MEASUREMENT.

INDUCTANCE COILS, CONDENSERS, CALIBRATION OF CONDENSERS.

QUESTION #1. What is an inductance coil? What are its uses in radio circuits?

ANSWER #1. An inductance coil is a conductor so arranged that a magnetic field will be generated and maintained. Usually the arrangement is such that the field progressively generated along the length of the conductor will be in such a direction as to cause the total resultant field to be strengthened. The inductance coil is used in radio frequency circuits to maintain circuits in an oscillatory condition when so desired, to obtain the desired frequency, to transfer energy from one circuit to another and to suppress undesired frequencies with high inductive reactance.

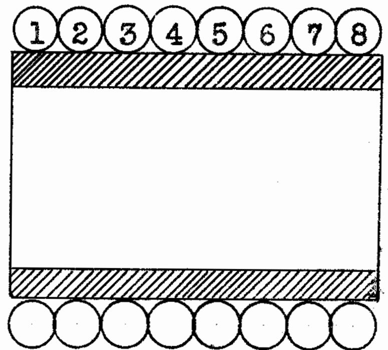
QUESTION #2. Draw and explain the four common methods of winding receiving coils, giving the uses, advantages and disadvantages of each.

ANSWER #2. Sketches on next page. Sketch 1 is a single layer solenoid, the turns being progressively placed side by side. As the potential existing between turns is equal in every case and is equivalent to the total emf divided by the number of turns, the distributed capacity of the coil is low. At the turns, the distributed capacity of the coil is low. At the present time this type is considered to be the most efficient of all windings and is used extensively in high frequency work. Its main disadvantage is that when a large inductance is required the coil must necessarily be quite bulky. If the form has a minimum amount of insulation and the material used has a high efficiency dielectric. This type of coil will usually be found superior for any frequency.

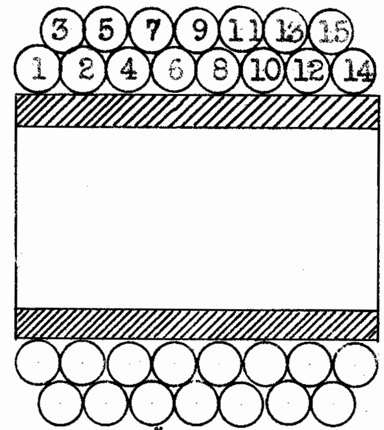
Sketch 2 shows a bank wound coil and while its distributed capacity is much higher than the one previously described it has the lowest distributed capacity that can be obtained in a multi-layer winding. The illustration shows how the windings is accomplished. Turn number one and two are placed side by side then turn three is kinked and wound between and above turns one and two. Turn four is then wound next to turn two, turn five is now kinked and placed above and between turns two and four, etc. It is not practicable to use more than five layers as the distributed capacity will be so high as to make the coil little more efficient than would be the case in an ordinary multi-layer coil. This type of coil is used when the inductance is high and the space available for the coil is small, and it is desired to maintain as high an efficiency with small distributed capacity as is possible.

Sketch 3 shows an ordinary multi-layer coil. It has a very high distributed capacity insofar as the potential is not equally distributed between the turns of the coil. In the illustration, the potential across two layers of the coil (16 turns) is impressed between turns one and sixteen

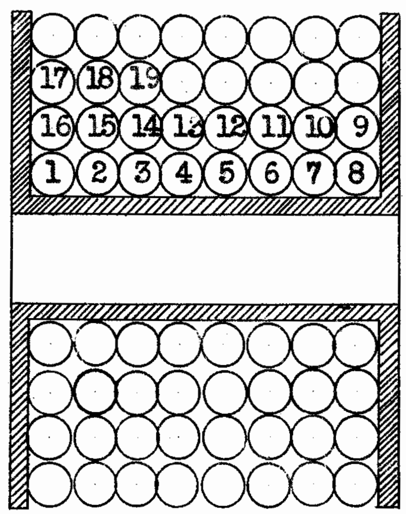
ANSWER #2. Continued.



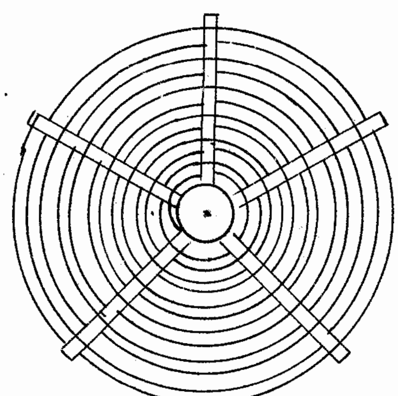
Sketch #1 - Single layer solenoid.



Sketch #2 - Bank-wound coil.



Sketch #3 - Ordinary Multi-layer coil.


Sketch #4 - Spider-web wound coil.

which are adjacent It is possible with this type of winding to obtain a large inductance with minimum space and it is used when high efficiency and low distributed capacity are not required.

Sketch 4 shows the spider-web winding. It has a low distributed capacity and as most of its bulk is evident within two dimensions, it can sometimes be used where type 1 would be impracticable. This type is not used nearly as extensively at present as was the case several years ago when its efficiency was thought to be much higher than type 1.

QUESTION #3. How do transmitting inductances differ from receiving inductances?

ANSWER #3. Transmitting inductances usually must carry much heavier currents than receiving coils and also a higher potential is impressed between adjacent turns, therefore the conductor must be heavier and the insulation better than is necessary with receiving coils. Good insulation between turns with a good dielectric constant is readily obtained by space winding. The conductor must have large surface area so than the radio frequency resistance will be low, for the losses due to resistance will be the product of the current squared and the resistance and the currents in transmitting inductance are sometimes very large. Ordinarily, transmitting inductances are wound with copper tubing or copper strip and the turns are space wound.

QUESTION #4. What is meant by tapped inductance? Why used? How constructed?

ANSWER #4. Where it is desired to use various frequencies without changing inductance coils, a tapped inductance provides a convenient means of varying the number of turns included in the circuit and therefore the inductance of the circuit. The frequency of the circuit is therefore varied by varying the inductance. The construction is usually such that clips or a switching arrangement can be used to incorporate more or less turns in the circuit.

QUESTION #5. What is the effect of dead ends? How is this effect eliminated?

ANSWER #5. Where a portion of the inductance is being used and the remaining portion of the inductance is left in the field of the coil, the inductance of the unused portion together with its distributed capacity may tune close enough to the resonant frequency of the used portion so that a large amount of energy will be transferred and wasted. A dead end switch may be used to disconnect the unused portion and thus eliminate the auto-transformer effect and thus decrease the effective coupling so that the energy transfer will not be so great or better yet, the unused portion may be disconnected and each of its individual turns short circuited so the effect will only be due to that from eddy

ANSWER #5. Continued.

currents generated in the mass of metal placed in the field of the coil. These losses may become very appreciable at times and the best method is to use interchangeable coils where possible, especially at the higher frequencies.

QUESTION #6. What is meant by distributed capacity of inductance coils? How can it be reduced to a minimum?

ANSWER #6. Distributed capacity is caused by the surface area of the turns of the coil. These surface areas are separated by insulation which becomes the dielectric of the condenser. As the potential of adjacent turns are at different values with respect to each other the capacity will therefore become charged and discharged as the potential across the coil reverses. The distributed capacity can only be reduced by spacing the turns from each other but the effect of the distributed capacity can be greatly reduced by such an arrangement so that adjacent turns will have as low potential difference as is possible. The condenser then will not become charged to such a high value as otherwise would be the case. An ordinary layer wound coil will have as high a distributed capacity as a coil of the same dimensions which is bank wound but the effect of the distributed capacity of the bank wound coil will be much less as the condenser will not be charged to such a high value. The effect of distributed capacity is equivalent to a shunt condenser placed across the terminals of the coil and if the dielectric used is good the effect of distributed capacity is not detrimental. When space wound self supporting coils are used, and no dielectric or insulation other than air is present, the distributed capacity is nothing to worry about, but when the winding form has a large amount of insulation, which is a poor dielectric, the losses become large and the winding form may become hot and even char as a result of eddy currents.

QUESTION #7. Why are coil forms and wire insulation important factors when constructing inductance coils?

ANSWER #7. Becuase it is necessary to use good delectric material between the turns of the coil so that the losses due to distributed capacity will not be high. It is not so important to keep the distributed capacity of the coil low if the dielectric is good but where insulated wire closely wound, is used, the only way of reducing losses is to maintain the distributed capacity at a minimum

QUESTION #8. Explain why a single layer coil will have lower loss and lower distributed capacity than a multi-layer coil

ANSWER #8. The distributed capacity of the multi-layer coil will be much greater becuase the winding is more concentrated and each turn will have a conductor separated by an insulator on all sides of it. The single layer coil

ANSWER #8. Continued.

will not have any conducting surface area above or below it. The insulation is usually very poor at the best and therefore the single layer coil having a lower distributed capacity will have the lower loss.

QUESTION #9. What are the advantages in bank winding inductance coils? Explain briefly how coils are so constructed.

ANSWER #9. When bank winding is used, the effect of the distributed capacity is not so detrimental because adjacent turns do not have the difference of potential as excessive as is the case of ordinary multi-layer winding. The distributed capacity therefore is not charged to such an extent and the loss in the dielectric becomes less. Turns one and two are wound side by side, turn three is kinked and wound between and above one and two turn four is placed beside turn two, turn five is above and between two and four, turn six is above and between three and five, turn seven is wound next to turn four, turn eight is above and between four and seven, turn nine is above and between five and eight, turn ten is above and between six and nine, etc. This is the sequence for a four layer bank or more than four layers. Turns one, two, four, and seven will be on the bottom layer. The electrical separation of turns is thus greater than would be the case of an ordinary multi-layer coil.

QUESTION #10. Give design formula and symbols for determining the inductance of a single layer coil.

ANSWER #10. Formula:

$$L = \frac{0.0395\ a^2 n^2}{b} \times K.$$

Where:

L = Inductance in microhenries.
n = number of turns in winding.
a = mean radius of coil in cms.
b = length of coil in cms = n x D
D = distance between centers of two adjacent turns.
K = shape factor as obtained from the ratio 2a/b. Table #19 Robison's.

QUESTION #11. A coil has 150 turns of wire in a single layer with a mean radius of 5 cms and a winding pitch of .15 cms. Calculate the inductance in microhenries.

ANSWER #11.

$n = 150$
$a = 5$
$b = n \times D = 22.5$

$$K = \frac{2a}{b} = .4444$$

$D = .15$

Interpolating in the table for the value of K:

ANSWER #11. Continued.

Difference between next lowest and next highest in table equals .0500

Difference between next lowest and K equals .0444

Difference between next lowest and next highest values of K in table equals .0162

Therefore:

$$\frac{.0444}{.0500} \times .0162 = .0143$$

Next highest K in table equals .8499. Since the value of K decreases as 2a/b increases, this amount must be subtracted from .8499

$$.8499 - .0143 = .8355 \text{ value of K}$$

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Formula:

$$L = \frac{.0395 \times 25 \times 150 \times 150 \times .8355}{22.5}$$

L = 825.05625 microhenries. Ans.

QUESTION #12. What is the inductance in microhenries of a coil single layer type, whose diameter is 29.8 cms, wound with 15 turns of wire, the distance between centers of adjacent turns being 1 cm, and the diameter of wire .5 cms.

ANSWER #12.

$$n = 15.$$

$$a = \frac{\text{diameter of core}}{2} \text{ plus } \frac{\text{dia. of wire}}{2}$$

$$= \frac{29.8}{2} \text{ plus } \frac{.5}{2} = 15.15$$

$$b = n \times D = 15 \times 1 = 15$$

$$K = \frac{2a}{b} = \frac{30.3}{15} = 2.02$$

K from table = .52314

Formula:

$$L = \frac{.0395 \times 15.15 \times 15.15 \times 15 \times 15 \times .52314}{15}$$

L = 71. 142735 microhenries. Ans.

QUESTION #13. Referring to the tables 25 A, B, and C, what is the formula and symbols for computing the inductance of single layers woils closely wound with insulated wire'

ANSWER #13. Formula:

$$L = PK$$

Where: L = inductance in microhenries.
P = shape factor, depending on the relation of diameter to length.

$K = \frac{N^2}{25}$, where N = number turns per inch.

P can be found from table 25 A.
K can be found from table 25 B and C.

QUESTION #14. Explain how the tables 25 A, B, and C are used.

ANSWER #14. First ascertain the size of wire the coil is wound with (B & S) and opposite this size wire in table 25C will give the number of turns per inch.

Under table 25B opposite the turns per inch will be found the value of factor K.

In table 25A the diameter of the coil in inches has been plotted along the abcissae while the length of the coil has been plotted along the ordinates. Where the coordinates intersect at right angles will be found the values of P which is the coil shape factor. Tables A and B require only simple interpolation in the same manner as was used in interpolating Table 1. However, Table A may require double interpolation as the length as well as the diameter of the coil may fall between table graduations.

QUESTION #15. Compute using tables 25 A, B, and C for inductance in uh: A coil is closely wound with 200 turns of #30 B & S gauge, double cotton covered wire, in a coil 3 inches in diameter.

ANSWER #15. By Table 25C, #30 dcc wire = 55.5 turns per inch.

$\frac{200}{55.5}$ = 3.6 inches, length of coil.

Using table 25A, under 3 inch diameter, the value of P for 3.5 inch length is .370, and for 4 inch length is .424. Interpolating P is equal to .3808
By Table 25B at 54 turns per inch the value of K is 4.65 and at 56 turns per inch the value of K is 5. Interpolating K equals 4.9125.

Formula: $L = PK$

$L = 4.9125 \times .3808$

L = <u>1.8707 uh. Ans.</u>

QUESTION #16. Give design formula and symbols for determining the inductance of a helix, flat conductor wound edgewise.

ANSWER #16. Formula:

$$L = \frac{.0395\ a^2n^2}{b}K - \frac{.0126\ acn^2}{b}$$

Where:

L = inductance in uh.
a = mean radius of coils in cms.
b = length of coil in cms = n x D
c = width of strip in cms.
D = distance between centers of two adjacent turns in cms.
n = number of turns.
K = shape factor of coil as obtained from ratio 2a/b. Table #19 Robison's.
L = inductance in uh.

QUESTION #17. A helix is edgewise wound with 60 turns of flat copper strip .6 cms deep and .1 cms thick. The winding pitch is .35 cms and the mean radius of the coil is 11.75 cms. Calculate the inductance in uh.

ANSWER #17.

a = 11.75
b = n x D = 60 x .35 = 21
c = .6
n = 60

2a/b= 1.119

K from table = .6635

Formula:

$$L = \frac{.0395 \times 138.06 \times 3600 \times .6635}{21} - \frac{.0126 \times 11.75 \times .6 \times 3600}{21}$$

L = 605.06283 uh.

QUESTION #18. Give the design formula and symbols for determining the inductance of multi-layer coils wound closely with insulated wire when the length of the coil is greater than the deptch of the winding.

ANSWER #18. Formula:

$$L = \frac{.0395 \times a^2n^2K}{b} - \frac{.0126\ acn^2}{b} \times .693 \text{ plus Bs}$$

Where:

L = inductance in uh.
n = number of turns
a = mean radius of coil.
D = distance between centers of two adjacent turns in cms.

ANSWER #18. Continued.

b = length of coil in cms: n x D
c = radial depth of winding; distance between centers of wire times n. o. l.
K = shape factor from Table 1, ratio 2a/b
Bs= shape factor from table 2, based on ratio b/c

QUESTION #19. Calculate the inductance of a five layer coil wound with #20 double cotton covered wire, one inch long, the mean radius of the coil is 2 cms.

ANSWER #19.
n = 125 turns (table 25C)
a = 2 cms.
D = .1016 cms.
b = 2.54 cms.
c = .1016 x 5 = .508 cms.
K = .58333 as obtained from 2a/b
Bs= .2292 as obtained from table 2 from the ratio b/c

Formula:

$$L = \frac{.0395 \times 4 \times 15625 \times .58333}{2.54} - \frac{.0126 \times 2 \times .508 \times 15625}{2.54} \times$$

$$.693 \text{ plus } .2292$$

L = <u>494.3469 uh. Ans.</u>

QUESTION # 20. Give formula and symbols for calculating the inductance of single layer square coils where the width b is small when compared to the length a.

ANSWER #20. Formula:

$$L = .008an^2(2.303 \log_{10} \frac{a}{b} \text{ plus } .726 \text{ plus } .2231\frac{b}{a})$$

$$-.008an(A \text{ plus } B)$$

Where:
a = side of square in cms, measured to the center of the wire.
n = number of turns.
D = pitch of winding, that is, the distance between centers of adjacent wires in cms.
b = nD = length of winding in cms.

A and B are form factors taken from Tables 20 and 21.

QUESTION #21. Calculate the inductance of a radio compass coil having 38 turns of #12 B & S gauge bare copper wire average length on side being five feet one and $\frac{1}{4}$ inches and the average winding pitch being $1\frac{1}{2}$".

ANSWER #21.

$$a = \frac{61.25 \text{ inches}}{.3937 \text{ in. in 1 cm.}} = 155.57 \text{ cms.}$$

$$n = 38.$$

$$D = \frac{1.5}{.3937} = 3.81 \text{ cms.}$$

$$b = n \times D = 38 \times 3.81 = 144.78$$

$$d = \text{for \#12 B \& S} = .2053 \text{ cms.}$$

$$\frac{d}{D} = \frac{.2053}{3.81} = .053$$

$$A = \text{from Table 20} = -2.449$$

$$B = \text{from Table 21} = .3138$$

$$\frac{a}{b} = \frac{155.57}{144.78} = 1.08$$

$$\text{Log}_{10} \frac{a}{b} = 0.03342$$

$$\frac{b}{a} = \frac{144.78}{155.57} = .928$$

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By formula:

$$L = .008 \times 155.57 \times 38 \times 38(2.303 \times .03342 \text{ plus } .726 \text{ plus } .2231 \times .928) -.008 \times 155.57 \times 38 (-2.449 \text{ plus } .3138)$$

$$= 1797.155(.0769 \text{ plus } .726 \text{ plus } .197)-47.293 (-2.1352)$$

$$= 1797.155(.9999)-47.293(-2.1352)$$

$$= 1796.975 \text{ plus } 100.97$$

$$= \underline{1897.945 \text{ uh. Ans.}}$$

QUESTION #22. What is a condenser and how is it used in conjunction with radio circuits?

ANSWER #22. A condenser consists, primarily, of two conductors separated by an insulating substance having dielectric properties. The quality of the substance as an insulator is not necessarily an indication of its dielectric value. The condenser is used in radio in conjunction with inductance to vary the oscillatory period of any circuit, to place circuits in resonance with each other, to by-pass radio or audio frequencies, to block direct currents while allowing audio or radio frequency components to pass, and to adjust power factors by compensating for any inductive reactance that is present in the circuit.

QUESTION #23. Describe briefly, fixed condensers. What precautions should be observed when constructing mica dielectric condensers?

ANSWER #23. Fixed condensers are usually so constructed as to obtain a maximum value of capacity in a minimum amount of space. Alternate layers of tin foil or copper sheets and sheets of the insulating substance are stacked together. The insulating sheets are always larger than the conducting sheets so that the edges will be well insulated. Every other metal sheet is then connected together and then the remaining sheets are joined and terminals attached to each group. There are thus two terminals and the resistance between these tereminals in a good condenser should be near infinity. The capacity is dependent upon the area of the plates of metal and inversely upon the square of the distance of their separation and upon the dielectric constant of the material used as an insulator. In constructing mica dielectric condensers, care should be taken to grade the insulating sheets so that none have flaws or scratches and that all are of the desired thickness. The conducting sheets should be soldered together at their points of contact so that the phase angle of the condenser will be low. The assembled condenser should be subjected to pressure to eliminate air pockets and insure a maximum capacity which will remain constant. In commercial manufacture the condensers are subjected to treatment to render them impervious to moisture and while so treated they are placed in a vacuum.

QUESTION #24. How are fixed condensers constructed to be used in high voltage circuits?

ANSWER #24. Sometimes the delectric used is thick enough to enable the condenser to be used on high voltage circuit but more often two or more units or condensers are constructed as explained above, and then these units connected in series or series parallel, to obtain the correct capacity and to maintain the insulation sufficient to provide a safety factor at the rated voltage.

QUESTION #25. What four advantages have mica dielectric condensers over other fixed condensers?

ANSWER #25. Mica dielectric condensers can be made compact, as their dielectric constant is high and the breakdown voltage is high due to mica being a good insulator. Their capacity remains very constant for they can be sealed tightly and mica does not readily absorb moisture. The mica dielectric condenser has a low phase angle and thus the losses are low. Good sheet mica is readily obtainable and it is easy to cut, grade and assemble.

QUESTION #26. Give a brief description of the various types of variable condensers.

ANSWER #26. Most variable condensers have an air dielectric, although some are used in oil. A number of fixed plated are spaced and connected together and the rotating element has a number of plates spaced and connected together. The spacing of the fixed and rotating plates are staggered so that as the rotor is turned the plates will interleave without making contact. Thus the capacity is varied by varying the active surface area. There are several types of variable condensers. The straight line capacity condenser is constructed with semi-circular rotor plates so that the surface area varies in the same ratio as the angle of rotation and a curve plotted to show capacity against degrees of rotation and a curve plotted to show capacity against degrees of rotation will be in a straight line. The straight line wave length condenser has its rotating plates somewhat elongated so that the capacity variation when only a small portion of the plates are meshed is small in comparison to the angle of rotation, while the ratio of capacity to rotation angle is large at the maximum end of the scale. Such a condenser is designed to show a straight line as a curve when rotation is plotted against wave length. The straight line frequency condenser is built on the same principle as the straight line wavelength condenser but the elongation of the plates is more pronounced allowing the capacity to increase very gradually at the beginning of the scale and quite rapidly at the maximum end of the scale. Such a condenser will show a straight line for its curve when rotation is plotted against the frequency range. Some variable condensers are so arranged that their capacity is varied by varying the separation between plates. These are usually the low capacity neutralizing condensers. A type of condenser sometimes used in decremeters has its plates so shaped that each degree is a certain percentage of the capacity at that particular setting. Variable condensers are usually provided with a scale which is calibrated in degrees from zero to one hundred and eighty degrees or from zero to one hundred divisions, in equal scale divisions. Straight line wave length of straight line frequency condensers are usually built for use with some definite value of inductance and the scale can be calibrated directly in wavelength of frequency.

QUESTION #27. Give formula and symbols for determining the capacity (approximate) of parallel, multi-plate condensers.

ANSWER #27. Formula:

$$C = 8.85 \times 10^{-2} \times K \frac{(n-1)S}{r}$$

Where:
K = dielectric constant (unity for air)
S = area of one plate in cms. (square)
n = number of plates.
r = thickness of dielectric in cms.
C = capacity in Micromicrofarads.

QUESTION #28. Calculate the capacity in microfarads of a condenser having 20 metal plates 2 x 2 inches separated by sheets of mica 1 millimeter thick. The dielectric constant being 8.

ANSWER #28.
K = 8.
$S = (2.54 \times 2.00)^2 = 25.8$ square cms.
n = 20
r = 0.1 cms.

By formula:

$$C = 8.85 \times 10^{-2} \times 8 \times \frac{(20-1)2.58 \times 10}{10^{-1}}$$

$$C = 8.85 \times 10^{-1} \times 3.92 \times 10^{4} = 8.85 \times 3.92 \times 10^{2}$$

C = 3469.2 mmf = .0034692 mfd. Ans.

This capacity is only approximate insofar as it does not take into effect the edge effect.

QUESTION #29. Give the general formula and symbols for computing the capacitance of a semi-circular plate condenser.

ANSWER #29. Formula:

$$C = .139K \times \frac{(n-1)s^2-u^2}{r}$$

Where:
C = capacity in mmf.
K = dielectric constant (unity for air).
n = number of plates.
r = thickness of dielectric in cms.
s = outside radius of plates in cms.
u = inner radius of plates in cms.

QUESTION #30. Calculate the capacity in micro-farads of a condenser having 12 fixed plates 11 moveable plates the separation being 0.7 millimeter. The outside radius is 1 and 1/8 inches and the inner radius is 5/16 inches.

ANSWER #30. Continued.

K = 1
n = 23
r = .07 cms.
s = 2.54 x 1 1/8 = 2.8575 cms.
u = 2.54 x 5/16 = .79375 cms.

By formula:

$$C = .139 \times \frac{(23-1)\ 2.8575^2 - .79375^2}{.07}$$

$$C = .139 \times \frac{22 \times 8.1653 - .63}{.07}$$

$$C = .139 \times \frac{22 \times 7.5353}{.07}$$

$$C = \frac{.139 \times 165.7766}{.07}$$

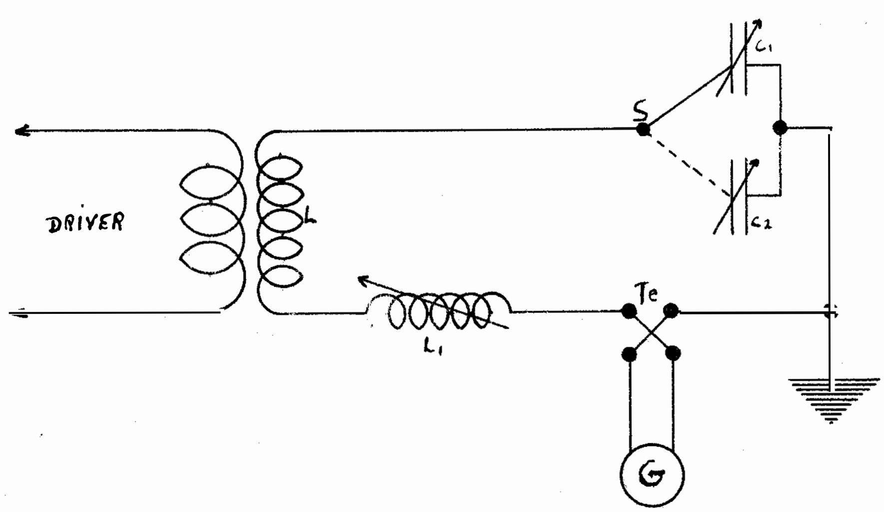
$$C = \frac{23.0429474}{.07}$$

C = 329.184 mmf.

C = .000329 mfd. Ans.

QUESTION #31. Draw circuit used in calibration of condensers by the substitution method.

ANSWER #31.



QUESTION #32. Explain how a condenser is calibrated when its capacity falls in the range of a standard condenser.

ANSWER #32. The method of substitution is employed with a circuit as shown in #31. C1 is the standard condenser, and C2 the condenser to be calibrated. The shields of C1 and C2 are connected together and grounded. An SPDT switch S is used to connect either of the condensers into the circuit. The leads from the switch to the condensers are made as short as possible by mounting the switch on a level with the condenser terminals, and should be of equal length so as to have equal capacity. A variable inductance L, may be employed to compensate for changes in capacity in the circuit instead of retuning the driver with every change in condenser setting. The inductance L should be of fair size so as to avoid the use of very short wave lengths A quick acting current-squared meter, or thermoelement and galvanometer, may be used to indicate resonance. The switch is first thrown to C2, which is set at any desired position, and the driver is loosely coupled to L and adjusted to resonance with the circuit. The setting of C2 is noted, and C1 is substituted in the circuit for C2 by throwing the switch to the other position. C1 is now varied to bring the circuit back into resonance with the driver. The capacity of C1 at this setting equals that of C2 at the setting noted By repeating this process at a number of settings, C2 may be calibrated throughout its range, provided C2 is not greater than C1, and a capacity calibration curve plotted with condenser settings in degrees as abcissae and the capacity in uuf as ordinates. To determine if any error is being introduced into the measurements due to the position of the condensers with respect to the rest of the circuit, one condenser should be tuned to the driver first in its own position and then in that of the other condenser. The settings at resonance should, of course, be the same. Direct substitution may be employed, by eliminating the switch and connecting one condenser in the circuit After a reading is obtained, it is removed and the other is inserted in its place. But with due care the more rapid method above described should be found as accurate as the latter.

QUESTION #33. Explain how variable condensers are claibrated when they fall beyond the range of a standard condenser.

ANSWER #33. If the capacity of the condenser C2 is greater than that of the standard C1, it should first be calibrated by the substitution method up to the maximum capacity of C1. For example, assume that a 0.005 uf variable condenser is to be calibrated, and that the maximum capacity of the standard condenser is only 0.001 uf. By the substitution method readings are taken up to 0.001 uf, which may be at about 35° on C2. The same circuit is used as in #31, except for one change: a jumper is placed from the middle point of the switch to the end point to which C2 is connected, as indicated by the dotted line in the sketch. This connects

ANSWER #33. Continued.

C2 permanently into the circuit. The condensers are now placed in parallel by closing the switch to C1. C2 is set at the highest point for which the capacity has been determined by the substitution method, say 0.001 uf. C1 is next set at a capacity that is equal to a change of about 10° or 20° on C2, for example 0.0005 uf. The driver is brought into resonance with the circuit, then the switch is opened, disconnecting C1 from the circuit, and C2 varied to retune the circuit to the driver. The setting is noted and the corresponding value of capacity equals that previously determined by the substitution plus the amount used in C1. Thus, for this point on C2, the capacity equals 0.001 uf plus 0.0005 uf or 0.0015 uf. C2 is left at this new setting, the switch closed, and the desired amount of capacity again added at C1, and the procedure repeated. In this manner C2 may be calibrated to its maximum capacity. Since an error made in any observation by this capacity variation method will be passed on to all successive readings, it is important to exercise the greatest care in making all resonance adjustments and in all scale readings. When C2 has been adjusted to tune the circuit as described above, the setting should not be changed until C1 has been again inserted in the circuit and resonance with the driver again obtained. An attempt to reset C2 other than by the resonant method will introduce an avoidable error in the succeeding readings.

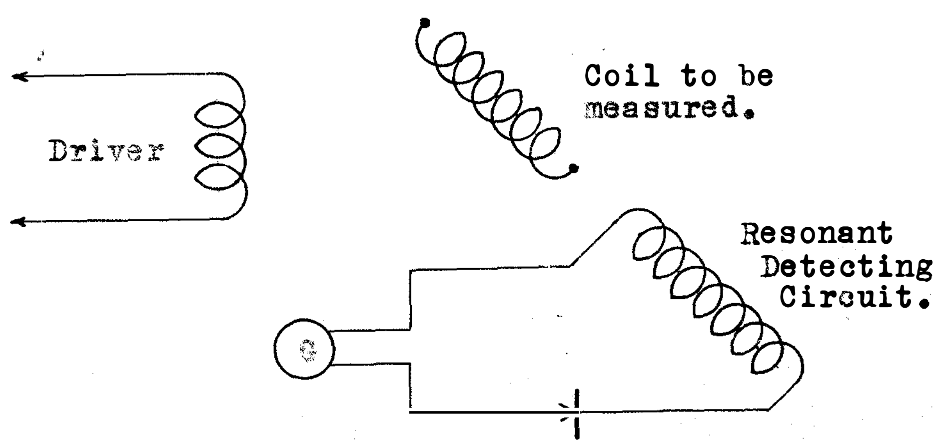
MEASUREMENT OF THE FUNDAMENTAL AND HARMONIC FREQUENCIES OF OSCILLATION OF A COIL.

QUESTION #34. What apparatus is required to make the measurement?

ANSWER #34. The apparatus required to make this measurement consists of an oscillating vacuum-tube driver, and an aperiodic resonance indicating circuit. The latter consists of a coupling coil of a few turns, crystal detector and galvanometer connected in series. The galvanometer should be sensitive to a microampere or less.

QUESTION #35. Draw the arrangement of the circuit and show coil to be measured.

ANSWER #35.



QUESTION #36. Give procedure for measuring the fundamental of a coil.

ANSWER #36. The procedure for measuring the fundamental of a coil is as follows: Place the coil to be measured in such a position that the driver may be coupled to it. Place the coupling coil of the resonance indicating circuit in such a position that it will be coupled to the coil but not to the driver. Vary the wavelength of the driver until resonance is indicated by maximum deflection of the galvanometer. Measure the wavelength of the driver. This should give the fundamental wavelength of the coil under measurement.

QUESTION #37. What precaution should be observed in making this measurement.

ANSWER #37. Two precautions are to be observed in making this measurement. First, make certain that the wavelength represents an oscillation in the coil and not a natural period of the indicating circuit. This can be tested by removing or shorting the coil under measurement, which should cause the deflection of the galvanometer to drop. Second, it is necessary to ensure that the resonant wavelength corresponds to the fundamental, rather than to a harmonic of the coil. If resonance is not indicated at a longer wavelength, then the measured wavelength represents the fundamental of the coil. By decreasing the wavelength of the driver, harmonic oscillations can be found. It is possible to demonstrate the nodes and loops of voltage across a coil while it is oscillating at its fundamental or a harmonic frequency. This is done by passing a finger across the coil. A drop in the deflection of the galvanometer will be observed when the finger rests upon a potential loop (antinode) of the coil. When the finger passes over a node the deflection of the galvanometer is a maximum. It is possible to make this measurement with or without leads, also with or without one end of the coil under measurement grounded, so that the conditions obtaining in practice can be simulated. When one end of the coil is grounded, the coil and ground lead can act as an antenna system and oscillate as such. This condition can be usually recognized because of the considerably greater deflection obtained in the indicating circuit. Also, when this condition exists a sensitive radio-frequency ammeter in the ground lead will indicate a flow of current to ground.

TABLE 19 - VALUES OF X FOR USE IN FORMULA FOR CALCULATING THE INDUCTANCE OF A SINGLE-LAYER COIL OR SOLENOID.

$\frac{2a}{b}$	K	Difference	$\frac{2a}{b}$	K	Difference	$\frac{2a}{b}$	K	Difference
0.00	1.0000	-0.0209	2.00	0.5255	-0.0118	7.00	0.2584	-0.0047
.05	.9791	203	2.10	.5137	112	7.20	.2537	45
.10	.9588	197	2.20	.5025	107	7.40	.2491	43
.15	.9391	190	2.30	.4918	102	7.60	.2448	42
.20	.9201	185	2.40	.4816	97	7.80	.2406	40
.25	.9016	178	2.50	.4719	93	8.00	.2366	94
.30	.8838	173	2.60	.4626	89	8.50	.2272	86
.35	.8665	167	2.70	.4537	85	9.00	.2185	79
.40	.8499	162	2.80	.4452	82	9.50	.2106	73
.45	.8337	156	2.90	.4370	78	10.00	.2033	..
.50	.8181	150	3.00	.4292	75	10.00	.2033	133
.55	.8031	146	3.10	.4217	72	11.00	.1903	113
.60	.7885	140	3.20	.4145	70	12.00	.1790	98
.65	.7745	136	3.30	.4075	67	13.00	.1692	87
.70	.7609	131	3.40	.4008	64	14.00	.1605	78
.75	.7478	127	3.50	.3944	62	15.00	.1527	70
.80	.7351	123	3.60	.3882	60	16.00	.1457	63
.85	.7228	118	3.70	.3822	58	17.00	.1394	58
.90	.7110	115	3.80	.3764	56	18.00	.1336	52
.95	.6995	111	3.90	.3708	54	19.00	.1284	48
1.00	0.6884	-0.0107	4.00	0.3654	-0.0052	20.00	0.1236	-0.0085
.05	.6777	104	4.10	.3602	51	22.00	.1151	73
.10	.6673	100	4.20	.3551	49	24.00	.1078	63
.15	.6573	98	4.30	.3502	47	26.00	.1015	56
.20	.6475	94	4.40	.3455	46	28.00	.0959	49
.25	.6381	91	4.50	.3409	45	30.00	.0910	102
.30	.6290	89	4.60	.3364	43	35.00	.0808	80
.35	.6201	86	4.70	.3321	42	40.00	.0728	64
.40	.6115	84	4.80	.3279	41	45.00	.0664	53
.45	.6031	81	4.90	.3238	40	50.00	.0611	43
.50	.5950	79	5.00	.3198	76	60.00	.0528	61
.55	.5871	76	5.10	.3122	72	70.00	.0467	48
.60	.5795	74	5.20	.3050	69	80.00	.0419	38
.65	.5721	72	5.30	.2981	65	90.00	.0381	31
.70	.5649	70	5.40	.2916	62	100.00	.0350	..
.75	.5579	68	5.50	.2854	59			
.80	.5511	67	5.60	.2795	56			
.85	.5444	65	5.70	.2739	54			
.90	.5379	63	5.80	.2685	52			
.95	.5316	61	5.90	.2633	49			
$\frac{2a}{b}$	K	Difference	$\frac{2a}{b}$	K	Difference	$\frac{2a}{b}$	K	Difference

TABLE 20 - VALUES OF CORRECTION TERM A IN FORMULAE USED IN CALCULATING THE INDUCTANCE OF SINGLE-LAYER COILS OR SOLENOIDS, SINGLE-LAYER SQUARE COILS AND FLAT SQUARE COILS.

$\frac{d}{D}$	A	Difference	$\frac{d}{D}$	A	Difference	$\frac{d}{D}$	A	Difference
1.00	0.557	-0.051	0.40	-0.359	-0.052	0.15	-1.340	-0.069
0.95	.506	54	.38	.411	54	.14	1.409	74
.90	.452	57	.36	.465	57	.13	1.483	80
.85	.394	61	.34	.522	61	.12	1.563	87
.80	.334	65	.32	.583	64	.11	1.650	96
0.75	0.269	-0.069	0.30	-0.647	-0.069	0.10	-1.746	-0.105
.70	.200	74	.28	.716	74	.09	1.851	.118
.65	.126	80	.26	.790	80	.08	1.969	.133
.55	-.041	95	.22	.957	96	.06	2.256	.173
0.50	-0.136	-0.041	0.20	-1.053	-0.051	0.05	-2.439	-0.223
.48	.177	43	.19	1.104	54	.04	2.662	.288
.46	.220	44	.18	1.158	57	.03	2.950	.405
.44	.264	47	.17	1.215	61	.02	3.355	.693
.42	.311	48	.16	1.276	64	.01	4.048	....

TABLE 21 - VALUES OF CORRECTION B IN FORMULAE USED IN CALCULATING THE INDUCTANCE OF SINGLE-LAYER COILS OR SOLENOIDS, SINGLE-LAYER SQUARE COILS AND FLAT SQUARE COILS.

Number of turns, n	B	Number of turns, n	B
1	0.000	40	0.315
2	.114	45	.317
3	.166	50	.319
4	.197	60	.322
5	.218	70	.324
6	0.233	80	0.326
7	.244	90	.327
8	.253	100	.328
9	.260	150	.331
10	.266	200	.333
15	0.286	300	0.334
20	.297	400	.335
25	.304	500	.336
30	.308	700	.336
35	.312	1000	.336

TABLE 25 (a)

TABLES FOR CALCULATING THE INDUCTANCE OF SINGLE-LAYER COILS.

VALUES OF P

Length of Coil in inches.

Diameter of coil	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.5
2.0	.0865	.1035	.147	.186	.217	.348	.280	.304	.368
2.5	.107	.145	.188	.226	.285	.328	.363	.403	.483
3.0	.166	.228	.290	.370	.424	.494	.580	.655	.795
3.5	.212	.292	.357	.458	.547	.655	.705	.871	1.050
4.0	.280	.373	.490	.597	.711	.823	.978	1.080	1.400
4.5	.315	.438	.567	.700	.830	.968	1.110	1.280	1.580
5.0	.375	.523	.670	.840	1.000	1.160	1.350	1.520	1.880
5.5	.425	.600	.782	.980	1.160	1.360	1.560	1.760	2.170
6.0	.458	.668	.882	1.040	1.320	1.550	1.770	2.020	2.490
7.0	.662	.811	1.140	1.430	1.710	2.030	2.350	2.730	3.320
8.0	.692	1.020	1.390	1.800	2.160	2.590	2.940	3.380	4.150
9.0	.720	1.210	1.720	2.070	2.590	3.050	2.490	4.030	5.030
10.0	.838	1.350	1.900	2.430	2.990	3.570	4.240	4.800	6.030
12.0	1.200	1.630	2.300	2.960	3.730	4.540	5.330	6.120	7.880
14.0	1.350	2.060	2.600	3.680	4.780	5.680	6.780	7.850	10.300
16.0	1.620	2.440	3.200	4.210	5.500	6.800	8.100	9.700	12.600
18.0	1.850	2.760	4.150	4.840	5.990	7.820	9.680	11.500	14.700
20.0	2.540	3.180	4.450	6.030	6.990	8.710	10.800	12.700	17.400

TABLE 25 (b)

VALUES OF K FOR N.

$$K = \left(\frac{N}{25}\right)^2$$

N	K	N	K	N	K	N	K	N	K
1	.0015	15	.360	29	1.33	44	3.10	72	8.30
2	.0064	16	.410	30	1.44	46	3.38	74	8.74
3	.0144	17	.462	31	1.54	48	3.68	76	9.25
4	.0256	18	.519	32	1.64	50	4.00	78	9.72
5	.0400	19	.578	33	1.74	52	4.32	80	10.20
6	.0575	20	.640	34	1.85	54	4.65	82	10.80
7	.0784	21	.705	35	1.96	56	5.00	84	11.25
8	.1024	22	.772	36	2.08	58	5.38	86	11.82
9	.1296	23	.849	37	2.17	60	5.75	88	12.40
10	.1600	24	.940	38	2.31	62	6.13	90	12.90
11	.1940	25	1.000	39	2.46	64	6.54	92	13.50
12	.2300	26	1.080	40	2.56	66	6.95	94	14.20
13	.2700	27	1.165	41	2.70	68	7.40	96	14.70
14	.3140	28	1.250	42	2.82	70	7.80	98	15.30

TABLE 25 (c)

VALUES OF N.

N = Number of Turns per inch.

B & S GAUGE	ENAMEL	S.C.C	D.C.C.
12		11.4	10.9
14		14.2	13.5
16		17.8	16.9
17		20.0	18.8
18		22.2	20.8
19		25.6	23.2
20	30	27.7	25.0
21	33	30.7	27.3
22	37	34.4	30.3
23	42	37.5	32.6
24	46	41.4	35.5
25	53	45.6	38.6
26	58	50.2	41.8
27	66	54.9	45.0
28	73	60.2	48.5
29	82	65.3	51.8
30	91	71.4	55.5
31	104	77.5	59.1
32	116	84.0	62.8
33	138	90.0	66.2
34	145	97.0	69.9
35	161	104.0	73.5
36	178	117.0	83.3

THE METRIC SYSTEM.

The fundamental unit of the metric system is the meter (unit of length). From this, the gram (unit of mass) and the liter (unit of capacity) are derived. All other units are decimal subdivisions or multiples of these. These three units are simply related, so that the volume of one kilogram of water is, for practical purposes, equal to one cubic decimeter. The following table shows the metric system:

PREFIX	MEANING	UNITS
milli-	$\frac{1}{1,000} = 0.001 = 10^{-3}$	
centi-	$\frac{1}{100} = 0.01 = 10^{-2}$	Meter (for length
deci-	$\frac{1}{10} = 0.1 = 10^{-1}$	
unit	$\frac{1}{1} = 1 = 10^{0}$	Gram (for mass)
deka-	$\frac{10}{1} = 10. = 10^{1}$	
hecto-	$\frac{100}{1} = 100. = 10^{2}$	Liter (for capacity)
kilo-	$\frac{1000}{1} = 1000. = 10^{3}$	

The metric terms are formed by combining the words meter, gram and liter with the six numerical prefixes. These are given below for the units of length:

LINEAR UNITS

10 millimeters mm	=	1 centimeter cm
10 centimeters	=	1 decimeter dm
10 decimeters	=	1 meter m
10 meters	=	1 dekameter dkm
10 dekameters	=	1 hecto-meter hm
10 hectometers	=	1 kilometer km

The units of area and volume are the squares and cubes of the linear units. They are written according to the following form;

$3m^2$ = 3 square meters.

$4m^3$ = 4 cubic meters

The metric units in general use are the millimeter, centimeter, meter and kilometer.