I_L ?

(B) What is the C branch current I_c ?

(C) Draw vector diagram showing the position of the branch current vectors and their sum.

(D) What power is being delivered to the resistance R in the L branch?

3. (A) How much error occurs if the resonant impedance Z_{AB} is calculated by the expression $Z = L/CR$ instead of the more exact method of Problem 1?

(B) What is the Q of the parallel circuit?

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4. Reference Problem 1. In the place of the 750-kc/s, 750-volt r.m.s. generator substitute a 500v r.m.s. generator operating at 3,000 kc/s. Assume R in L branch remains 28 ohms.

(A) What is the impedance between A and B?

(B) What is the power delivered to the R of the L branch?

5. (A) Given two point charges of +6 and +3 statcoulombs, 4 cm apart in a vacuum. What is the force in dynes between them, and is it one of repulsion or of attraction?

(B) You have constructed a slide wire bridge which uses a 24 inch slide wire and a standard resistance of 200 ohms. It is occasionally required to measure resistance values higher and lower than is possible with the bridge in its present form. Experience has shown that reasonable accuracy can be obtained only when the slider is not closer than 4 inches from each end.

What two additional standard resistance values would you use in order to extend the *accurate* range continuously from 2 to 25,000 ohms?

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1. A 6C5 is to be employed in a Class A power output amplifier. The signal input is assumed to have sine wave form in all the following work. Construct load lines on the accompanying curves—see next page for the conditions of:

(A) Load $R = 20,000$ ohms, Power Supply Voltage $E_{bb} = 360$ V, d. c.

(B) Load $R = 10,000$ ohms, Power Supply Voltage $E_{bb} = 300$ V, d. c.

Check the position of the load lines by a second method. Show your work. Use the load lines to solve 2, 3, 4, and 5.

2. What is the average peak a-c voltage across the load resistance at full excitation (positive and negative) within Class A limitations? (Swing to zero grid bias).

(A) For the condition of the loadline of Problem 1(A) at a bias of -6 volts and at a bias of -8 volts.

(B) For the condition of the loadline of Problem 1(B) at a bias of -6 volts and at a bias of -8 volts.
3. What is the voltage gain of the stages expressed in terms of the ratio of the output a. c. voltage to the input excitation voltage for each of the four conditions of Problem 2?
4. What is the maximum power output within Class A limitations on excitation for each of the four conditions of Problem 2?
5. What is the percentage of second harmonic distortion to be expected for each of the four conditions of problem 2?

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Tabulate results obtained in Problems 2 to 5 inclusive on the following chart:

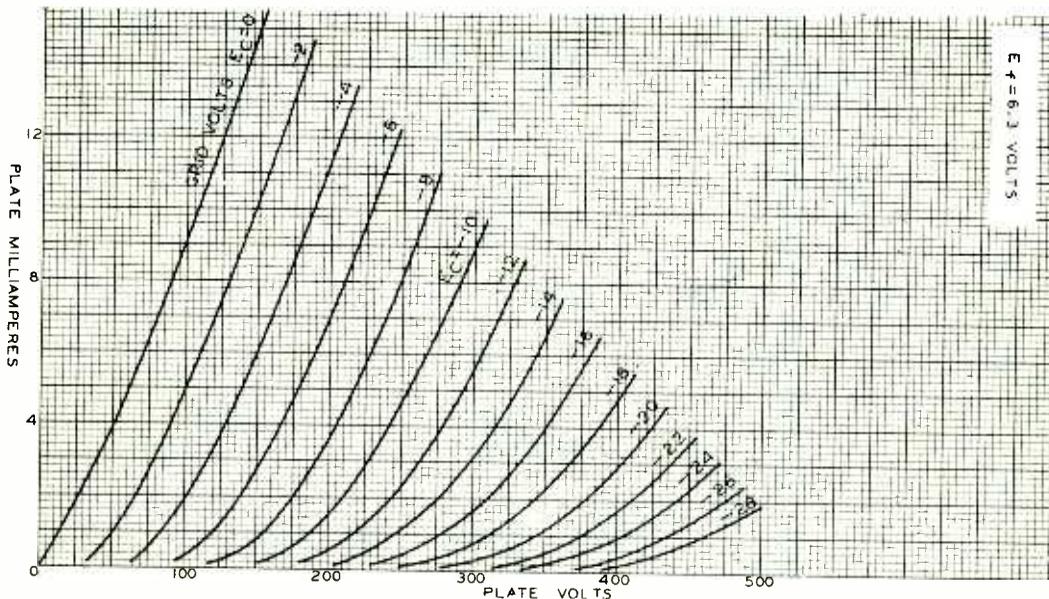
Condition No.....	1.	2.	3.	4.
E_{bb}	360	360	300	300
R_{load}	20,000	20,000	10,000	10,000
Bias.....	-6	-8	-6	-8
Prob. 2. Peak a. c. output..	_____	_____	_____	_____
Prob. 3. Voltage gain.....	_____	_____	_____	_____
Prob. 4. Power output, watts	_____	_____	_____	_____
Prob. 5. % 2nd harmonic....	_____	_____	_____	_____

6C5



6C5

AVERAGE PLATE CHARACTERISTICS

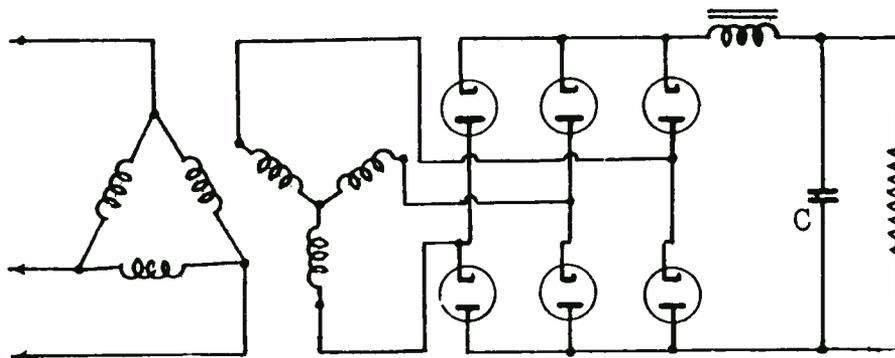


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1.



The three-phase full-wave rectifier and filter system shown above for a television transmitter, operates from 220-volt r.m.s. 60-cycle mains. The output is to be 3,000 volts at 3 amperes. The inductance of the filter choke is 4 henries at full load and its resistance is 5 ohms. The peak output ripple is not to exceed .1% of the d.c. output.

- (A) What is the minimum permissible value of C?
 - (B) What is the cut-off frequency?
 - (C) What is the r.m.s. voltage across each secondary coil?
 - (D) What is the step-up turns ratio of the transformer?
 - (E) What is the peak inverse voltage applied to the tubes?
2. You have a 3-phase 60-cycle transformer with a step-up turns ratio of 50. Calculate the following when the transformer is connected delta-delta, delta-Y, Y-delta, and Y-Y. Use a line voltage of 220 volts.
- (A) Voltage across each secondary winding.
 - (B) Voltage across each pair of secondary line terminals.

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3. Design a single-phase full-wave rectifier power supply, employing a type 5U4G tube, to the following specifications:

Output: Voltage = 385 volts d.c. at filter output.
Current = .175 amps. This includes bleeder current.
A.C. Ripple = 0.2 per cent of d.c. output voltage.

Power supply frequency is 60 cycles. The filter will be in two sections, using $4\mu\text{f}$ as C_1 and $8\mu\text{f}$ as C_2 . Total resistance in L_1 and L_2 assumed to be 150 ohms. Consult tube manual for any further necessary data. Employ a choke input type filter. Calculate the inductance of L_1 and L_2 . Determine the r.m.s. volts per plate required at the secondary terminals of the transformer. Use tube manual as a reference.

4. Design a voltage divider for the rectifier of Problem 3 to provide for the following requirements:

75 MA at 385 volts
50 MA at 300 volts
40 MA at 200 volts
Use 10 MA bleeder current

Specify resistance values and power ratings for the divider.

5. It is desired to employ a spare 0-1 MA D.C. milliammeter as an ohmmeter. The scale is marked for every .1 MA. Use a 4.5 volt C battery and a 4500 ohm series resistance. Tabulate each current division from .1 to 1 MA in terms of resistance. Consider the meter resistance as included in the 4500 ohm resistor.

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1. Given a class C stage consisting of a 891 tube that is to be plate-modulated. The plate supply potential is 6,000 volts, and the d.c. current drawn by the tube at this potential is 0.75 ampere (carrier conditions). The r.f. power output is 3.5 kw when unmodulated.

(A) What is the resistance that this tube presents to the modulator stage?

(B) How much modulator power is required for 100 per cent plate modulation?

(C) How does this compare with the d.c. power supplied to the class C stage?

2. A pair of 833-A tubes in class B push-pull are to be used in the modulator stage. Forced-air cooling is to be employed. The following data applies to the two tubes when employed in this manner:

$$E_{bb} = 4,000 \text{ volts}$$

$$E_c = -100 \text{ volts}$$

Peak a. f. Grid-to-grid voltage = 480 volts

Maximum signal d.c. plate current = 800 ma

Plate-to-plate resistance = 12,000 ohms

Maximum signal power output = 2,400 watts

(A) What should be the turns ratio between the primary and secondary of the output modulation transformer for proper impedance match?

(B) Does the modulator stage have sufficient power output for the 891 tube?

(C) What is the plate efficiency of the modulator stage when furnishing 100 per cent plate modulation for the 891 tube?

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3. The input level to an amplifier is -56 db (.001 watt = 0 db). The output power is 25 watts. What is the gain of the amplifier?
4. (A) A db meter is calibrated to read 0 db with a reference level of 1 mw. When this meter reads +10 db what would be the equivalent reading on a meter having a reference level of .006 watt?

(B) How many speakers can be operated at a level of 24 db from an amplifier that has a rated output of 33 db? (.006w reference level.)
5. (A) Design an H-type pad to give an attenuation of 25 db between 500-ohm impedances.

(B) A certain T-pad consists of a shunt resistance of 220 ohms and two series resistances of 420 ohms each. The pad is designed to operate between impedances of 600 ohms.

NOTE: The solution of Problem 5(B) *must* be obtained by actual calculations. A simple attack is to assume a unity voltage and current at the input. The ratio of the input and output power may then be calculated and the db attenuation figured from this ratio.

Calculate the attenuation of the pad in db. *Do not use tables.*

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1. (A) A tube has a $G_m = 5,000 \mu$ mhos and an input conductance of 60μ mhos at 150 mc/s. At what frequency will the gain of this tube be reduced to unity when operating into another similar tube?

(B) An amplifier stage operates at 150 mc/s. The tube has a $G_m = 4,000 \mu$ mhos, a grid-to-cathode capacity of 4μ f, and a cathode lead inductance of $.04 \mu$ henry. Find the input loading (resistance).
2. What will be the capacity of the capacitor across a diode load resistor $250,000$ ohms if the diode distortion is to be negligible at 95% modulation at frequencies as high as $5,000$ c/s. Assume the grid resistance of the following tube to be so high as to have negligible shunting effect.
3. An r.f. amplifier stage is to operate over the range of 500 to 1650 kc, and the intermediate frequency is 450 kc. The r.f. amplifier stage is to have a band width (to either side of the carrier frequency) of 4 kc at 500 kc.

(A) What should be the secondary coil Q at 500 kc?

(B) What is the db image attenuation at 500 kc?

(C) If the secondary Q is the same at 1650 kc as at 500 kc, what will be the band width at the higher frequency?

(D) What will be the db image attenuation at 1650 kc?
4. The constants of a tuned RF amplifier using a 6BA6 tube at $E_p = 250$, $E_{s,g} = 100$, are $L_s = 300 \mu$ H, $M = 40 \mu$ H, $Q_s = 120$ at a frequency of 1000 kc/s. Determine the voltage amplification of the amplifier at the resonant frequency of 1000 kc/s. Express amplification as a numerical ratio of output to input voltages. Hint: (Solve for L_p in terms of L_s and M and k).
5. Design a biconical horn to operate at $2,000$ mc with a power gain of 24 using a $TE_{1,0}$ mode. Find all dimensions.

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1. (A) A transmitter at a height of 150 feet radiates 50 watts at a frequency of 180 mc. If an array is used at both transmitter and receiver and the latter is 100 feet high. What is the line-of-sight distance of transmission?

(B) What power is received at the receiving location?
S = 25 square meters.

(C) Find the field strength in μ volts/meter at the receiving location.

2. (A) By graphical construction and calculations, determine the amplification factor, dynamic plate resistance and mutual conductance of a 6C5 tube under the conditions $E_r = 6.3$ volts, $E_c = -16$ volts, $E_b = 300$ volts.

(B) What approximate voltage gain may be expected when the tube is operated under the above conditions with a 20,000-ohm load? If the load is in the form of a resistor, what plate supply voltage (E_{bb}) would be required?

3. (A) A 50-kw (rated) broadcast station is operating at 2 db below its normal carrier output. What is the percentage of reduction of power output?

(B) Reference 3(A). The effective resistance of the antenna is 143 ohms; what is the antenna ammeter reading before and after the reduction in output?

4. (A) A single layer coil contains 55 turns of wire on a 1.6" radius form with a winding length of 1.25". What is its approximate inductance?

(B) What value of capacity would tune the above coil to resonance at 1150 kc/s?

(C) The coil Q at 1150 kc/s is 60. What is its resistance at this frequency?

(D) The coil together with its tuning capacity is induc-

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tively coupled to another coil in which a current at 1150 kc/s is flowing. A *peak* r.f. voltage of 18.5 volts is measured across the terminals of the tuning capacitor by the use of a vacuum tube voltmeter. What is the RMS voltage induced in the tuned coil, assuming a condition of resonance? Note: the induced voltage is not IX_L .

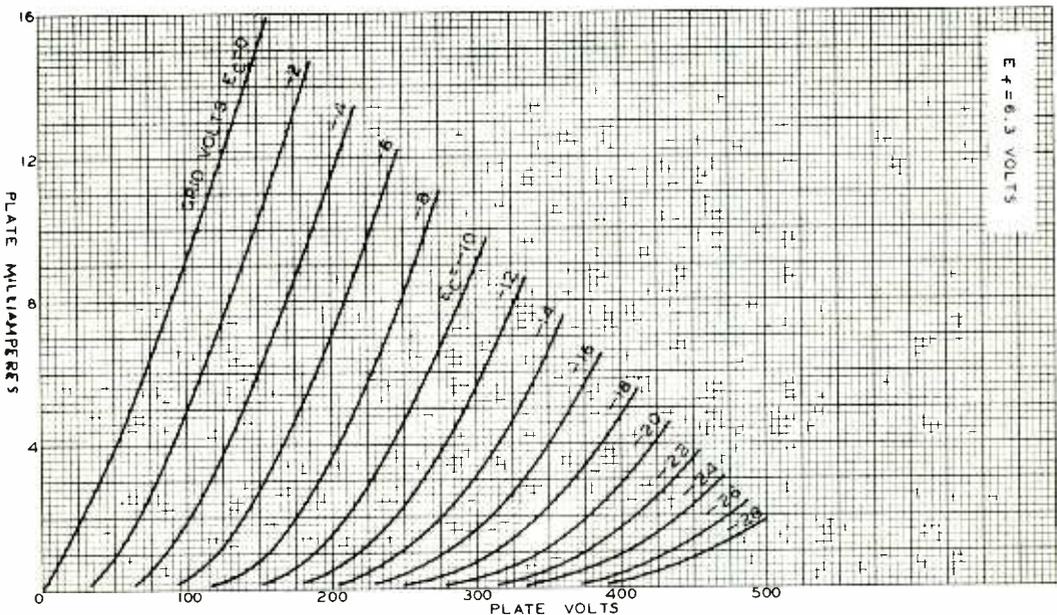
5. In calibrating a heterodyne frequency meter, the zero beat for 1666.7 kc/s is noted at 804 dial divisions and that for 1750 kc/s at 1136.5 divisions. Assuming a straight-line-frequency characteristic to exist between these settings, what is the setting for 1700 kc/s?

6C5



6C5

AVERAGE PLATE CHARACTERISTICS



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1. (A) When coupling a transmission line to an antenna, what two conditions must be satisfied by the coupling network?

(B) In the circuit of Fig. 1 the magnitudes of X_1 and X_4 are equal. Develop the mathematical formula for the impedance Z_t looking into the circuit from points 1 and 2.

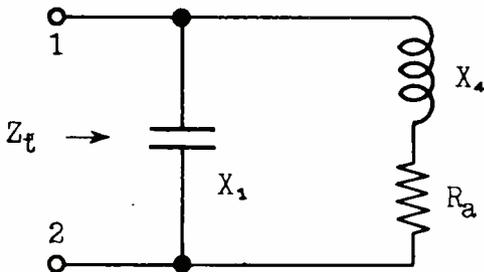


Fig. 1.

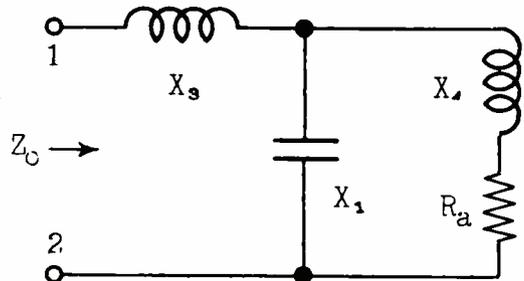


Fig. 2.

- (C) What part of the formula, developed in 1(B) represents the resistive component of Z_t , and what part represents the reactive component?

(D) In Fig. 2 the values of X_1 , X_4 and R_a are identical with those in Fig. 1. Write the expression for the reactance of X_3 that will make the impedance looking into the network at terminals 1 and 2 purely resistive in character.

(E) Write the expression for X_1 in terms of Z_0 and R_a . (Fig. 2)
2. A converter tube has an input capacitance of $3 \mu\text{f}$ and an input resistance of 2,100 ohms. A half-band width of 4 mc is desired at an operating frequency of 500 mc. A quarter-wave shorted concentric line is to be employed as the step-up device between the antenna line and the converter grid. The inner conductor of this quarter-wave line is to be 0.125 inch in diameter, and the outer conductor is to have a diameter of $3.6 \times 0.125 = 0.45$ inch, so that the characteristic impedance is 76.8 ohms. A dipole antenna connects to the proper tap on the quarter-wave line through a nonresonant coaxial line of 75 ohms. The intermediate frequency is 40 mc.

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- (A) Calculate the necessary Q of the resonant line when loaded with the tube and the antenna line in order to give the desired band width.
- (B) Find the position of the grid tap in degrees θ_t , on the resonant line and in inches from the shorted end.
- (C) Find the position of the antenna line tap in degrees θ_a on the resonant line and in inches from the shorted end.
3. (A) What is the actual length of the line?
- (B) What is the image rejection in db?
- (C) Check the Q of the actual line.
4. (A) Given a 4,000 mc $TE_{1,0}$ wave mode propagated in a square guide whose width and height are each 5.25 cm, and whose length is 37.5 feet long. Find the db attenuation.
- (B) A paraboloidal reflector is to have a power gain of 50 at 4000 mc (horizontal polarization). The focus is in the plane of the mouth of the reflector. A doublet antenna is assumed. What are the beam widths in the horizontal and vertical planes?
- (C) A tube whose $G_m = 4,000 \mu\text{mhos}$ and whose $\mu = 20$ is connected as a grounded-grid amplifier. The cathode load resistance R_1 owing to transit time is 1,500 ohms, and the plate load resistance is 2,200 ohms. Disregard the generator impedance, and calculate the impedance looking in between cathode and ground Z_{a-b} , and the impedance looking in between plate and ground Z_{c-b} .

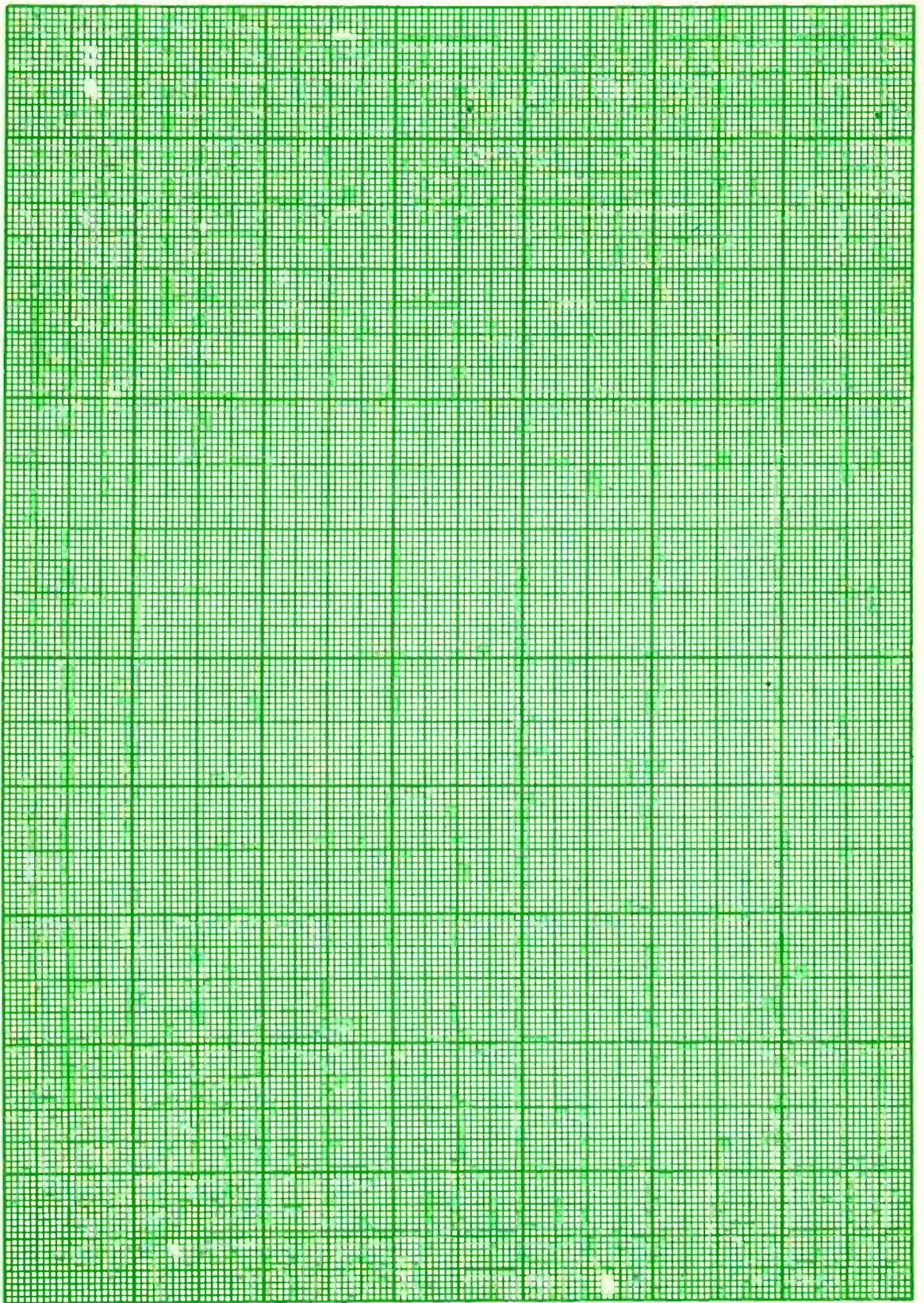
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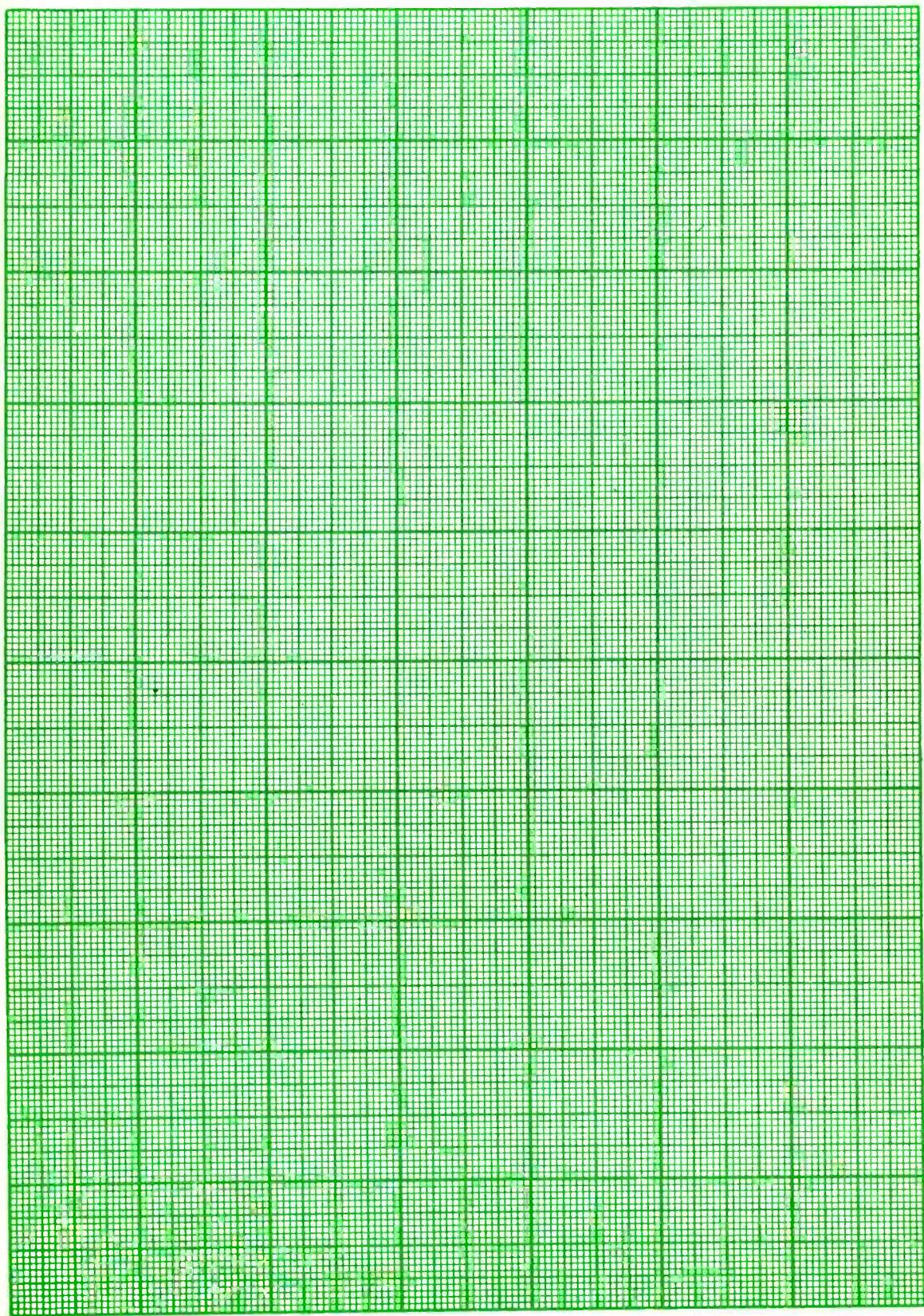
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5. It is desired to match an antenna having a base impedance of $140 - j200$ ohms to a 70 ohm (surge impedance) transmission line by the use of a π network. The inductive reactance of the series element of the network is 90 per cent of its theoretically maximum permissible value. The transmitter frequency is 800 KC/s. Draw diagram of the circuit giving inductance or capacity values of all circuit components.

Two methods are possible, and since CREI solutions discuss only resistive matching, it is necessary to take care of the antenna reactance to achieve the condition of resistive impedance at the antenna end.





TITLE PAGE FOR EXAMINATIONS

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