UNIVERSITI MALAYSIA PERLIS

Peperiksaan Akhir Semester Pertama
Sidang Akademik 2025/2026

Februari 2026

EMJ27303 – Power Electronics
[Elektronik Kuasa]

Masa : 3 jam

Please make sure that this question paper has **TWELVE (12)** printed pages including this front page before you start the examination.
*[Sila pastikan kertas soalan ini mengandungi **DUA BELAS (12)** muka surat yang bercetak termasuk muka hadapan sebelum anda memulakan peperiksaan ini.]*

This question paper has **FOUR (4)** questions. Answer **ALL** questions. Each question contributes 25 marks.
*[Kertas soalan ini mengandungi **EMPAT (4)** soalan. Jawab **SEMUA** soalan. Setiap soalan menyumbang 25 markah.]*

Dicetak oleh Unit Peperiksaan & Pengijazahan, Bahagian Pengurusan Akademik, Pusat Pengurusan Akademik UniMAP

Question 1
[Soalan 1]

(a) The voltage and current for a device are periodic functions with T = 20 ms described by:
[Voltan dan arus yang dihasilkan oleh sebuah alat merupakan fungsi berkala dengan T = 20 ms diterangkan seperti berikut:]

$$v(t) = \begin{Bmatrix} 10\,V & 0\,ms \le t \le 10\,ms \\ 0\,V & 10\,ms \le t \le 20\,ms \end{Bmatrix}$$

$$i(t) = \begin{Bmatrix} t\,A & 0\,ms \le t \le 5\,ms \\ (-t+10)A & 5\,ms \le t \le 10\,ms \\ 0\,A & 10\,ms \le t \le 20\,ms \end{Bmatrix}$$

(i) Sketch **TWO (2)** complete cycles of instantaneous voltage and current waveforms.
*[Lakarkan untuk tempoh **DUA (2)** kitaran lengkap gelombang voltan dan arus ketika.]*

(4 Marks/*Markah*)

(ii) Calculate and sketch **TWO (2)** complete waveform cycle of the instantaneous power absorbed by the device.
*[Kirakan dan lakarkan **DUA (2)** gelombang tempoh kitaran, kuasa ketika yang diserap oleh peranti tersebut.]*

(3 Marks/*Markah*)

(b) Differentiate diode, thyristor and MOSFET as electronic switch.
[Bezakan diod, tiristor dan MOSFET sebagai suis elektronik.]

(3 Marks/*Markah*)

(c) The full-wave controlled bridge rectifier circuit has an AC input of 120 V_{rms} at 60 Hz and a 20 Ω load resistor. The delay angle is 40°.
[Litar penerus titi terkawal gelombang penuh mempunyai voltan masukan AU 120 V_{pmkd} pada 60 Hz dan satu perintang beban 20 Ω. Sudut lengah adalah 40°.]

(i) Sketch the waveforms of output voltage, input voltage, output current and switch gating signal synchronized.
[Lakarkan gelombang-gelombang voltan keluaran melawan voltan masukan, arus keluaran dan isyarat get suis dalam keadaan segerak.]

(4 Marks/*Markah*)

(ii) Determine the average current in the load.
[Tentukan arus purata dalam beban.]

(4 Marks/*Markah*)

(iii) Determine the power absorbed by the load and the power factor.
[Tentukan kuasa yang diserap oleh beban dan faktor kuasa.]

(7 Marks/*Markah*)

Question 2
[Soalan 2]

(a) Circuit in **Figure 2** consists of DC source and resistive load in series with electronic switch operating.
*[Litar dalam **Rajah 2** terdiri daripada, sumber AT dan beban rintangan sesiri dengan suis elektronik yang beroperasi.]*

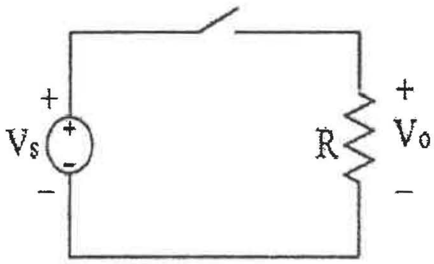

Figure 2
[Rajah 2]

(i) Explain how the output voltage of this circuit can be controlled and propose the most suitable type of electronic switch in this circuit.
[Terangkan bagaimana voltan keluaran litar ini boleh dikawal dan cadangkan jenis suis elektronik yang paling sesuai digunakan dalam litar ini.]

(4 Marks/*Markah*)

(ii) Explain the operation of linear converter.
[Terangkan operasi pengubah lelurus.]

(3 Marks/*Markah*)

(b) A converter circuit converts an input voltage of 20 V to an output of 14 V. Switching frequency is set to 5 kHz. Converter must be able to supply 60 W power at load with output ripple 5% and converter operation in Continuous Conduction Mode (CCM).
[Sebuah litar pengubah mengubah voltan masukan 20 V kepada voltan keluaran 14 V. Frekuensi pensuisan ditetapkan pada 5 kHz. Pengubah mesti boleh membekalkan kuasa 60 W pada beban dengan riak keluaran pada 5% dan beroperasi dalam keadaan mod pengaliran berterusan (CCM).]

(i) Determine the duty cycle.
[Tentukan kitar tugas.]

(2 Marks/*Markah*)

(ii) Sketch the converter circuit topology.
[Lakarkan topologi litar pengubah.]

(2 Marks/*Markah*)

(iii) Determine the suitable load resistance, inductance and capacitance for the circuit.
[Tentukan nilai beban rintangan, kearuhan dan kemuatan yang sesuai.]

(6 Marks/*Markah*)

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(iv) Sketch the complete cycle of inductor voltage and inductor current waveforms for the converter.
[Lakarkan gelombang voltan dan arus peraruh bagi pengubah tersebut untuk tempoh satu kitaran masa.]

(4 Marks/*Markah*)

(c) Discontinuous Conduction Mode (DCM) refers to the operating mode of a power converter circuit. For a buck converter, sketch a waveform illustrating the DCM operation and list **TWO (2)** methods that can switch operating modes back to CCM.
[Mod Pengaliran Tak Berterusan (DCM) merujuk kepada salah satu mod operasi litar pengubah kuasa. Bagi litar pengubah buck, lakarkan bentuk gelombang yang menunjukkan operasi DCM dan senaraikan DUA (2) cara untuk mengubah mod operasi kepada CCM.]

(4 Marks/*Markah*)

Question 3
[Soalan 3]

(a) In **Figure 3(a)**, a MOSFET, operated as electronic switch with 30% duty cycle is connected in series with load resistor 100 Ω circuit and is powered by V_{DD} = 10 V.
*[Dalam **Rajah 3(a)**, MOSFET, digunakan sebagai suis elektronik dengan 30% kitaran kitaran tugas disambung secara sesiri dengan litar beban rintangan 100 Ω dan dikuasakan dengan V_{DD} = 10 V.]*

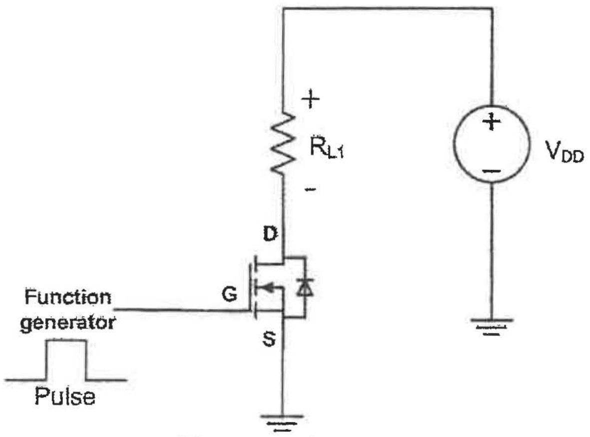

Figure 3(a)
[Rajah 3(a)]

(i) Assuming MOSFET operating in saturation during switch ON, determine the conduction power loss with $R_{DS(ON)}$ = 10 Ω.
[Dengan anggapan MOSFET beroperasi dalam keadaan tepu semasa suis BUKA, tentukan kehilangan kuasa konduksi diberi $R_{DS(ON)}$ = 10 Ω .]

(4 Marks/*Markah*)

(ii) Determine the switching loss when the switching frequency, f_{sw} = 5 kHz. Provided ON delay time = 10 μs and OFF delay time = 20 μs
[Tentukan kehilangan pensuisan apabila kekerapan pensuisan, f_{sw} = 5 kHz. Diberi masa lengah BUKA = 10 μs, dan masa lengah TUTUP = 20 μs.]

(3 Marks/*Markah*)

(b) A converter circuit is shown in **Figure 3(b)** can increase the output voltage, V_O to 60V with the input voltage, V_S at 24V through operation of electronic switch. Switching frequency is set to 5 kHz. Converter must be able to supply 60 W power at load with output ripple 5% and converter operation must be in continuous current mode (CCM).
*[Litar pengubah seperti dalam **Rajah** 3 boleh meningkatkan voltan keluaran kepada 60V dengan voltan masukan pada 24V melalui operasi suis elektronik. Frekuensi pensuisan ditetapkan pada 5 kHz. Pengubah mesti boleh membekalkan kuasa 60 W pada beban dengan riak keluaran pada 5% dan beroperasi dalam keadaan mod pengaliran berterusan (CCM).]*

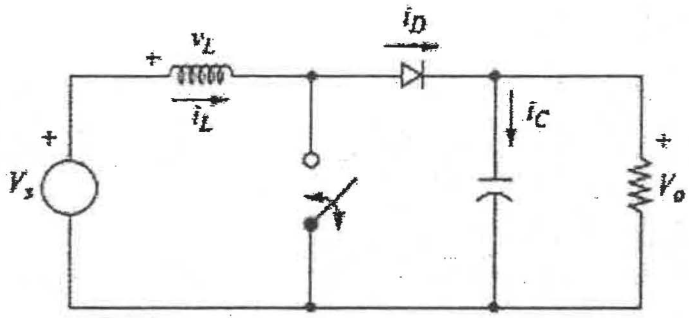

Figure 3(b)
[Rajah 3(b)]

(i) Determine the OFF time.
[Tentukan masa TUTUP.]

(3 Marks/*Markah*)

(ii) Determine the suitable load resistance, inductance and capacitance for the circuit.
[Tentukan nilai beban rintangan, aruhan dan kapasitans yang sesuai.]

(6 Marks/*Markah*)

(iii) Determine the average inductor current and peak inductor current.
[Tentukan nilai arus peraruh purata dan arus peraruh puncak.]

(4 Marks/*Markah*)

(c) In a buck-boost converter circuit, given V_S = 12 V, D = 0.7, R = 50 Ω, L = 1 mH, C = 40 μF and the f_{sw} = 1 kHz. Assume ideal components for the circuit.
[Dalam litar pengubah buck-boost, diberi V_S = 12 V, D = 0.7, R = 50 Ω, L = 1 mH, C = 40 μF dan f_{sw} = 1 kHz. Anggapkan komponen ideal.]

(i) Determine the output voltage for the circuit.
[Tentukan voltan keluaran bagi litar tersebut.]

(2 Marks/*Markah*)

(ii) Analyze whether the circuit is operating under CCM or DCM mode.
[Analisakan sama ada litar tersebut beroperasi dalam mod CCM atau DCM.]

(3 Marks/*Markah*)

Question 4
[Soalan 4]

(a) A circuit in **Figure 4** produces AC output, v_o from DC input V_{dc}.
*[Litar **Rajah 4** menghasilkan keluaran AU, v_o daripada masukan AT, V_{dc}.]*

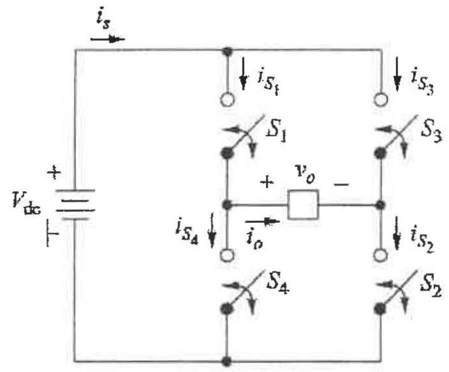

Figure 4
[Rajah 4]

(i) Describe the switching operation to synthesize square wave output voltage for the circuit in **Figure 4** and sketch the output voltage.
*[Jelaskan operasi pensuisan bagi menghasilkan voltan keluaran gelombang petak bagi litar dalam **Rajah 4** dan seterusnya lakarkan gelombang voltan keluaran tersebut.]*

(4 Marks/*Markah*)

(ii) Describe the switching operation to synthesize bipolar PWM output voltage for the circuit in **Figure 4** and sketch the output voltage.
*[Jelaskan operasi pensuisan bagi menghasilkan voltan keluaran gelombang gelombang dwipolar bagi litar dalam **Rajah 4** dan seterusnya lakarkan gelombang voltan keluaran tersebut.]*

(3 Marks/*Markah*)

(b) Compare the difference between a square wave inverter and a PWM inverter in the aspect of harmonics elimination.
[Bandingkan perbezaan antara penyongsang gelombang petak dan penyongsang PWM dari segi menghilangkan harmonik.]

(3 Marks/*Markah*)

(c) The full-bridge inverter produces square wave output across a R-L load. Given the switching frequency = 60 Hz, V_{dc} = 120 V load resistance R = 10 Ω and inductor, L = 40 mH.
[Satu litar penyongsang titi penuh menghasilkan gelombang petak merentasi beban R-L. Diberi frekuensi pensuisan = 60 Hz, V_{dc} = 120 V beban rintangan R = 10 Ω dan induktor, L = 40 mH]

(i) Sketch the waveform of inverter output voltage and current.
[Lakarkan gelombang voltan keluaran dan arus keluaran penyongsang.]

(3 Marks/*Markah*)

(ii) Determine expression for instantaneous load current.
[Tentukan ungkapan bagi arus beban ketika.]

(4 Marks/*Markah*)

(iii) Determine the power absorbed by the load.
[Tentukan kuasa yang diserap oleh beban.]

(4 Marks/*Markah*)

(iv) Evaluate total harmonics distortion (THD) for load current. Assume harmonics truncated at 7^{th} component.
[Nilaikan jumlah herotan harmonic (THD) bagi arus beban. Anggapkan harmonik dipotong pada komponen ke-7.]

(4 Marks/*Markah*)

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APPENDIX A

[LAMPIRAN A]

MATHEMATICAL FORMULAE

Power Computations

Fourier Series	$f(t)=a_0+\sum_{n=1}^{\infty}[a_n\cos(n\omega_0 t)+b_n\sin(n\omega_0 t)]=a_0+\sum_{n=1}^{\infty}C_n\cos(n\omega_0 t+\theta_n)$
RMS of function f(t)	$F_{rms}=\sqrt{\frac{1}{T}\int_{t_0}^{t_0+T}f^2(t)dt}$
	$F_{rms}=\sqrt{\sum_{n=0}^{\infty}F_{n,rms}^2}=\sqrt{a_0^2+\sum_{n=1}^{\infty}\left(\frac{C_n}{\sqrt{2}}\right)^2}$
Average of function f(t)	$F=\frac{1}{T}\int_0^T f(t)dt$
Instantaneous Power	$p(t)=v(t)i(t)$
Average/real power:	$P=\frac{1}{T}\int_{t_0}^{t_0+T}p(t)dt=\frac{1}{T}\int_{t_0}^{t_0+T}v(t)i(t)dt$
If $v(t)=V_{dc}$	$P=V_{dc}I_{avg}$
If $i(t)=I_{dc}$	$P=V_{avg}I_{dc}$
If $v(t)$ and $i(t)$ are sinusoidal waveforms	$P=V_{rms}I_{rms}\cos(\theta-\phi)$, $pf=\cos(\theta-\phi)$
If $v(t)$ and $i(t)$ are nonsinusoidal periodic waveforms	$P=V_0I_0+\sum_{n=1}^{\infty}\left(\frac{V_{n,max}I_{n,max}}{2}\right)\cos(\theta_n-\phi_n)$
Power in a resistor	$P=\frac{V^2_{rms}}{R}=I^2_{rms}R$
Apparent power	$S=V_{rms}I_{rms}$
Power factor	$pf=\frac{P}{S}=\frac{P}{V_{rms}I_{rms}}$

Controlled Full-Wave Rectifier

R load	
Average output voltage	$V_o=\frac{1}{\pi}\int_{\alpha}^{\pi}V_m\sin(\omega t)d(\omega t)=\frac{V_m}{\pi}(1+\cos\alpha)$
RMS output current	$I_{rms}=\sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi}\left(\frac{V_m}{R}\sin\omega t\right)^2d(\omega t)}=\frac{V_m}{R}\sqrt{\frac{1}{2}-\frac{\alpha}{2\pi}+\frac{\sin(2\alpha)}{4\pi}}$
RL load	

Instantaneous output current for DCM: $\beta<\pi+\alpha$	$i_o(\omega t)=\frac{V_m}{Z}\left[\sin(\omega t-\theta)-\sin(\alpha-\theta)e^{-(\omega t-\alpha)/\omega\tau}\right]$ for $\alpha\le\omega t\le\beta$ where $Z=\sqrt{R^2+(\omega L)^2}$, $\theta=\tan^{-1}\left(\frac{\omega L}{R}\right)$, and $\tau=\frac{L}{R}$
Output voltage for CCM: $\alpha\le\tan^{-1}\left(\frac{\omega L}{R}\right)$	$v_o(\omega t)=V_o+\sum_{n=1}^{\infty}V_n\cos(n\omega_0 t+\theta_n)$ $V_o=\frac{1}{\pi}\int_{\alpha}^{\alpha+\pi}V_m\sin(\omega t)d(\omega t)=\frac{2V_m}{\pi}\cos\alpha$ $V_n=\sqrt{a_n^2+b_n^2}$ $a_n=\frac{2V_m}{\pi}\left[\frac{\cos(n+1)\alpha}{n+1}-\frac{\cos(n-1)\alpha}{n-1}\right]$ $b_n=\frac{2V_m}{\pi}\left[\frac{\sin(n+1)\alpha}{n+1}-\frac{\sin(n-1)\alpha}{n-1}\right]$ $n=2, 4, 6\ldots$
RL-Source load	
Minimum triggering angle	$\alpha\ge\sin^{-1}\left(\frac{V_{dc}}{V_m}\right)$
Average output voltage for CCM	$V_o=\frac{2V_m}{\pi}\cos\alpha$

Buck DC-DC Converter

CCM	
Average output voltage	$V_o=V_sD$
Maximum inductor current	$I_{max}=I_L+\frac{\Delta i_L}{2}=\frac{V_o}{R}+\frac{1}{2}\left[\frac{V_o}{L}(1-D)T\right]=V_o\left[\frac{1}{R}+\frac{(1-D)}{2Lf}\right]$
Minimum inductor current	$I_{min}=I_L-\frac{\Delta i_L}{2}=\frac{V_o}{R}-\frac{1}{2}\left[\frac{V_o}{L}(1-D)T\right]=V_o\left[\frac{1}{R}-\frac{(1-D)}{2Lf}\right]$
Minimum inductance for CCM	$L_{min}=\frac{(1-D)R}{2f}$
Peak-to-peak output voltage ripple	$\Delta V_o=\frac{V_o(1-D)}{8LCf^2}$
Peak-to-peak output voltage ripple due to ESR	$\Delta V_{o,ESR}=\Delta i_C r_C=\Delta i_L r_C$
Peak-to-peak inductor current ripple	$\Delta i_L=\left(\frac{V_o}{L}\right)(1-D)T$
DCM	
DC voltage gain	$\frac{V_o}{V_s}=\frac{D}{D+D_1}=\frac{2D}{D+\sqrt{D^2+8L/RT}}$

Boost DC-DC Converter

CCM	
Average output voltage	$V_o = \frac{V_s}{1-D}$
Average inductor current	$I_L = \frac{V_s}{(1-D)^2 R} = \frac{V^2_o}{V_s R} = \frac{V_o I_o}{V_s}$
Maximum inductor current	$I_{max} = I_L + \frac{\Delta i_L}{2} = \frac{V_s}{(1-D)^2 R} + \frac{V_s DT}{2L}$
Minimum inductor current	$I_{min} = I_L - \frac{\Delta i_L}{2} = \frac{V_s}{(1-D)^2 R} - \frac{V_s DT}{2L}$
Minimum inductance for CCM	$L_{min} = \frac{D(1-D)^2 R}{2f}$
Peak-to-peak output voltage ripple	$\Delta V_o = \frac{DV_o}{RCf}$
Peak-to-peak output voltage ripple due to ESR	$\Delta V_{o,ESR} = \Delta i_C r_C = I_{L,max} r_C$
Peak-to-peak inductor current ripple	$\Delta i_L = \frac{V_s DT}{L}$
DCM	
DC voltage gain	$\frac{V_o}{V_s} = \frac{1}{2}\left(1+\sqrt{1+\frac{2D^2RT}{L}}\right)$

Single Phase Full-Bridge Inverter

Square-Wave	
Steady-state current	$i_o(t) = \begin{cases} \frac{V_{dc}}{R} + \left(I_{min} - \frac{V_{dc}}{R}\right)e^{-t/\tau} & \text{for } 0<t<\frac{T}{2} \\ \frac{-V_{dc}}{R} + \left(I_{max} + \frac{V_{dc}}{R}\right)e^{-(t-T/2)/\tau} & \text{for } \frac{T}{2}<t<T \end{cases}$
Maximum and minimum current	$I_{max} = -I_{min} = \frac{V_{dc}}{R}\left(\frac{1-e^{-T/2\tau}}{1+e^{-T/2\tau}}\right)$
RMS value of current	$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)d(t)} = \sqrt{\frac{2}{T}\int_0^{T/2}\left[\frac{V_{dc}}{R} + \left(I_{min} - \frac{V_{dc}}{R}\right)e^{-t/\tau}\right]^2 dt}$
Fourier Series Analysis	
RMS currents at each of components	$I_{rms} = \sqrt{\sum_{n=1}^{\infty} I^2_{n,rms}} = \sqrt{\sum_{n=1}^{\infty}\left(\frac{I_n}{\sqrt{2}}\right)^2}$

Square-wave inverter of odd harmonics	$v_o(t)=\sum_{n\ odd} \frac{4V_{dc}}{n\pi} \sin n\omega_0 t$
	Total Harmonic Distortion
THD of load voltage	$THD_V=\frac{\sqrt{\sum_{n=2}^{\infty}\left(V_{n,rms}\right)^2}}{V_{1,rms}}=\frac{\sqrt{V^2_{rms}-V^2_{1,rms}}}{V_{1,rms}}$
THD of load current	$THD_I=\frac{\sqrt{\sum_{n=2}^{\infty}\left(I_{n,rms}\right)^2}}{I_{1,rms}}$
	Amplitude and Harmonic Control
Amplitude of voltage waveform	$V_n=\frac{2}{\pi}\int_{\alpha}^{\pi-\alpha} V_{dc}\sin(n\omega_0 t)d(\omega_0 t)=\frac{4V_{dc}}{n\pi}\cos(n\alpha)$
Amplitude of fundamental-frequency voltage	$V_1=\left(\frac{4V_{dc}}{\pi}\right)\cos\alpha$
	Pulse-Width-Modulated Output
Frequency modulation ratio	$m_f=\frac{f_{carrier}}{f_{reference}}=\frac{f_{tri}}{f_{sine}}$
Amplitude modulation ratio	$m_a=\frac{V_{m,reference}}{V_{m,carrier}}=\frac{V_{m,sine}}{V_{m,tri}}$
The *k*th pulse of the PWM output	$V_{nk}=\frac{2V_{dc}}{n\pi}\left[\cos n\alpha_k+\cos n_{\alpha_k+1}-2\cos n(\alpha_k+\delta_k)\right]$
Normalized Fourier coefficients V_n/V_{dc} for Bipolar PWM	(table below)

	$m_a=1$	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
n=1	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10
$n=m_f$	0.60	0.71	0.82	0.92	1.01	1.08	1.15	1.20	1.24	1.27
$n=m_f\pm 2$	0.32	0.27	0.22	0.17	0.13	0.09	0.06	0.03	0.02	0.00