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ABSTRACT

The 135 clock-hour course for the 11th year consists of outlines for blocks of instruction on series resonant circuits, parallel resonant circuits, transformer theory and application, vacuum tube fundamentals, diode vacuum tubes, triode tube construction and parameters, vacuum tube tetrodes and pentodes, beam-power and multisection tubes, and multigrid and special purpose tubes. Behavioral objectives are listed. A 19-item bibliography of references and films is included together with a posttest sample. (AG)

AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

Course Outline
RESONANT CIRCUITS AND INTRODUCTION
TO VACUUM TUBES
(Industrial Electronics 2 - 9325)
Department 48 - Course 9325.03

DADE COUNTY PUBLIC SCHOOLS

DIVISION OF INSTRUCTION•1971

D A D E C O U N T Y P U B L I C S C H O O L S
1 4 1 0 N O R T H E A S T S E C O N D A V E N U E
M I A M I, F L O R I D A 33132

Course Outline

INDUSTRIAL ELECTRONICS 2 - 9325
(Resonant Circuits and Introduction to Vacuum Tubes)

Department 48 - Course 9325.03

the division of

VOCATIONAL, TECHNICAL AND ADULT EDUCATION

Dr. E. L. Whigham, Superintendent of Schools
Dade County Public Schools
Miami, Florida 33132

Published by the Dade County School Board

Course Description

9325	48	9325.03	Resonant Circuits and Introduction to Vacuum Tubes
State Category Number	County Dept. Number	County Course Number	Course Title

This course of study includes Series Resonant Circuits, Parallel Resonant Circuits, Transformer Theory and Application, Vacuum Tube Fundamentals, The Diode Vacuum Tube, Triode Tube Construction and Static Characteristics, Triode Tube Parameters, Vacuum Tube Tetrodes and Pentodes, Beam-Power and Multisection Tubes, and Multigrid and Special Purpose Tubes.

The Laboratory Experiments relating to the text material will be covered.

Clock Hours: 135

PREFACE

The following pages contain a course outline entitled Resonance Circuits and Introduction to Vacuum Tubes. This is the third quinmester course of the eleventh year course No. 9325. There will be four more quinmesters as follows:

- 9325.01 Basic Electrical Concepts and D.C. Circuits
- 9325.02 D. C. Circuits and Introduction to A. C.
- 9325.04 Semiconductors
- 9325.05 Independent Study in Electronics

This quinmester course will be available to all students who satisfactorily complete the post test of quinmester 9325.02.

This course material is presented to the student in 135 hours of classroom-laboratory instruction. The content of this course will be covered in ten blocks and concluded by a post test.

Upon completion of this course the student will be well grounded in the areas of resonant circuits, transformers, and vacuum tube fundamentals.

The teaching methods will vary according to the ability of the individual student. As the content of the course varies, teaching techniques which lend themselves to each particular situation are employed. The instructor uses demonstrations and lectures which are supplemented by the performance of laboratory experiments and assignments by the student. The instruction is further developed by the use of films, information sheets, diagrams, and other aids which make the instruction more meaningful.

The outline was developed through the cooperative efforts of electronic instructors, supervisory personnel, the Quinmester Advisory Committee, and the Teacher Training Service, Dade County Public Schools, Division of Vocational, Technical and Adult Education, and has been approved by the Dade County Vocational Curriculum Committee.

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with Suggested Hourly Breakdown

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Bandwidth	1
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Parallel Resonant Circuit Q and Bandwidth	2
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Transformer Action	2
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Transformer Losses and Transformer Ratings	2
Power Transformers	2
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Static Characteristics	3
Dynamic Characteristics	3

VI. TRIODE TUBE CONSTRUCTION AND STATIC CHARACTERISTICS (15 Hours)
Triode Construction and Plate Current Control 4
Grid Control 4
Static Characteristics 4
Bias In A Triode Tube Circuit 4
Types of Bias 4

VII. TRIODE TUBE PARAMETERS (18 Hours)
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Dynamic Characteristics 4
The Dynamic Transfer Curve 4
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VIII. VACUUM TUBE TETRODES AND PENTODES (12 Hours)
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Tetrode Tube Constants 5
Pentodes 5

IX. BEAM-POWER AND MULTISECTION TUBES (9 Hours)
Beam Power Tubes 5
The Duo-diode 5
The Diode-Triode 5
The Dual Triode 5

X. MULTIGRID AND SPECIAL PURPOSE TUBES (24 Hours)
Multigrid Tubes 5
Subminiature, Gas-filled and Thyratron Tubes 5
Phototubes and Electron-Ray Indicators . . 6
The Cathode Ray Tube 6
High-frequency Tubes 6

XI. QUINMESTER POST TEST

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GOALS

The student technician will be able to:

1. Demonstrate an understanding of tuned circuits.
2. Demonstrate an understanding of transformer theory and application.
3. Demonstrate an understanding of the basic fundamentals of vacuum tubes including the diode, triode, and pentode.
4. Demonstrate an understanding of vacuum tube characteristic curves and parameters.
5. Demonstrate an understanding of special purpose tubes such as VR tubes, thyraton tubes, phototubes, cathode-ray tubes, and high frequency tubes.
6. Satisfactorily complete the post test.

SPECIFIC BLOCK OBJECTIVES

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BLOCK I - SERIES RESONANCE CIRCUITS

The student will be able to:

1. Explain the theory of Series Resonance in terms of reactance, resistance, voltage and current.
2. Demonstrate an understanding of Q, its effect on bandwidth, voltages, and current.
3. Explain applications of Series Resonant circuits as tuning devices, band pass and band-reject filters.
4. Calculate resonant frequency, reactances, bandwidth and Q.

BLOCK II - PARALLEL RESONANT CIRCUITS

The student will be able to:

1. Explain the theory of Parallel Resonance in terms of reactance, resistance, voltage and current.
2. Demonstrate an understanding of Q, its effect on bandwidth, voltages, and current.
3. Explain applications of Parallel Resonant circuits as tuning devices, band pass and band-reject filters.
4. Calculate resonant frequency, reactances, bandwidth and Q.
5. Demonstrate an understanding of practical application of Parallel Resonant circuits and combination series-parallel resonant circuits.

BLOCK III - TRANSFORMER THEORY AND APPLICATION

The student will be able to:

1. Demonstrate an understanding of transformer operation and solve problems related to turns, voltage, current, and impedance ratio.
2. Identify and explain applications of various types of transformers and their construction.

BLOCK IV - VACUUM TUBE FUNDAMENTALS

The student will be able to:

1. List four types of electron emission, and two types of commonly used cathodes for thermionic emission.

BLOCK V - [illegible] VACUUM TUBES

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The student will be able to:

1. Explain the construction and theory of operation of a diode vacuum tube.
2. Experimentally derive static and dynamic characteristic curves and A.C. and D.C. plate resistance.
3. Demonstrate an understanding of the use of diodes in rectifier applications.

BLOCK VI - TRIODE TUBE CONSTRUCTION AND STATIC CHARACTERISTICS

The student will be able to:

1. Explain the construction and theory of operation of a triode vacuum tube.
2. Experimentally derive static characteristic curves of a triode vacuum tube.
3. Demonstrate an understanding of bias and list three methods of obtaining bias.

BLOCK VII - TRIODE TUBE PARAMETERS

The student will be able to:

1. Explain the operation of a triode amplifier including input and output relationships.
2. Explain, derive, and solve problems related to the three triode tube parameters.
3. Construct load lines, dynamic transfer curves, and graphically predict the operation of triode vacuum tube amplifiers.
4. List the four classes of amplifier operation and explain each.

BLOCK VIII - VACUUM TUBE TETRODES AND PENTODES

The student will be able to:

1. Explain the construction and theory of operation of a tetrode and pentode vacuum tube.
2. Explain, derive and solve problems related to the three tetrode and pentode parameters.
3. Construct load lines, dynamic transfer curves, and graphically predуct the operation of a pentode vacuum tube.

BLOCK IX - BEAM POWER AND MULTISECTION TUBES

The student will be able to:

1. Explain the construction and theory of operation of a beam power tube.
2. Use family of curves to solve beam power amplifier problems.
3. Demonstrate an understanding of multisection tubes.

BLOCK X - MULTIGRID AND SPECIAL PURPOSE TUBES

The student will be able to:

1. Explain the construction and theory of operation of multigrid tubes, subminiature tubes, VR tubes, thyraton tubes, phototubes, electron-ray indicator tubes, cathode-ray tubes, and high frequency tubes.

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Course Outline

INDUSTRIAL ELECTRONICS 2 - 9325
(Resonant Circuits and Introduction to Vacuum Tubes)

Department 48 - Course 9325.03

I. SERIES RESONANCE CIRCUIT

A. The Series Tuned Circuit
1. Resonance
2. The resonance curves
3. General rule for R-L-C circuit
4. The series resonance circuit current curves

B. Quality
1. Sample calculation of Q
2. Quality and the series resonant circuit current curve

C. Bandwidth
1. Frequency and bandwidth
2. Q and bandwidth
3. Formula for bandwidth

D. Analysis of Series Resonant Circuits
1. The resonant frequency
2. The Q of the circuit
3. The bandwidth
4. Voltage gain
5. Variation in circuit properties

E. Series Resonant Circuit Applications
1. The band-pass series resonant network
2. The band-reject series resonant network

II. PARALLEL RESONANT CIRCUITS

A. Parallel L-C Circuits
1. Circuit analysis
2. Resonance curves
3. Reactance curves
4. Line current curve
5. Impedance curve

B. Circulating current in an Ideal Parallel Resonant Circuit
1. Ideal circuit analysis at resonance
2. Ideal circuit analysis at frequencies other than resonance

C. Practical Tuned Circuit Analysis
   1. Resistance in a practical circuit
   2. Analysis

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D. Parallel Resonant Circuit Q and Bandwidth
   1. Circuit Q
   2. Circuit bandwidth

E. Applications of Series and Parallel Tuned Circuits in Combination
   1. Applications of parallel tuned circuits
   2. Applications of series and parallel tuned circuits in combination
   3. Example of a series and parallel tuned circuit

III. TRANSFORMER THEORY AND APPLICATION

A. Transformer Action
   1. Coefficient of coupling
   2. Phase relationships
   3. Effects of the secondary on the primary of a transformer
   4. Phase angles in a transformer

B. Turns Ratio
   1. Relationship between voltage and turns ratio
   2. Relationship between power in the primary and power in the secondary
   3. Relationship between current and turns ratio

C. Impedance Matching
   1. Reflected impedance
   2. Reflected capacitance and inductance

D. Transformer Losses and Transformer Ratings
   1. Copper loss
   2. Hystersis loss
   3. Saturation loss
   4. Eddy current loss

E. Power Transformers
   1. Filament transformers
   2. Tapped winding transformers
   3. Multiple winding transformer
   4. Autotransformer

F. Audio Transformers
   1. Input transformer
   2. Interstage transformer
   3. Output transformer

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C. Radio-Frequency Transformers
   1. R-F interstage transformer
   2. I-F transformer
   3. Antenna coupling with R-F transformers

E. Special Applications of Transformers
   1. Isolation transformers
   2. Instrument transformers
   3. Potential transformers
   4. Current transformer
   5. Saturable reactor

IV. VACUUM TUBE FUNDAMENTALS

A. Electron emission
   1. Thermionic Emission
   2. Cold-cathode emission
   3. Photoelectric emission
   4. Secondary emission

B. The Emitter

C. Emitter Construction
   1. Directly heated cathode
   2. Indirectly heated cathode

V. THE DIODE VACUUM TUBE

A. Physical Construction
   1. Base
   2. Cathode
   3. Plate
   4. Envelope

B. Theory of Operation
   1. Space Charge
   2. Current
   3. Peak Inverse Plate Voltage

C. Static Characteristics
   1. Static curve
   2. Saturation
   3. D-C plate resistance
   4. A-C resistance

D. Dynamic Characteristics
   1. Diode load resistor
   2. Dynamic curve
   3. Dynamic operation and applications
      a. Half-wave rectifier
      b. Full-wave rectifier

VI. TRIODE TUBE CONSTRUCTION AND STATIC CHARACTERISTICS

A. Triode Construction and Plate Current Control
   1. Physical construction
   2. Grid control
      a. Zero voltage
      b. No connection
      c. Positive voltage
      d. Negative voltage

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B. Static Characteristics
   1. Plate family of curves
   2. Grid family of curves

C. Bias In A Triode Tube Circuit

D. Types of Bias
   1. Fixed
   2. Cathode
   3. Grid-leak
   4. Contact

VII. TRIODE TUBE PARAMETERS

A. The Triode Amplifier Circuit
   1. Amplification
   2. Input and output signals
   3. Phase
   4. Voltage gain

B. Tube Constants
   1. Amplification factor
   2. Transconductance
   3. Plate resistance

C. Dynamic Characteristics

D. The Dynamic Transfer Curve
   1. Construction of the curve
   2. Slope of the curve
   3. Linearity of the curve
   4. Gain formulas

E. Classes of Amplifier Operation
   1. Class A
   2. Class B
   3. Class AB
   4. Class C

VIII. VACUUM TUBE TETRODES AND PENTODES

A. Tetrodes
  1. Construction
  2. Voltage connections
  3. Electrostatic fields
  4. Plate characteristic curves

B. Tetrode Tube Constants
  1. A-C plate resistance
  2. Amplification factor
  3. Transconductance

C. Pentodes
  1. Construction
  2. Plate characteristic curve
  3. Dynamic characteristics
  4. Classification

IX. BEAM-POWER AND MULTISECTION TUBES

A. Beam power tubes
  1. Construction
  2. The virtual cathode
  3. Dynamic load lines and transfer curves
  4. Distortion
  5. Applications

B. The Duo-diode

C. The Diode-Triode

D. The Dual Triode

X. MULTIGRID AND SPECIAL PURPOSE TUBES

A. Multigrid Tubes
  1. Structure of pentagrid tubes
  2. Frequency conversion
    a. The pentagrid mixer
    b. The pentagrid converter

B. Subminiature, Gas-filled and Thyratron Tubes
  1. Subminiature tubes
  2. Gas-filled regulator tubes
  3. VR tubes
  4. Thyratron tubes

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G. Phototubes and Electron-Ray Indicators
  1. Phototubes
    a. Construction
    b. Sensitivity
    c. Distortion
    d. Photomultipliers
    e. Applications

  2. Electron-Ray Indicators

D. The Cathode Ray Tube
  1. Structure
  2. Focusing and accelerating the beam
  3. Deflection
    a. Electrostatic
    b. Electromagnetic

E. High-frequency Tubes
  1. Acorn tubes
  2. Lighthouse tubes
  3. The Klystron

XI. SEMESTER POST TEST

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(Resonance Circuits and Introduction to Vacuum Tubes)

Basic References:

1. Fundamentals of A. C. and A. C. Circuits Analysis. Vol. II. Philadelphia: Philco Corporation, 1968.

2. Supplement to Fundamentals of A. C. and A. C. Circuits Analysis. Vol. II. Philadelphia: Philco Corporation, 1968.

3. Vacuum Tube and Semiconductor Fundamentals. Vol. III. Philadelphia: Philco Corporation, 1969.

4. Supplement to Vacuum Tube and Semiconductor Fundamentals. Vol. III. Philadelphia: Philco Corporation, 1969.

5. Cooke, Nelson M. Basic Mathematics for Electronics. 2nd ed. New York: McGraw-Hill Book Company, Inc. 1960. Pp. 679.

6. Mathematics for Electronics. 1st ed. Dade County Public Schools, 1970.

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Supplementary References:

8. Suffern, Maurice G. Basic Electrical and Electronic Principles. 3rd ed. New York: McGraw-Hill Book Company, Inc., 1962. Pp. 604.

9. U.S. Department of the Air Force. Fundamentals of Electronics (Af) Manual 101-8) Washington, D. C.: U. S. Government Printing Office, 1957. Pp 448.

10. United States Department of the Army. Basic Theory and Application of Electron Tubes. (TM 11-661). Washington, D. C. : United States Government Printing Office, 1952. Pp. 215.

Dade County Film Ordering Number

Films:

11. <u>Cathode Ray Tube: How It Works</u>. 16 mm. 15 min. B/W. Sound. 1943. United World Film, Inc. — 1-12974

12. <u>Diode Principles and Applications</u>. 16 mm. 17 min. B/W Sound. 1945. United World Films, Inc. — 1-12966

13. <u>Electromagnetic Cathode Ray Tube. Theory of Operation</u>. 16 mm. 20 min. B/W Sound. 1958. United World Films, Inc. — 1-21317

14. <u>Principles of Gas Filled Tubes</u>. 16 mm. 15 min. B/W. Sound. United World Films, Inc. — 1-13112

15. <u>Photoelectric Effect</u>. 16 mm. 30 min. B/W. Sound. 1962. Encyclopedia Britannica Films, Inc. — 1-30217

16. <u>Television Picture Tube Implosions</u>. 16 mm. 10 min. B/W. Sound. 1956. Iowa State College, Visual Instruction Service. — 1-05587

17. <u>Tuned Circuits</u>. 16 mm. 28 min. B/W. Sound. 1943. United World Films, Inc. — 1-21372

18. <u>Vacuum Tubes: Electron Theory and Diode Tubes</u>. 16 mm. 16 min. B/W. Sound. 1942. United World Films, Inc. — 1-13174

19. <u>Vacuum Tubes: Triode and Multipurpose Tubes</u>. 16 mm. 14 min. B/W. Sound. 1942. United World Films, Inc. — 1-13192

A P P E N D I X

Quinmester Post Test Sample

POST TEST
for
RESONANT CIRCUITS AND INTRODUCTION TO VACUUM TUBES
9325.03

1. At the resonant frequency, a series R-L-C circuit appears as a (an)
   a. open circuit
   b. resistive circuit
   c. short circuit
   d. reactive circuit

2. In a series-resonant circuit the capacitive reactance is:
   a. maximum
   b. minimum
   c. equal to the inductive reactance
   d. in phase with the inductive reactance

3. A series resonant circuit contains an X_L of 100 ohms, an X_C of 100 ohms, and an R of 10 ohms. If the applied voltage is 100 volts, what is the voltage across the inductor?
   a. zero volts
   b. 100 volts
   c. 141 volts
   d. 1000 volts

4. The current at resonance in a series R-L-C circuit is one ampere. The current at the half-power points is:
   a. 1.5 amperes
   b. 1.414 amperes
   c. 500 milliamperes
   d. 707 milliamperes

5. If the Q of a circuit is 12 and the resonant frequency is 9.6 mc, what is the bandwidth?
   a. 10.4 mc
   b. 800 kc
   c. 8.8 mc
   d. 12 kc

6. The effect of adding resistance to a series resonant circuit is to:
   a. decrease the resonant frequency
   b. increase the discrimination of the circuit
   c. broaden the frequency response
   d. increase the voltage across the circuit

7. The bandwidth of a series resonant R-L-C circuit:
   a. varies directly as Q
   b. varies inversely as the resistance
   c. is not related to Q
   d. varies directly as the resistance

8. In a parallel circuit, one branch contains an X_C of 50 ohms, the second branch an X_L of 90 ohms, and the third branch is resistive.
The total circuit impedance is:
a. inductive
b. resistive
c. inductive and resistive
d. capacitive and resistive

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9. At parallel resonance:
a. circuit impedance is minimum
b. circuit current is minimum
c. the circuit is inductive
d. the circuit is capacitive

10. A parallel resonant circuit is often referred to as:
a. an ideal circuit
b. a tank circuit
c. a complex circuit
d. a reflex circuit

11. In a parallel resonant circuit, at resonance, the impedance is:
a. maximum
b. minimum
c. equal to the resistance of the circuit
d. equal to the reactance of the circuit

12. In a parallel resonant circuit, at resonance, the line current is:
a. maximum
b. minimum
c. 180° out of phase with applied voltage
d. 90° out of phase with the applied voltage

13. In a parallel resonant circuit, at resonance, the circulating current is:
a. maximum
b. minimum
c. equal to the line current
d. there is no circulating current

14. A parallel circuit at resonance is characterized by:
a. high circuit current
b. high branch current
c. higher voltage than applied voltage
d. low branch voltage

15. In a parallel tank circuit, the generator is tuned below its resonant frequency, the total impedance is:
a. decreased and inductive
b. increased and capacitive
c. decreased and capacitive
d. increased and inductive

16. Circuit current in a practical parallel resonant circuit is never zero because:

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a. practical circuits are never resonant
b. every circuit component has some resistance
c. current is constantly being exchanged between L and C
d. reactance never reaches an absolute minimum

17. In a parallel resonant circuit, the generator is operating above resonance, the phase angle is positive because the circuit acts like a (an):
a. inductance in series with a resistor
b. resistor
c. capacitor in series with a resistor
d. inductance

18. In tuning a high-Q parallel tank circuit from the point of resonance, the line-current meter would:
a. have a sharpe rise in reading
b. have no change in reading
c. read zero
d. have a sharp drop in reading

19. The inductive reactance of a parallel resonant circuit is 4800 ohms. If the resistance of the coil is 160 ohms, what is the Q of the circuit?
a. 33
b. 30
c. 76.5
d. 130

20. A parallel circuit resonant at 115 mc has a bandwidth of 800 kc. In order to double the bandwidth, the Q of the circuit should be:
a. 36
b. 72
c. 92
d. 144

21. What is the resonant frequency of a parallel high-Q circuit if the capacitance is 1 micro-microfarad and the inductance is 1 microhenry?
a. 63 mc.
b. 159 mc.
c. 1000 mc.
d. 6280 mc.

22. A parallel circuit is resonant at 98 megacycles. If the Q of the circuit is 56, how wide is the bank of frequencies it rejects?
a. 99.75 mc.
b. 0.57 mc.
c. 1.75 mc.
d. 96.25 mc.

23. In a series R-L-C circuit, L = 2.5 mh, C = .01 ufd, R = 48 ohms, fr =
   a. 31.9 KHz
   b. [illegible]14 KHz
   c. 6[illegible].8 KHz
   d. 15.7 KHz

24. In a parallel R-L-C circuit, C = .1 ufd, fr = 1.77 KHz, R = 150 ohms, L =
   a. [illegible]30 mh
   b. [illegible]3 mh
   c. 2.[illegible] mh
   d. 126 uh

25. In a parallel R-L-C circuit, L = 230 uh, C = 43.1 uufd, R = 4 ohms, fr =
   a. 160 KHz
   b. 2360 KHz
   c. 1600 KHz
   d. 2.1 MHz

26. If the phase angles between the voltage and current are zero in a transformer, the transformer is connected to a:
   a. resistive and capacitive load
   b. resistive and inductive load
   c. resistive load
   d. capacitive load

27. The major difference between an autotransformer and a conventional transformer is:
   a. the use of an iron core
   b. step-up possibilities
   c. copper losses
   d. the use of only one winding

28. In a conventional transformer, power is transferred from the primary to the secondary by:
   a. self-induction
   b. conduction
   c. mutual-induction
   d. transconductance

29. A center-tapped transformer secondary is usually used to:
   a. obtain a high and low value of secondary voltage from a single-voltage source
   b. deliver two equal voltages of opposite phase
   c. double the voltage available at the secondary of the transformer
   d. deliver two equal in-phase voltages

30. Maximum energy is transferred from one circuit to another when the impedance of the source:
   a. equals the impedance of the load
   b. is greater than the impedance of the load
   c. is less than the impedance of the load
   d. is at least ten times the impedance of the load

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31. Copper losses are:
   a. losses due to the core material
   b. losses due to magnetizing effects
   c. D. C. resistance losses
   d. A. C. resistance losses

32. Eddy currents are:
   a. currents set up in the core of the transformer
   b. out of phase currents in the secondary
   c. current flowing in the primary when the secondary is unloaded
   d. current flowing in the secondary when no current flows in the primary

33. Hysteresis is:
   a. heat loss in a transformer
   b. loss due to loose laminations
   c. lagging of the flux density behind the magnetizing force
   d. loss due to use of wire too small to handle current

34. An autotransformer is:
   a. an automatic transformer
   b. designed to be used only in automobiles
   c. a transformer designed with only one winding
   d. a transformer with multiple windings

35. The power rating of transformers is given in either watts or voltamperes. Power in watts is equal to:
   a. EI
   b. EI cos θ
   c. EI sin θ
   d. I^2Z

36. If the resistance in the secondary of a power transformer is decreased, the current in the primary will:
   a. remain the same
   b. decrease
   c. increase
   d. shift in phase from the voltage

37. A power amplifier has an impedance of 9600 ohms. For a maximum power transfer to a voice coil of a 6-ohm speaker, the matching transformer should have a turns ratio of:
   a. [illegible] to 1
   b. 40 to 1
   c. 96 to 1
   d. 3100

38. A transformer no-load has 110 volts across the primary, 12 turns in the primary, and 40 turns in the secondary. The secondary terminal voltage is:
   a. 36.6 volts
   b. 366 volts
   c. 180 volts
   d. 146 volts

39. A transformer with no losses has 100 volts at 5 amperes applied to the primary. With 250 volts output in the secondary, what is the output current?
   a. 2 amperes
   b. 10 amperes
   c. 12 amperes
   d. 25 amperes

40. A transmission line has an output impedance of 2500 ohms. For maximum power transfer to a 100-ohm load, the matching transformer should have a:
   a. 5 to 1 step-down ratio
   b. 5 to 1 step-up ratio
   c. 25 to 1 step-down ratio
   d. 25 to 1 step-up ratio

41. The primary of a power transformer draws 4.6 amperes at 110 volts from the line, while the secondary has a load consuming 2 amperes at 235 volts. What is the efficiency of the transformer?
   a. 93%
   b. 9.29%
   c. 95%
   d. 1.07%

42. A filter passes signals from zero to 1500 cps and from 3000 cps upward. The filter is called a:
   a. low-pass filter
   b. high-pass filter
   c. band-pass filter
   d. band-rejection filter

43. The impedance in the series-resonant branch of a band-pass filter is:
   a. low in the rejection bands
   b. low in the pass band
   c. the same in the pass band as the impedance of the parallel-resonant branch in the pass band.
   d. high in the pass band

44. What type of filter is usually used to eliminate the ripple from a rectifier power supply?
   a. low-pass filter
   b. high-pass filter
   c. band-pass filter
   d. band-reject filter

45. Emission of electrons through the application of heat is known as:
   a. photoelectric emission
   b. cold cathode emission
   c. secondary emission
   d. thermionic emission

46. Emission of electrons through the application of a high potential is known as:
   a. photoelectric emission
   b. cold cathode emission
   c. secondary emission
   d. thermionic emission

47. Emission of electrons by the application of light is known as:
   a. thermionic emission
   b. cold cathode emission
   c. photoelectric emission
   d. secondary emission

48. Emission of electrons through impact is known as:
   a. secondary emission
   b. photoelectric emission
   c. cold cathode emission
   d. thermionic emission

49. The element within the vacuum tube which emits electrons is called the:
   a. anode
   b. getter
   c. cathode
   d. heater

50. The most efficient type of cathode is the:
a. tungsten
b. oxide coated
c. thoriated tungsten
d. pure nickel

51. In a directly heated cathode:
a. heating must be with A. C. current
b. the heater and cathode are one and the same
c. only tungsten may be used
d. the cathode is a metal cylinder

52. An indirectly heated cathode:
a. requires longer warm up time
b. is usually made of tungsten
c. must use D. C. current only
d. is seldom used in receiving type tubes

53. Tungsten and thoriated tungsten cathodes are usually used:
a. in low power requirements
b. in high power requirements
c. in indirectly heated cathodes
d. in tubes for portable radios

54. A two element tube is called a:
a. duo tube
b. diode
c. rectifier
d. static tube

55. In a vacuum tube, current is considered to flow from:
a. plate to cathode
b. heater to cathode
c. cathode to plate

56. Plotting variation in plate current vs. variation in plate voltage with the tube operating with no load will produce a:
a. dynamic characteristic curve
b. static characteristic curve
c. straight line
d. exponential curve

57. The D. C. plate resistance of a tube is:
a. always constant
b. expressed in ohm's
c. E_p/I_p
d. linear

58. The A. C. plate resistance of a tube is:
   a. always constant
   b. E_p/I_p
   c. De_p/di_p
   d. linear

59. As the load on a vacuum tube is increased, the dynamic characteristic curve:
   a. becomes more curved
   b. becomes straighter
   c. maximum value of current drawn increases
   d. causes a great change in load voltage

60. The ripple frequency of a half-wave rectifier is:
   a. twice the input frequency
   b. four times the input frequency
   c. equal to the input frequency
   d. a sine wave

61. Rectification is:
   a. changing D. C. to A. C.
   b. changing A. C. to D. C.
   c. changing one frequency to another frequency
   d. reactivating the cathode to produce more electrons

62. A vacuum tube is said to be negatively biased when:
   a. the control grid is positive with respect to the cathode
   b. the control grid is negative with respect to the cathode
   c. the control grid and the cathode are at the same potential
   d. the control grid is positive with respect to the plate

63. A vacuum tube will draw grid current when:
   a. the control grid is negative with respect to the cathode
   b. the plate is positive with respect to the cathode
   c. the plate is positive with respect to the control grid
   d. the control grid is positive with respect to the cathode

64. If the plate voltage of a triode is made more positive:
   a. plate current will increase
   b. plate current will decrease
   c. grid current will increase
   d. there will be no effect on plate current

65. If the bias on the grid of a triode vacuum tube is made more negative:
   a. the grid will draw current
   b. plate current will decrease
   c. plate current will increase
   d. there will be no effect at all

66. When the bias on a vacuum tube is increased to a point where plate current no longer flows, this point is called:
   a. point of no return
   b. saturation point
   c. cutoff point
   d. limiting point

67. The curves of a triode that show the relationship between plate voltage and plate current for constant values of a grid voltage are called:
   a. $E_g I_g$ curves
   b. grid characteristic curves
   c. static transfer characteristic curves
   d. E_p-I_p curves

68. Bias, obtained by returning the grid to a fixed source of potential, is called:
   a. grid-leak bias
   b. cathode bias
   c. fixed bias
   d. semiautomatic bias

69. A type of bias obtained by placing a resistor in the cathode circuit to make the cathode positive with respect to the grid is called:
   a. grid-leak bias
   b. cathode bias
   c. fixed bias
   d. resistor bias

70. The load resistance of an amplifier:
   a. controls the plate supply voltage
   b. controls the grid voltage signal
   c. has no effect on the gain of an amplifier
   d. has a marked effect on amplifier gain

71. The ratio of a change in plate voltage, which causes a change in plate current, to the change in grid voltage that will cause the same change in plate current, is called:
   a. amplification factor
   b. transconductance
   c. plate resistance
   d. conversion transconductance

72. Amplification factor is also known as:
a. gm
b. rp
c. mu
d. gain

73. The ratio of a change in plate current to the change in grid voltage, causing it at constant plate voltage, is called:
a. amplification factor
b. plate resistance
c. transconductance
d. conversion transconductance

74. The ratio of a change in plate voltage to a corresponding change in plate current is called:
a. amplification factor
b. transconductance
c. conversion transconductance
d. plate resistance

75. Transconductance is also known as:
a. gm
b. rp
c. mu
d. gain

76. A graphical representation of the plate load resistance value drawn on the plate family of characteristic curves is called:
a. a tangent curve
b. a load line
c. a schematic diagram
d. Ep - ip curve

77. A vacuum tube biased at approximately cutoff would be operating:
a. class A
b. class B
c. class C
d. class D

78. In a class A amplifier, current flows for:
a. 180° of the cycle
b. 360° of the cycle
c. 90° of the cycle
d. 10° of the cycle

79. A class C amplifier is biased:
a. in the center of a linear portion of the curve
b. at or near cutoff
c. 1.5 to 4 times cutoff
d. at zero

80. The gain of an R C coupled vacuum tube amplifier
 a. is always greater than the mu of the tube
 b. is always equal to the mu of the tube
 c. can never exceed the mu of the tube
 d. can never be less than one

81. The effect of the suppressor grid is achieved in a beam power tetrode by:
 a. the beam forming plates
 b. the virtual cathode
 c. using lower plate voltage
 d. using a suppressor grid but calling it another name

82. In a beam power tube, maximum power output is obtained when:
 a. the load is equal to r_p
 b. the load is less than r_p
 c. the load is 3 times r_p
 d. the voltage amplification is greater than 100

83. A tube containing two diodes and one triode is called:
 a. duodiode
 b. two diode-triodes
 c. duodiode-triode
 d. multipurpose tube

84. Limitations of the triode tube used as an amplifier at high frequencies is caused by:
 a. insufficient emission from the cathode
 b. interelectrode capacitance
 c. too small a grid structure
 d. two low a mu

85. A four element tube is called a:
 a. triode
 b. pentode
 c. diode
 d. tetrode

86. The region on the characteristic curve where an increase in plate voltage produces a decrease in plate current, is called:
 a. the setback region
 b. the quiescent point
 c. the dynatron region
 d. the dynamic region

87. In comparison with a triode, the plate resistance of a tetrode is:
 a. high
 b. low
 c. the same
 d. none of the above.

88. In comparison with a triode, the amplification factor of a pentode is:
   a. high
   b. low
   c. the same
   d. none of the above

89. The main drawback to a tetrode tube is:
   a. too hard to control plate current
   b. too low a mu to be practical
   c. secondary emission
   d. all of the above

90. The effects of secondary emission are minimized by the addition of an additional grid in the tube. This grid is called:
   a. screen grid
   b. secondary grid
   c. control grid
   d. suppressor grid

91. Remote cutoff is a term associated with:
   a. diodes
   b. triodes
   c. tetrodes
   d. pentodes

92. In a sharp cutoff tube, the grid wires are:
   a. unevenly spaced
   b. evenly spaced
   c. heavier than in other tubes
   d. made from electron emitting material

93. The screen grid of a vacuum tube is operated at:
   a. a negative potential with respect to cathode
   b. a positive potential with respect to cathode
   c. a positive potential with respect to the plate
   d. a negative potential with respect to the suppressor grid

94. How does the action of the control grid in a thyratron differ from that of a high vacuum triode:
   a. when the discharge starts, the thyratron grid loses control
   b. the thyratron grid retains control throughout the cycle
   c. the thyratron grid gains control when the arc discharge begins
   d. the thyratron grid voltage is used to stop the arc discharge

95. The klystron tube uses which principle of modulation for its operation:
    a. amplitude
    b. velocity
    c. frequency
    d. phase

96. Another name for a lighthouse tube is:
    a. an acorn tube
    b. a planar tube
    c. pentode tube
    d. a VR tube

97. What is the purpose of the conductive coating within the cathode ray tube:
    a. return path for electrons striking the deflection plates
    b. return path for secondary emitted electrons
    c. acts as a magnetic shield
    d. provides a uniform area for light distribution

98. Which element is referred to as the first electronic lens of a cathode ray tube:
    a. control grid
    b. screen grid
    c. focusing anode
    d. accelerating anode

99. How does the control grid of a cathode ray tube differ from the control grid of an amplifier tube:
    a. it is used to control the amount of current
    b. it is always negative with respect to the cathode
    c. it is solid with the exception of one small opening
    d. it cannot completely cut off the flow of electrons

100. An advantage of gas filled rectifiers over high vacuum diode rectifiers is that they:
    a. convert A. C. to pulsating D. C.
    b. convert D. C. to A. C.
    c. also emit a glow
    d. are capable of handling large currents

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ANSWER KEY for POST TEST RESONANT CIRCUITS AND INTRODUCTION TO VACUUM TUBES 9325.0[illegible]

1.	B	26.	C	51.	B	76.	[illegible]
2.	C	27.	D	52.	A	77.	B
3.	D	28.	C	53.	B	78.	B
4.	D	29.	B	54.	B	79.	C
5.	B	30.	A	55.	C	80.	C
6.	C	31.	C	56.	B	81.	A
7.	D	32.	A	57.	C	82.	A
8.	D	33.	C	58.	C	83.	C
9.	B	34.	C	59.	B	84.	[illegible]
10.	B	35.	B	60.	C	85.	D
11.	A	36.	C	61.	B	86.	C
12.	B	37.	B	62.	B	87.	B
13.	A	38.	B	63.	D	88.	A
14.	B	39.	A	64.	A	89.	C
15.	A	40.	A	65.	B	90.	D
16.	B	41.	A	66.	C	91.	D
17.	C	42.	D	67.	D	92.	B
18.	A	43.	B	68.	C	93.	B
19.	B	44.	A	69.	B	94.	A
20.	B	45.	D	70.	D	95.	B
21.	B	46.	B	71.	A	96.	[illegible]
22.	C	47.	C	72.	C	97.	B
23.	A	48.	A	73.	C	98.	A
24.	B	49.	C	74.	D	99.	C
25.	C	50.	B	75.	A	100.	D