LEAD CITY UNIVERSITY, IBADAN
FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
SEMESTER/SESSION: 2ND SEMESTER, 2024/2025

Course Particulars

Course Code: EEE 513
Coarse Title: Power Electronics
Course Units: 3
Course Status: Core

Lecturer's Details

Name: EMMANUEL, Babatunde Steven
Qualifications: BEng (Electrical/Electronic Engineering), MSc (Microprocessor and Control Engineering), PhD (Electrical Engineering) Registered Engr. (COREN)
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Areas of Specialization
Systems design, modeling, simulation, optimization and control. Power electronics and energy conversion systems

Course Synopsis

Fundamentals of power electronics. The basics of three-phase circuits, connections. Voltage and current analysis and real and reactive power calculations. The fundamentals of electricity conversion from the form supplied by the source to the forms required by the load. Power electronic conversion techniques. The basic converters (DC-DC, AC-DC and DC-AC). Power switching. Control methods for converters. Methods of circuit analysis applicable to switched mode circuits. Essential properties of the relevant semiconductor devices. Simple converters for practical applications. Characteristics of power devices. DC-DC converters. AC Current, Voltage and Power. AC-DC converters. Inverters (DC-AC converters).

COURSE OBJECTIVES
Objectives

The objectives of the course are to:

1. Describe the concepts and principles of power electronics
2. Describe the analysis process for DC-DC converters based on their operational principles;
3. Derive equations for selecting power electronics components;
4. Explain the relationship between steady-state AC voltage and current in power circuits
5. Explain and quantify power electronics variables;

6. Analyse different modes of operations of inverters.

Course Learning Outcomes:

On the completion of this course, students should be able to:

1. Describe the principles of power control and switching;
2. Described the benefits of switched mode circuits;
3. Demonstrate ability to analyse at least four (4) DC-DC converters on their operation principles;
4. Develop design equations for selecting power electronics components;
5. Explain the relationship between steady-state AC voltage and current in power circuits using phasor analysis;
6. Explain and quantify active, reactive and apparent power;
7. Explain and quantify current harmonics and the average power drawn by a rectifier;
8. Analyse different modes of operations of inverters.

Lecture Delivery Method

- Lecture with interactive sessions

LECTURE PLAN

Course Modules
Module 1: Course overview, concepts, principles, applications of Power Electronics
Module 2: Power Semiconductors and Characteristics
Module 3: Rectifiers and Inverters
Module 4: DC-DC Converters

Course Outline
Module 1: Course overview, concepts, principles, applications of Power Electronics
Number of Lecture Hours: 12

Week	Lecture Topic	Contents	Learning Objectives
1	Introduction and Course Overview	Course outlines, delivery methods, assessments, course materials and recommended text books	Discuss the general overview of the course, rules and regulations for successful achievement in the course will be emphasized.
2	Fundamentals of power electronics	Fundamentals concepts Applications of power electronics. Linear circuit elements	Explain the motivation for the development of power electronics
3	Power Diodes	Characteristics and types of power diodes.	Explain of the different characteristics of power diode
4	Rectifier circuits	Half wave and full wave rectifier circuits	Explain the operational principles and design of rectifier circuits

Module 2: Power Semiconductors and Characteristics
Number of Lecture Hours: 12

Week	Lecture Topic	Contents	Learning Objectives
5	Silicon Controlled Rectifier (SCR)	Triode for Alternating Current (TRIAC), Bipolar junction transistor (BJT). Power MOSFETs. Insulated Gate Bipolar Transistors (IGBT)	Explain the characteristics and identify the different types of silicon-controlled rectifiers.
6	Phase Controlled Converters	AC to DC converters. AC to AC converters. AC voltage controllers. Cycloconverters	Explain the fundamental concepts of semiconductor materials, structures, doping and conduction mechanisms
7	Pulse converters	Phase Controlled Converters. Effects of Single Phase. Effect on Three Phase	Explain the concepts and operation of pulse converters
8	Mid-semester Assessment		

Module 3: Rectifiers and Inverters
Number of Lecture Hours: 9

Week	Lecture Topic	Contents	Learning Objectives
9	Battery Chargers	Types of Battery Chargers: Simple chargers, Fast chargers, Inductive chargers, Intelligent chargers, Motion powered charger	Explain the concepts and operation of battery charging circuits
10	Inverter circuits	Types of inverter designs: Single Phase Inverter, Half Bridge Inverter, Full Bridge Inverter, Three Phase Inverter	Explain the concepts, operation and circuit designs of inverters
11	Switched Mode Power Supply	Concepts, operations and applications of SMPS	Explain the concepts, operations and applications of SMPS

Module 4: DC-DC Converters
Number of Lecture Hours: 12

Week	Lecture Topic	Contents	Learning Objectives
12	Buck DC-DC Converter	Buck DC-DC Converter circuits, analysis, characteristics	Explain and model buck converter
13	Boost DC-DC Converter	Boost DC-DC Converter circuits, analysis, characteristics	Explain and model boost converter
14	Buck Boost DC-DC Converter	Buck- Boost DC-DC Converter circuits, analysis, characteristics	Explain and model buck boost converter

15	Revision		

Grading System

This course will be graded as follows:

Attendance:	10%
CA/Assignments:	30%
Examination:	60%
Total:	**100%**

References

1. Barry W Williams. Principles and Elements of Power Electronics: Devices, Drivers, Applications, and Passive Components
2. Honsberg, C., and S. Bowden. Photovoltaics: Devices, Systems and Applications.

EEE 715 Tutorial Questions

Q 1 **15 marks**

A crystal diode having internal resistance rf = 20Ω is used for half-wave rectification. If the applied voltage is v = 50sinwt and load resistance, R_L = 800 Ω, find:

i) I_m, I_{dc}, I_{rms}
ii) Ac power input and dc power output
iii) Dc output voltage
iv) Rectification efficiency.

Q2 **15 marks**

In a full-wave rectifier, the transformer rms secondary voltage from centre tap to each end is 50V. The load resistance is 900 Ω. If the diode resistance and secondary winding resistance together has a value of 100 Ω, determine:

i) Average load current
ii) Rms load current
iii) Form factor
iv) Peak factor
v) Ripple factor

Q3a

A full wave rectifier uses two diodes. The internal resistance of each diode is 20 Ω. The transformer secondary rms voltage from centre tap to each end is 50V and load resistance is 980 Ω. Find:

i) The mean load current
ii) The rms value of load current.

Q3b

In a bridge rectifier, the transformer is connected to a 200V, 60Hz supply with turns ratio 11:1. Assuming the diodes to be ideal and RL =600 Ω, find:

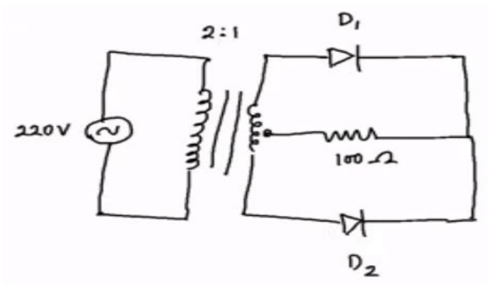
i) V_{dc}
ii) I_{dc}
iii) PIV

Q4 **15 marks**

With reference to the circuit diagram in Figure Q5, determine:

i) Peak value, dc value, rms value and ac component of load voltage
ii) Same parameter for load current
iii) Ripple factor
iv) Peak and average diode current
v) Total power supplied to load

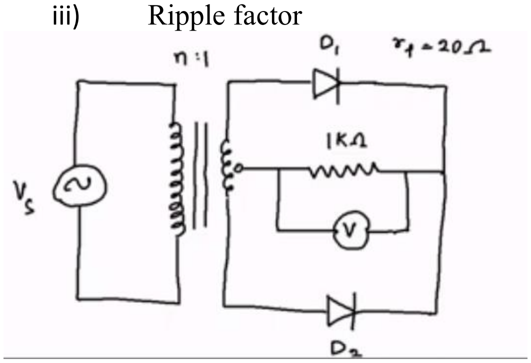
[Neglect diode resistance]



Q6 **15 marks**

A full wave rectifier uses two silicon diodes with a forward resistance of 20 Ω each. A dc voltmeter connected across the load of 1K Ω reads 55.4V. Calculate:

i) Irm and Idc
ii) Vrms, Vdc, and Vmax
iii) Ripple factor



Q7a **15 marks**

Show that the duty ratio in a bulk dc-dc converter is given by:

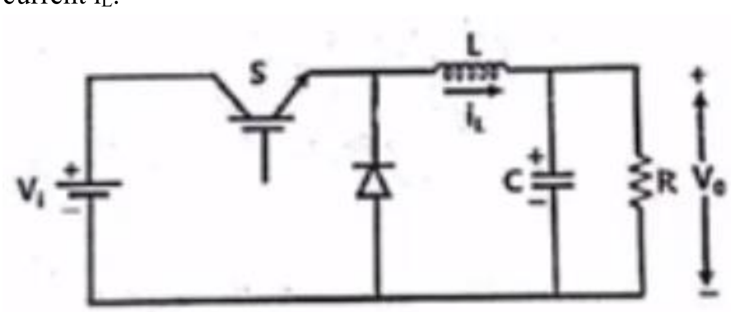
$$D = \frac{V_o}{V_i}$$

Q7b

Derive the expression for the dc output voltage V_o of a boost converter in terms of its duty ratio D and output voltage V_i?

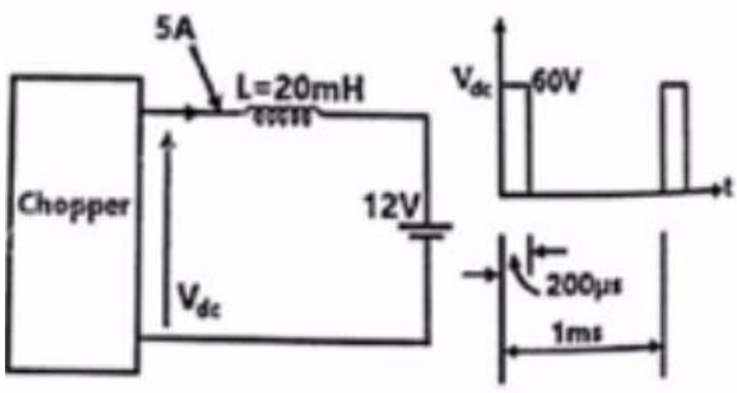
Q8a **15 marks**

In the chopper circuit shown in Figure Q, the input dc voltage has a constant value of Vs, the output voltage Vo is assumed ripple free. The switch S is operated with a switching time period T and a duty ratio D. Determine the value of D at the boundary of continuous and discontinuous conduction of the inductor current i_L.



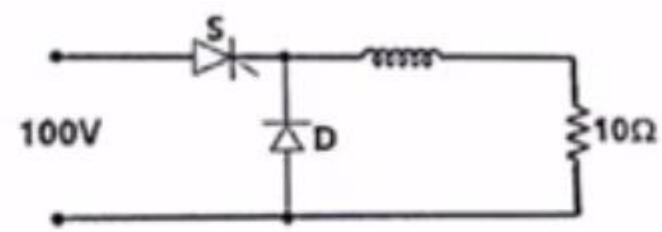
Q8b

A chopper is employed to charge a battery as shown in Figure Q. The charging current is 5A. The duty ratio is 0.2. The chopper output voltage is also shown in the Figure. Calculate the peak-to-peak ripple current in the charging current.



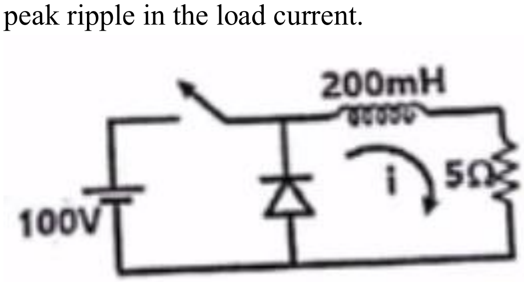
Q9a **15 marks**

Figure Q shows a chopper operating from a 100Vdc input. The duty ratio of the main switch S is 0.8. The load is sufficiently inductive so that the load current is ripple free. Calculate the average current through the diode D under steady state condition.



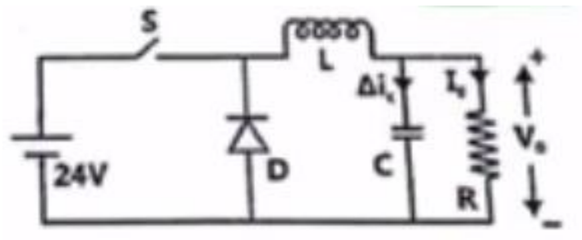
Q9b **15 marks**

Figure Q shows a step-down chopper switched at 1KHz with a duty ratio D =0.5. Determine the peak-to-peak ripple in the load current.



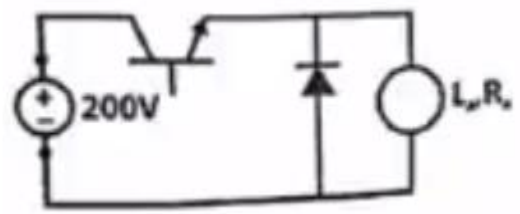
Q10a

In the circuit shown, an ideal switch S is operated at 100kHz with a duty ratio of 50%. Given that Δi_c is 1.6A peak-to-peak and i_o is 5A dc, calculate the peak current in S.



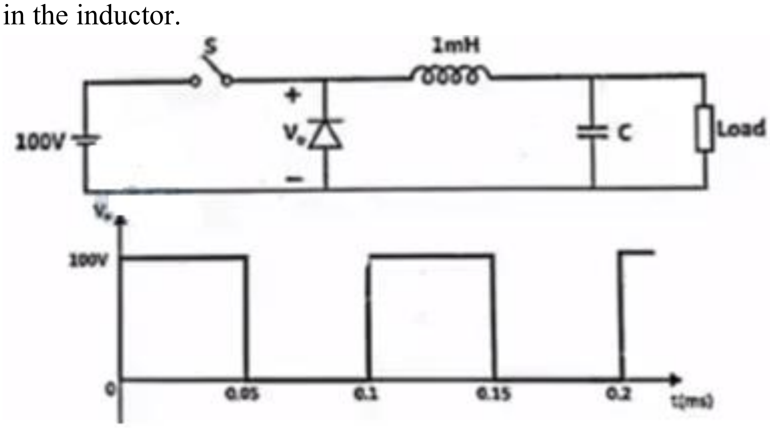
Q10b

The separately excited dc motor in Figure Q has a rated armature current of 20A and a rated armature voltage of 150V. An ideal chopper switching at 5kHz is used to control the armature voltage. If L_a = 0.1mH, Ra = 1Ω, neglecting armature reaction, determine the duty ratio of the chopper to obtain 50% of the rated torque at the rated speed and the rated field current.



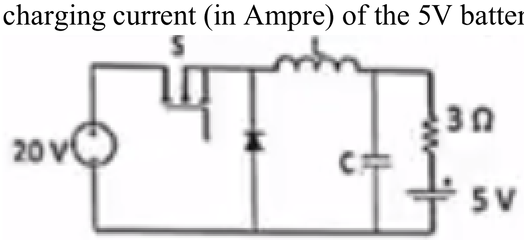
Q11 **15 marks**

Figure Qi shows the circuit diagram of a chopper. The switch S in the circuit in Figure Qi is switched such that the voltage V_D across the diode has the wave shape as shown in Figure Qii. The capacitance C is large so that the voltage across it is constant. If switch S and the diode are ideal, determine the peak ripple (in A) in the inductor.



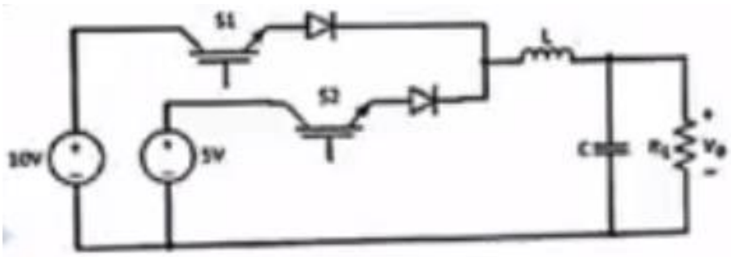
Q12 **15 marks**

In the chopper shown in Figure Q, the duty ratio of switch S is 0.4. If the inductor and capacitor are sufficiently large to ensure continous inductor current and ripple free capacitor voltage, determine the charging current (in Ampre) of the 5V battery, under steady state condition.



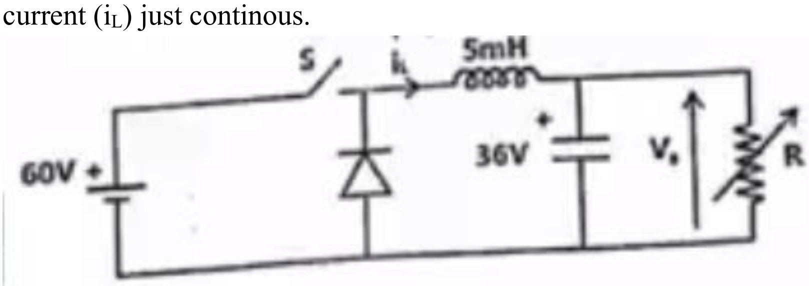
Q 13 **15 marks**

The circuit shown in Figure Q is meant to supply a resistive load R_L from separate DC voltage sources. The switches S1 and S2 are controlled so that only one of them is ON at any instant. S1 is turned on for 0.2 ms and S2 is turned on for 0.3 ms in a 0.5 ms switching cycle time period. Assuming continuous conduction of the inductor current and negligible ripple in the capacitor voltage, calculate the output voltage V_o (in volt) across R_L.



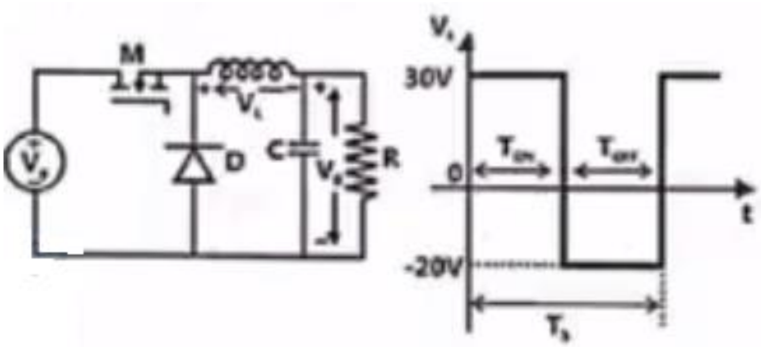
Q14 **15 marks**

A buck converter feeding a variable load is shown in the figure. The switching frequency of the switch is 100 kHz and the duty ratio is 0.6. The output voltage Vo is 36 V. Assume that all the components are ideal and that the output voltage is ripple free. Determine the value of R (in Ohm) that will make the inductor current (i_L) just continous.



Q15 **15 marks**

A buck converter shown in Figure Q(a) is working in steady state. The output voltage and the inductor current can be assumed to be ripple free. Figure Q(b) shows the inductor voltage V_L during a complete switching interval. Assuming all devices are ideal, determine the duty cycle of the buck converter.



(a) (b)