17.5

Jordan University
Dept. of Elect. Engg.

Power Electronics (0943461)
First Examination

Date: 23.10.2014
Time: 1 Hour

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Programmable calculators are not allowed.
Derive any formula you use.

1. Answer the following by marking √ for correct answer and **X** for wrong answer
2marks (each question 0.5 mark)

Power Electronics devices may inject harmonics into the power system which it is part of it	T ✓
Boost converters are used to step up ac voltage to ac voltage of different frequency	F X
The higher the power capability of power electronics devices, the higher is the frequency possible to use	T ✓ ×
HVDC transmission needs both rectifiers and inverters	F X ×

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1. Fig 1 shows the diode recovery characteristics of certain diode. **1mark**
Softness factor = $\frac{t_d}{t_a} = \frac{1.5}{0.5} = 3$ ✓ 1

2. Fig 2 shows the characteristics of two diodes connected in series with a total reverse voltage of 5kV.
Find the values of the equalizing resistances needed to get equal voltage drop across the two diodes and to have a total reverse current of 10mA. **2marks**

$I_{s1} + \frac{V_{D1}}{R_1} = I_{s2} + \frac{V_{D2}}{R_2}$

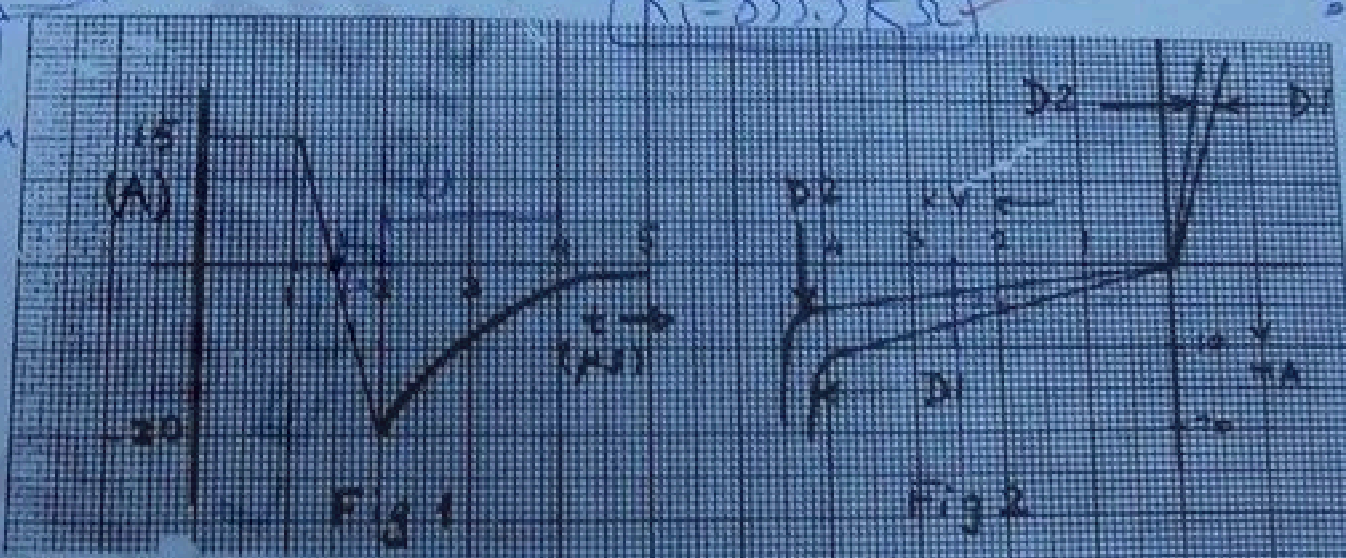
$I_{R_1} = 10mA - 7mA = 3mA$

$7m + \frac{2.5k}{R_1} = $ [illegible] $ + \frac{2.5K}{R_2}$ (3.5m)

10m − 7m

10 − 3.5 = 6.5m

$R_1 = 833.3 k\Omega$



$= 3m$

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$= 6.5m \Rightarrow R_2 = 384.62 k\Omega$

$100\cos(100\pi t - 60)$

2. A voltage of $v(t) = 100 \sin(100\pi t + 30^\circ)$ V, is applied to a certain non-linear load. The flowing current is given by:
$i(t) = 4 + 10\cos(100\pi t) + 6\sin(300\pi t + 30^\circ)$ A

5marks

Find:

(i) The rms value of the current

$$I_{rms} = \sqrt{4^2 + \left(\frac{10}{\sqrt{2}}\right)^2 + \left(\frac{6}{\sqrt{2}}\right)^2} = 9.165\ A$$

(ii) The distortion factor

$$D.F = \frac{I_{1rms}}{I_{rms}} = \frac{\frac{10}{\sqrt{2}}}{9.165} = 0.7715$$

(iii) The power factor

$$Power = \frac{(100)(10)}{2}\cos(60) = 250W$$

$$\therefore P.F = \frac{250}{V_{rms} I_{rms}} = \frac{250}{\left(\frac{100}{\sqrt{2}}\right)(9.165)} = 0.3858$$

(iv) The distortion volt ampere

$$Q = \frac{(100)(10)}{2}\sin(60) = 433.012\ VAR$$

$P = 250$

$$S = 648.06\ VA$$

$$D = \sqrt{S^2 - P^2 - Q^2} = \sqrt{(648.06)^2 - (250)^2 - (433.012)^2}$$

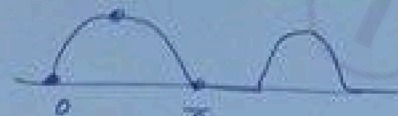
$$D = \sqrt{169982.3715} = 412.29\ VAD$$

(v) The total harmonic distortion

~~$THD = \sqrt{\frac{I_{rms}^2 - I_{1rms}^2}{I_{1rms}^2}}$~~

$$THD = \sqrt{\frac{1}{DF^2} - 1} = \sqrt{\frac{1}{(0.7715)^2} - 1} = 0.8825$$

$$= 88.25\%$$



$$\frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin^2(\omega t)\, dt \Rightarrow \frac{V_m^2}{2\pi}\left(\frac{1}{2} - \frac{1}{2}\cos\right)\Big|_0^{\pi}$$

3. A single-phase half wave rectifier supplied from a sinusoidal source and with a pure resistive load of 2Ω. The dc-power consumed by the load = 200W. Find: **5marks**

(i) The peak value of the transformer secondary voltage

$$P = \frac{V_{rms}^2}{R} \Rightarrow 200 = \frac{V_{rms}^2}{2} \Rightarrow V_{rms}^2 = 400$$

$$\boxed{V_{dc} = 20V} \quad V_{dc} = \frac{V_m}{\pi} \qquad \boxed{V_m = 62.832V}$$

$$~~V_{rms} = 20 = \sqrt{\frac{1}{2\pi}\int_0^{\pi} V_m^2 \sin(\omega t)^2\, dt} \Rightarrow \sqrt{\frac{V_m^2}{2\pi}\int_0^{\pi} \frac{1}{2} - \frac{1}{2}\cos(2\omega t)\, d\omega t}~~$$

$$~~20 = \sqrt{\frac{V_m^2}{2\pi}\left(\frac{1}{2}\omega t - \frac{1}{2}\sin(2\omega t)\right)\Big|_0^{\pi}} \Rightarrow \sqrt{\frac{V_m^2}{2\pi}\left(\frac{1}{2}\pi\right)} \Rightarrow 20 = \sqrt{\frac{V_m^2}{4}} \Rightarrow 20 = \frac{V_m}{2}~~$$

$$~~\Rightarrow V_m = 40V~~ \qquad \boxed{V_{rms} = \frac{V_m}{2}}$$

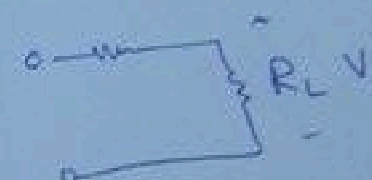
(ii) The rms value of the transformer secondary current

$$I_{rms} = \frac{V_{rms}}{R} = \frac{20}{2} = \qquad V_{rms} = \frac{62.832}{2} = \boxed{31.416V}$$

$$I_{rms} = \sqrt{\frac{1}{2\pi R}\int_0^{\pi} (62.832)^2 \sin^2(\omega t)\, d\omega t} \qquad \boxed{= 15.708\ A}$$

(iii) The total power consumed by the load

$$P = I_{rms}^2 R = (15.708)^2 (2) = 493.48W$$



(iv) The ac voltage of the load

$$V_{rms\,R} = (15.708)(2) = \boxed{31.416V}$$

$$V_R(t) = 62.832\sin(\omega t)$$

(v) The volt-ampere of the transformer

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$$S = (I_{rms})(V_{rms}) = 493.48\ VA$$

ABET Problem for evaluating Students Outcome E:

1. A half wave rectifier with sinusoidal supply voltage with $V_m = 200V$, 50Hz, a resistance of 4Ω, an inductance of 20mH and a dc source of 100V.

5marks

(i) Calculate the value of the distinction angle β

$\alpha = \sin^{-1}\left(\frac{V_{dc}}{V_m}\right) = \sin^{-1}\left(\frac{100}{200}\right) = 30^\circ$ & $\sin(\alpha) = 1/2$ (0.5)

$\frac{\omega L}{R} = \frac{(2\pi)(50)(20\times10^{-3})}{4} = 1.57$

from graph $\Rightarrow \beta = 185^\circ$

$\theta = \tan^{-1}\left(\frac{\omega L}{R}\right) = 57.52^\circ$

(ii) Calculate the dc value of the output voltage

$i(t) = \frac{V_m}{Z}\sin(\omega t) + \frac{V_{dc}}{R} - V$

$V_{dc} = \frac{1}{2\pi}\int_{\alpha}^{\beta} V(t)\,dt = \frac{1}{2\pi}\int_{30^\circ}^{185^\circ} 200\sin(\omega t)\,d\omega t$

$\frac{200}{2\pi}\left[-\cos(\omega t)\right]_{30}^{185} =$

(iii) Calculate the power supplied to the battery

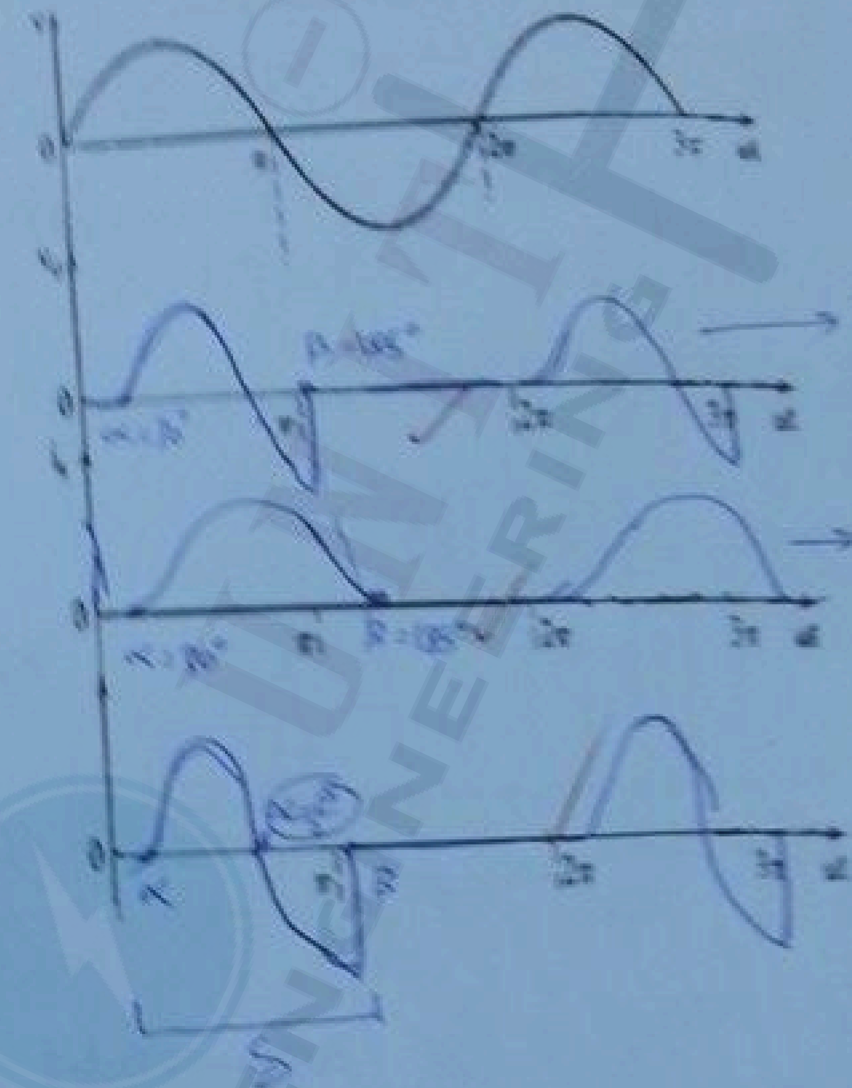
$P = I_{dc}V_{dc}$

$P = (22.78)\times(100) = 2277.61\ W$ X

(iv) Given the waveform of the input voltage, sketch the waveforms of the output voltage, the current and the voltage across the inductance

X

4.5



$$i(t) = \frac{V_m}{Z}\sin(\omega t) + \frac{V_{dc}}{R} - \left[\frac{V_m}{Z}\sin(\alpha-\theta)\,e^{\frac{\alpha}{\omega\tau}} + \frac{V_{dc}}{R}\right] e^{-\frac{t}{\tau}}$$

$\alpha = 30°$
$\beta = 185°$

$$I_{dc} = \frac{V_{dc}}{R} + \frac{1}{2\pi}\int_{\alpha}^{\beta} \frac{V_m}{Z}\sin(\omega t)\, d\omega t$$

$$= \frac{V_{dc}}{R} + \frac{V_m}{Z\,2\pi}\left(-\cos(\omega t)\right)\Big|_{\alpha}^{\beta} \Rightarrow I_{dc}$$

$$\frac{59.27}{4} + 7.957\text{ V}$$

$$14.81 + 7.957 = \boxed{22.78\text{ V}}$$

$Z = \sqrt{\ldots}$