[ENG15]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) ELECTRICAL & ELECTRONICS ENGINEERING

SEMESTER ONE EXAMINATION 2021/2022

INTERMEDIATE ELECTRICAL PRINCIPLES & ENABLING POWER ELECTRONICS

MODULE NO: EEE5013

Date: Monday 10th January 2022 **Time: 10:00 – 12:30**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleared prior to the examination.

CANDIDATES REQUIRE: **Formula Sheet (attached from page 8).**

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

Question 1

a) Sketch an equivalent circuit of an ideal operational amplifier. **[7 marks]**

b) Using **Figure Q1**, derive an expression for the output V_o of the following circuit in terms of the input voltages V_1 and V_2. **[10 marks]**

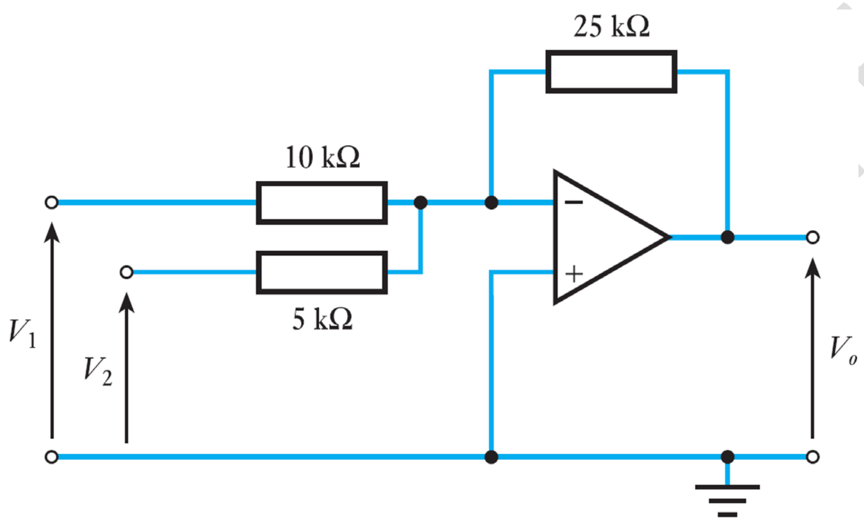


Figure Q1

c) Also, determine the output voltage if V_1 = 1 V and V_2 = 0.5 V. **[4 marks]**

d) A silicon transistor having a T_{JMAX} rating of 180 ^{0}C will dissipate 20W when its case temperature is 90 ^{0}C, calculate its thermal resistance. **[4 marks]**

Total 25 marks

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

Question 2

a) Differentiate between gauge pressure and absolute pressure. **[4 marks]**

b) Water flows from A to D and E through the series pipeline shown in **Figure Q2**. Given the pipe diameters, velocities, and flow rates below, complete the tabular data for this system. **[21 marks]**

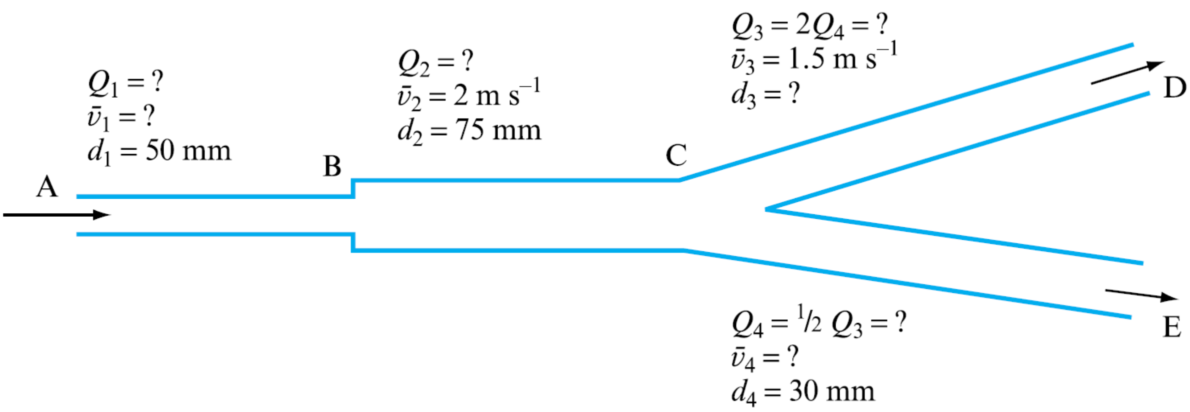


Figure Q2

PIPE	DIAMETER (mm)	FLOW RATE (m^3 s^{-1})	VELOCITY (m s^{-1})
AB	$d_1 = 50$	$Q_1 = ?$	$\bar{v}_1 = ?$
BC	$d_2 = 75$	$Q_2 = ?$	$\bar{v}_2 = 2.0$
CD	$d_3 = ?$	$Q_3 = 2Q_4$	$\bar{v}_3 = 1.5$
DE	$d_4 = 30$	$Q_4 = 0.5Q_3$	$\bar{v}_4 = ?$

Note that area can be determined as $\pi d^2/4$.

Total 25 marks

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

Question 3

(a) A half-wave rectifier circuit is used to charge a 150 V battery as shown in **figure Q3a** below. Calculate **[10 marks]** and plot the current i **[5 marks]** along with v_s if V_s=120 V , f=60 Hz, and L=10 mH.

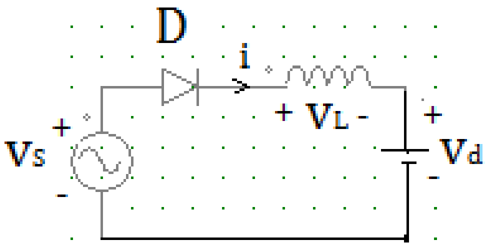


Figure Q3a

(b) A DC-DC buck converter has the following specifications:

Input voltage=110 V., maximum inductor current=300 A., Minimum inductor current=140 A., T_{ON}= 15 msec., T_{OFF}= 12 msec. , R_{Load}=60 Ohms, Calculate:

i. Chopping frequency **[1 marks]**
ii. Duty cycle **[1 marks]**
iii. Output voltage **[2 marks]**
iv. The value of the inductor's inductance **[2 marks]**
v. The capacitor's capacitance for 1.6 V ripple when the peak output voltage reaches 62 V. **[4 marks]**

Total 25 marks

PLEASE TURN THE PAGE….

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

Question 4

(a) Draw a circuit diagram for a boost converter **[4 marks]**, explain its operation **[6 marks]** and derive an expression for $\frac{V_{out}}{V_{in}}$ defining all parameters used in this circuit **[2 marks]**.

[12 marks]

(b) Enumerate the basic grounding system then explain what is meant by static grounding. **[4 marks]**

(c) For a single-phase inductive load (with parallel resistance and inductance).

i. Prove that the active power is always positive, has an average value of $\frac{V.I}{2}\,cos\theta$ and zero average reactive power both pulsating at double supply frequency (2ω) where V and I are the peak values of the voltage and current and θ is the power factor angle of the load. **[5 marks]**

ii. Draw the relevant waveforms for $v, i, and\ p$. **[4 marks]**

Total 25 marks

PLEASE TURN THE PAGE….

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

Question 5

(a) Calculate the line voltages and the line currents of a Y-Y source-load Connection. Given: V_{an} = 120 ∠60^{o} V . The system is balanced three-phase system. The system impedances per phase are given as follows:

Z_{source}=0.4+j0.3 Ω , Z_{line}=0.6+j0.7 Ω, Z_{load}=24+j19 Ω. **[12 marks]**

(b) Assume a delta-connected load, with each leg Z = 100<80^{o} Ω, is supplied from a 3-phase supply with voltage of 13.8 kV (L-L) source. Find:

i. The complex power of the source and load. **[6 marks]**

ii. The load power factor, active power and reactive power. **[3 marks]**

iii. The value of a shunt capacitor that brings the power factor of the load to unity. Assume system frequency is 50 Hz. **[4 marks]**

Total 25 marks

PLEASE TURN THE PAGE….

Question 6

a) A 3-phase, 50 Hz, 215 kV power line is delivering load of 125 MW at 0.8 power factor lagging and has an impedance per phase of $186.78\angle 79.46\ ^{o}\Omega$. find:

(i) The value of a series capacitance that compensates 70% of its inductive reactance. **[5 marks]**

(ii) The new value of its receiving end voltage assuming its sending end voltage remains constant. **[10 marks]**

b) (i). Prove mathematically that line to line voltage of a star-connected source is square root of three multiplied by its phase voltage and leads it by 30 degrees. **[5 marks]**

(ii). Prove mathematically that line current of a delta-connected load is square root of three multiplied by its phase current and lags it by 30 degrees.

[5 marks]

Total 25 marks

END OF QUESTIONS

Formula Sheet follows over the page….

PLEASE TURN THE PAGE….

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

Formula sheet

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

Converters:

$$\%\mathrm{THD}_i = 100 \times \frac{I_{\mathrm{dis}}}{I_{s1}} = 100 \times \frac{\sqrt{I_s^2 - I_{s1}^2}}{I_{s1}} = 100 \times \sqrt{\sum_{h \neq 1}\left(\frac{I_{sh}}{I_{s1}}\right)^2}$$

$$\mathrm{PF} = \frac{V_s I_{s1} \cos\phi_1}{V_s I_s} = \frac{I_{s1}}{I_s}\cos\phi_1$$

$$\mathrm{DPF} = \cos\phi_1$$

$$\mathrm{PF} = \frac{I_{s1}}{I_s}\mathrm{DPF}$$

$$\mathrm{PF} = \frac{1}{\sqrt{1 + \mathrm{THD}_i^2}}\mathrm{DPF}$$

$$A_u = \sqrt{2}V_s(1 - \cos u) = \omega L_s I_d$$

$$\cos u = 1 - \frac{\omega L_s I_d}{\sqrt{2}V_s}$$

$$V_d = 0.45V_s - \frac{\text{area } A_u}{2\pi} = 0.45V_s - \frac{\omega L_s}{2\pi} I_d$$

$$V_d = 1.35\, V_{LL} cos\alpha - 3\frac{\omega L_s}{\pi} I_d$$

$$\cos(\alpha + u) = cos\,\alpha - 2\frac{\omega L_s}{\sqrt{2}V_{LL}}\, I_d$$

$$\gamma = 180 - (\alpha + u)$$

PLEASE TURN THE PAGE….

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

$$V_L = \left[\frac{1}{T}\int_0^T v_L^2(t)dt\right]^{1/2}$$

$$V_{dc} = \frac{1}{T}\int_0^T v_L(t)\,dt$$

$$\mathrm{TUF} = \frac{P_{dc}}{V_s I_s} = \frac{V_{dc} I_{dc}}{V_s I_s}$$

$$\mathrm{RF} = \frac{V_{ac}}{V_{dc}}$$

$$(V_{peak} - V_{min}) = \frac{2P\Delta t}{(V_{peak} + V_{min})C}$$

$$\frac{di_L}{dt} = \frac{V_{in} - V_{out}}{L}$$

$$\sigma = \frac{P_{dc}}{P_L} = \frac{V_{dc} I_{dc}}{V_L I_L}$$

$$\mathrm{FF} = \frac{V_L}{V_{dc}} \quad \text{or} \quad \frac{I_L}{I_{dc}}$$

$$V_{d\alpha} = \frac{1}{2\pi}\int_\alpha^\pi V_{max}\sin(\omega t)d(\omega t) = \frac{V_{max}}{2\pi}(1+\cos\alpha)$$

$$V_{ph} = \frac{V}{\sqrt{3}}\ , I_{ph} = I \quad for\ star\ connection,\ V_{ph} = V,\quad I_{ph} = \frac{I}{\sqrt{3}} \quad for\ delta\ connection$$

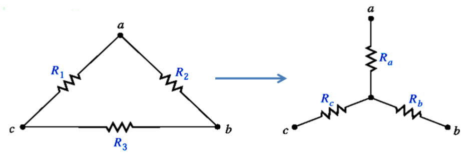
$$S = \sqrt{3}VI \quad V.A,\ P = \sqrt{3}VIcos\theta\ \ W.,Q = \sqrt{3}VIsin\theta\ \ V.A.r$$

$$Q_C = \sqrt{3}VI_C\ \ V.A.r,\ \ X_C = \frac{V}{\sqrt{3}I_C}\ \ \Omega$$

PLEASE TURN THE PAGE….

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

Three-phase systems

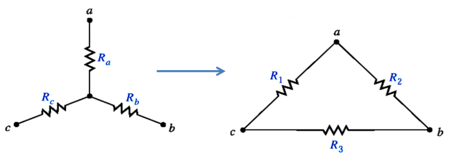


Delta to Star conversion:

$$R_a = \frac{R_1 R_2}{R_1 + R_2 + R_3}$$

$$R_b = \frac{R_2 R_3}{R_1 + R_2 + R_3}$$

$$R_c = \frac{R_3 R_1}{R_1 + R_2 + R_3}$$



Star to Delta conversion:

$$R_1 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b}$$

$$R_2 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$$

$$R_3 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_a}$$

Gravity: 9.81 m/s

Thermal resistance of the interface material:

$$\theta_{cs} = \frac{(\rho)(t)}{A}$$

Output voltage of a differentiator circuit:

$$v_0 = -R_2 C_1 \frac{dv_I}{dt}$$

Compressibility relationship:

$$K = -V \frac{dP}{dV}$$

General manometer:

$$\Delta P = |\, \Delta\rho\, g\, \Delta h \,|$$

PLEASE TURN THE PAGE….

School of Engineering
BEng (Hons) Electrical and Electronic Engineering
Semester One Examination 2021/2022
Intermediate Electrical Principles and Enabling Power Electronics
Module No: EEE5013

Venturi meter:

$$v_{\text{in}} = C_D \sqrt{\frac{2\,\Delta P}{\rho_f \left[\left(\frac{d_{\text{large}}}{d_{\text{small}}} \right)^4 - 1 \right]}}$$

Force on a submerged wall:

$$F = \frac{\rho g a h^2}{2}$$

Drag coefficient:

$$C_{Drag} = \frac{F_D}{\frac{1}{2} \rho v^2 A}$$

Flow through a small hole:

$$Q = C_D \sqrt{\frac{2\,\Delta P}{\rho}}\, A$$

Flow through a rectangular slit:

$$Q = \frac{2}{3} C_D\, W \sqrt{2g} \left[(Ho + L)^{\frac{3}{2}} - Ho^{\frac{3}{2}} \right]$$

Tank draining:

$$h^{\frac{1}{2}} = h_0^{\frac{1}{2}} - \frac{C_D a \sqrt{2g}}{2A} t$$

Flow over a rectangular weir:

$$Q = \frac{2}{3} C_D W \sqrt{2g}\; H^{\frac{3}{2}}$$

Flow over a V-notch weir:

$$Q = \frac{8}{15} C_D \tan\left(\theta/2\right) (2g)^{\frac{1}{2}}\, H^{\frac{5}{2}}$$

Poisseuille's Law:

$$Q = -\frac{\pi}{128\mu} \frac{dP}{dx} D^4$$

Darcy's Law: $\Delta P = \dfrac{2 f L \rho \bar{u}^2}{D}$

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Summary of phase and line voltages/currents for balanced three-phase systems.[1]

Connection	Phase voltages/currents	Line voltages/currents
Y-Y	$\mathbf{V}_{an} = V_p\angle 0^\circ$ $\mathbf{V}_{bn} = V_p\angle -120^\circ$ $\mathbf{V}_{cn} = V_p\angle +120^\circ$ Same as line currents	$\mathbf{V}_{ab} = \sqrt{3}V_p\angle 30^\circ$ $\mathbf{V}_{bc} = \mathbf{V}_{ab}\angle -120^\circ$ $\mathbf{V}_{ca} = \mathbf{V}_{ab}\angle +120^\circ$ $\mathbf{I}_a = \mathbf{V}_{an}/\mathbf{Z}_Y$ $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$ $\mathbf{I}_c = \mathbf{I}_a\angle +120^\circ$
Y-Δ	$\mathbf{V}_{an} = V_p\angle 0^\circ$ $\mathbf{V}_{bn} = V_p\angle -120^\circ$ $\mathbf{V}_{cn} = V_p\angle +120^\circ$ $\mathbf{I}_{AB} = \mathbf{V}_{AB}/\mathbf{Z}_\Delta$ $\mathbf{I}_{BC} = \mathbf{V}_{BC}/\mathbf{Z}_\Delta$ $\mathbf{I}_{CA} = \mathbf{V}_{CA}/\mathbf{Z}_\Delta$	$\mathbf{V}_{ab} = \mathbf{V}_{AB} = \sqrt{3}V_p\angle 30^\circ$ $\mathbf{V}_{bc} = \mathbf{V}_{BC} = \mathbf{V}_{ab}\angle -120^\circ$ $\mathbf{V}_{ca} = \mathbf{V}_{CA} = \mathbf{V}_{ab}\angle +120^\circ$ $\mathbf{I}_a = \mathbf{I}_{AB}\sqrt{3}\angle -30^\circ$ $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$ $\mathbf{I}_c = \mathbf{I}_a\angle +120^\circ$
Δ-Δ	$\mathbf{V}_{ab} = V_p\angle 0^\circ$ $\mathbf{V}_{bc} = V_p\angle -120^\circ$ $\mathbf{V}_{ca} = V_p\angle +120^\circ$ $\mathbf{I}_{AB} = \mathbf{V}_{ab}/\mathbf{Z}_\Delta$ $\mathbf{I}_{BC} = \mathbf{V}_{bc}/\mathbf{Z}_\Delta$ $\mathbf{I}_{CA} = \mathbf{V}_{ca}/\mathbf{Z}_\Delta$	Same as phase voltages $\mathbf{I}_a = \mathbf{I}_{AB}\sqrt{3}\angle -30^\circ$ $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$ $\mathbf{I}_c = \mathbf{I}_a\angle +120^\circ$
Δ-Y	$\mathbf{V}_{ab} = V_p\angle 0^\circ$ $\mathbf{V}_{bc} = V_p\angle -120^\circ$ $\mathbf{V}_{ca} = V_p\angle +120^\circ$ Same as line currents	Same as phase voltages $\mathbf{I}_a = \dfrac{V_p\angle -30^\circ}{\sqrt{3}\mathbf{Z}_Y}$ $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ$ $\mathbf{I}_c = \mathbf{I}_a\angle +120^\circ$

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