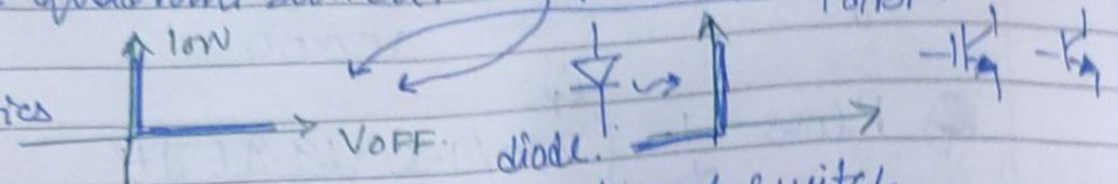
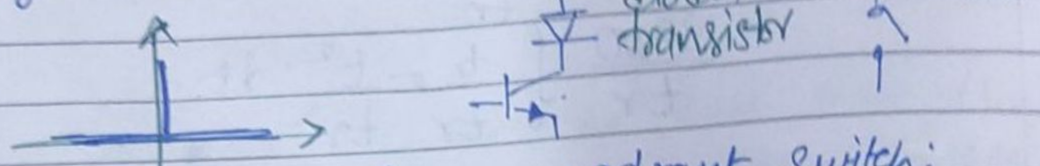
19EE10039 MANSI UNIYAL:

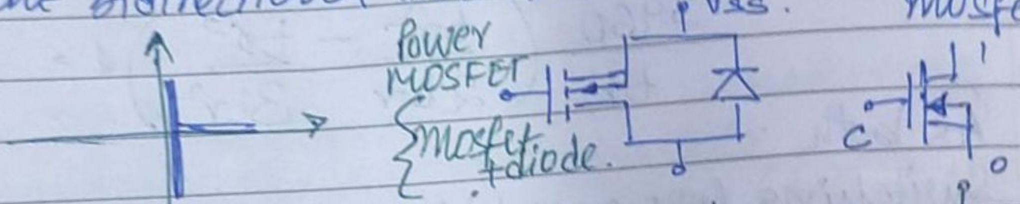
Q1. (A) Single quadrant switch. = Bipolar Junction Transistor, (BJT) IGBT.



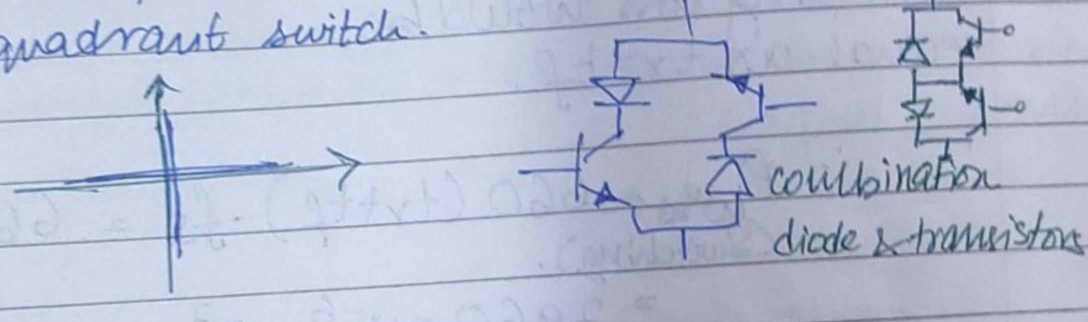
(B) Voltage Bidirectional two quadrant switch.



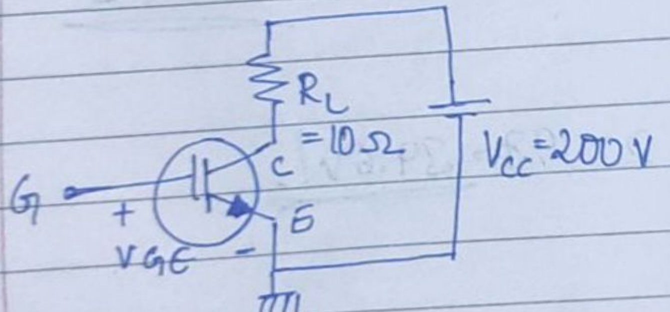
(C) current bidirectional two quadrant switch:



(d) Four quadrant switch.



Q2.



$t_{ON} = 3\mu s$

$t_{OFF} = 3\mu s$

$D = 0.7$

$V_{CE} = 2V$

$f_s = 1kHz$

$T_S = 1/f_s = 1 ms$

(A) Avg load current

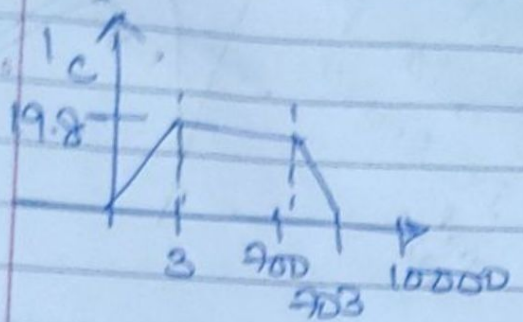
(B) Conduction loss

(C) Switching loss.

Q2. (A). $T_s = 1/f_s = 1ms.$

$t = 0.7\ ms$
$= 700\ \mu s.$

$I_c = \frac{200-2}{10}$
$= 19.8\ A.$



$$I_{c\,avg} = \frac{1}{2}(703+697) \times \frac{19.8}{10000} = 1.386\ A.$$

(C) $P_{loss} = \frac{1}{t_r}\int_0^{t_r} 200\left(1-\frac{t}{t_r}\right)\frac{19.9t}{t_r}\,dt.$

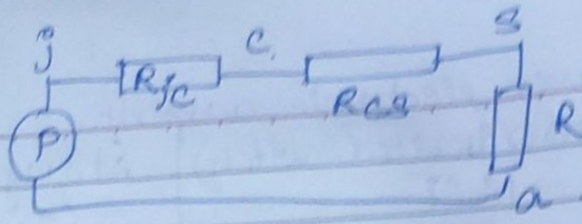
$$= \frac{3960}{t_r}\int_0^{t_r} \frac{t}{t_r} - \frac{t^2}{t_r^2}\,dt.$$

$$= \frac{3960}{t_r}\left(\frac{t_r^2}{2t_r} - \frac{t_r^3}{3t_r^2}\right) = \frac{3960}{6} = 660\,W.$$

As both
Switching loss would be
equal as $t_r = t_f$.

$\therefore P_{loss\,(Switching)} = 660\,(t_r+t_f)\cdot f_s = 660 \times 6\mu \times 1k$
$= 3960 \times 10^{-6} \times 10^3 = \underline{3.96}$

B) $P_{loss\,(c)} = V_{CE} \times I_c = 2 \times 19.8 = \underline{39.6\,W.}$

Q3. 

Thermal equivalent circuit.

$T_{c\,max} = 110°C$, $T_a = 35°C$, $T_{j\,max} = 125°C$, $R_{sa} = 0.5°C/W$,
$R_{ca} = 0.6°C/W$, $R_{ja} = 0.72°C/W$.

$$P_{loss} = \frac{T_j - T_a}{R_{ja}} = \frac{T_c - T_a}{R_{ca}} = \frac{T_s - T_a + T_c - T_s}{R_{ca}}$$

$$= \frac{R_{cs} P_{loss} + R_{sa} P_{loss}}{R_{ca}}$$

$R_{ca} = R_{cs} + R_{sa}$.
$\underline{R_{cs} = 0.1°C/W}$

$$\frac{T_s - T_a}{R_{sa}} = \frac{T_c - T_s}{R_{cs}}$$

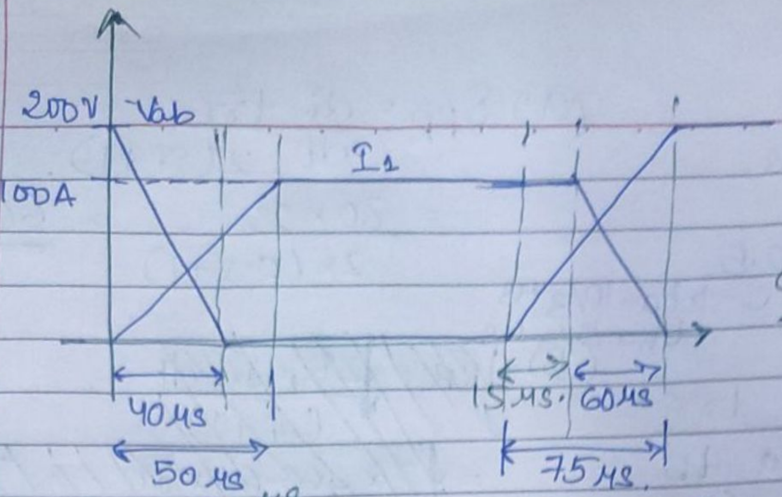
$$\frac{T_s - 35°}{0.5} = \frac{110° - T_s}{0.1}$$

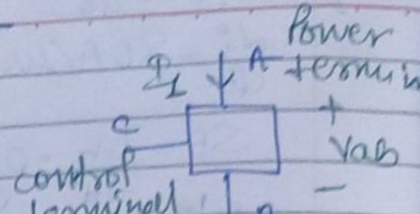
$6T_s = 585$ $\quad \underline{T_s = 97.5\,°C/W}$

$R_{jc} = R_{ja} - R_{cs} - R_{sa}$
$= 0.72 - 0.1 - 0.5$

$\underline{R_{jc} = 0.12°C/W.}$

Q4.





(A) $E_{ON} = \int_0^{40\mu s} V_{ab} I_1 \, dt \Rightarrow$ $\Big|$ $I_1 = \frac{100t}{50\times10^{-6}}$

$V_{ab} = 200\left(1-\frac{t}{40\times10^{-6}}\right)$

$$E_{ON} = \int_0^{4\times10^{-5}} 200\left(\frac{100t}{5\times10^{-5}}\right)\times\left(1-\frac{t}{4\times10^{-5}}\right)dt$$

$$= \frac{2\times10^4}{5\times10^{-5}} \int_0^{4\times10^{-5}} \left(t - t^2/4\times10^{-5}\right) dt$$

$$= 4\times10^8 \left(\frac{(40\times10^{-6})^2}{2} - \frac{(40\times10^{-6})^3}{3\times(40\times10^{-6})}\right)$$

$$= 4\times10^8 \, \frac{(4\times10^{-5})^2}{6}$$

$$= \cancel{2}\,\frac{4\times16\times10^{8-10}}{6} = \frac{64}{6}\times10^{-2} = \underline{0.1066\,J}$$

Q4 (B).

$$V_{ab} = \frac{200}{75} \times 10^6 t = \frac{8}{3} \times 10^6 t.$$

$$I_1 = 100. \quad t \leq 15\mu s$$

$$= 100 - \frac{100}{60} \times 10^6 t \quad 15\mu s \leq t.$$

$$\Rightarrow \left(100 - \frac{5}{3} \times 10^6 t\right)$$

$$E_{OFF} = \int_0^{t_{OFF}} V_{ab} I_1 \, dt.$$

$$= \int_0^{15\mu s} \frac{8}{3} \times 10^8 t \, dt + \int_{15\mu s}^{75\mu s} \frac{8}{3} \times 10^6 t \left(100 - \frac{5}{3} \times 10^6 t\right) dt.$$

$$= \frac{8}{3} \times 10^8 \left[\frac{(15 \times 10^{-6})^2}{2} + \int_{15\mu s}^{75\mu s} \left(t - \frac{5}{3} \times 10^4 t^2\right) dt.\right]$$

$$= 3 \times 10^{-2} + \frac{8 \times 10^8}{3} \left[\cancel{(75 \times 10^{-6} - 15 \times 10^{-6})} \left((60 \times 10^{-6})(90 \times 10^{-6}) - \frac{5}{3 \times 3} \times 10^4 \left[(75 \times 10^{-6})^3 - (15 \times 10^{-6})^3\right.\right.\right.$$

O/P $= 3 \times 10^{-2} + 8/3 \times 10^{8} [2.7 \times 10^{-10} + 2325 \times 10^{-12}]$

$= 3 \times 10^{-2} + \frac{8}{3} \times 5025 \times 10^{-4}$

$\underline{E_{OFF} = 1.37\ J}$

(C). Total energy $= (1.37 + 0.1067)\ J$

$\underline{= 1.4767\ J}$

(D) $T = 1/f_{s\,max}$

$\frac{1.4767}{T} = 1k.$

$f_{s\,max} = \frac{10^3}{1.4767} = \underline{677.18\ Hz}$

Q5. $t_{rr} = 5\mu s$

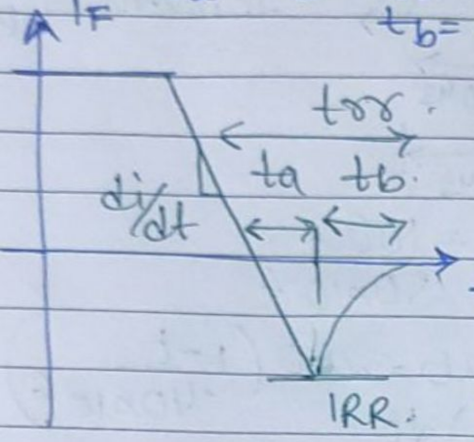
$\frac{di}{dt} = 80\,A/\mu s.$

$SF = \frac{t_b}{t_a} = 0.5 \rightarrow t_a = 10/3\,\mu s$

$t_b = 5/3\,\mu s.$

(a) $Q_{RR} = \frac{di}{dt}\,\frac{t_{rr}^2}{2(SF+1)}.$

$= \frac{80 \times 25}{2 \times (0.5+1)} = \underline{\underline{666.67C}}$



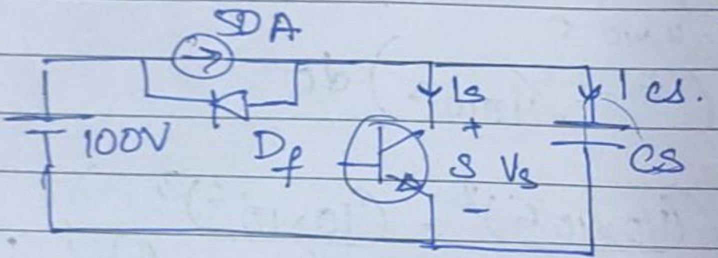
(B) $\cancel{I_{RR} = \sqrt{\frac{2 Q_R\, di/dt}{(SF+1)}}}$

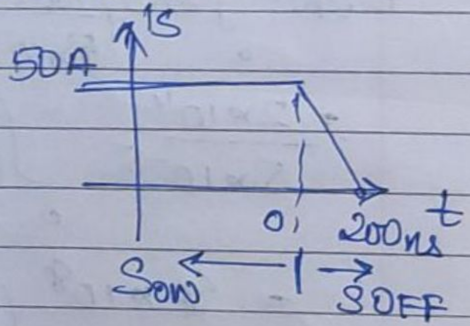
$\cancel{= \sqrt{\frac{2 \times 666.67 \times 80}{1.5}} = 266.66A}$

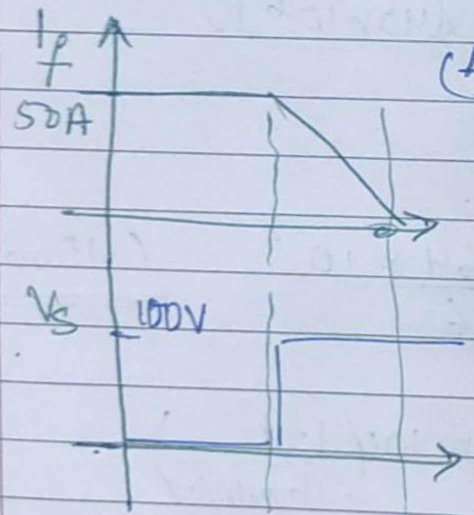
OR $\boxed{\frac{di}{dt} = \frac{I_{RR}}{t_a}}$ $\therefore I_{RR} = \frac{800}{3} = \underline{266.66A}$

$C = \frac{1}{2} t_{rr} I_{RR} = 666.67\,\mu F.$

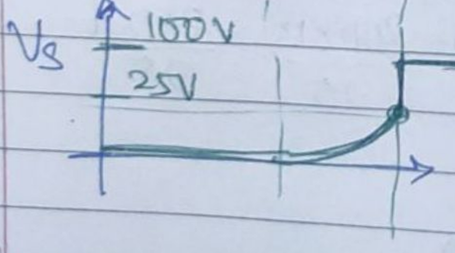
Q6.







(A) without snubber capacitor



(B) snubber capacitance = 0.2 μF.

$I_L = I_s + I_c$

$= I_L\left(1 - \frac{t}{t_f}\right) + I_c$

$I_c = I_L\, t/t_f.$

$V_s = V_c = \frac{1}{C}\int_0^{t_f} I_L\, t/t_f\, dt.$

$= I_L/C t_f \cdot t^2/2$

as $t = t_f$.

$V_s = \frac{I_L t_f}{2C} = 25V.$

Q6.

(c) $C = \frac{50}{200} \times 200 \times 10^{-9} = 50 nF$

$\underline{C = 50 nF}$

$\frac{V_{source}}{I_{s_{max}} - I_L} < R < \frac{t_{OFF min}}{5C}$

$R < \frac{200 \times 10^{-9}}{50 \times 5 \times 10^{-9}}$

$\underline{R < 0.8 \Omega}$

$\frac{V_{source}}{I_{s_{max}} - I_L} < R$

$\frac{100}{I_{s_{max}} - 50} < 0.8$

$\underline{I_{s_{max}} > 175 A}$

maximum allowed collector current in BJT.

$\frac{100}{0.8} < I_{s_{max}} - 50$

Q7. (A) practical power electronic converter:

Power Semiconductor Device (Switch)		Storage element (Filter)
— Diode	— IGCT	— Capacitor
— MOSFET	— IPM	— Inductor.
— IGBT	— GTO	
— Thyristor	— TRIAC.	
— SiC devices		
— GaN devices		

Other components
- Heat sink cooling arrangement
- Driver circuit.

(B) Advantages of wide Bandgap switching devices:

→ wide Bandgap switching devices results in high Breakdown voltage so that it can operate at high voltages.
Power Electronic prefer high breakdown voltage semiconductors.

→ These devices also have excellent thermal stability to operate on high temperatures. (in comparison with Si, Ge, GaAs).

→ They also have critical electrical field strength which result in low ON state resistance hence conduction loss can be reduced.

→ More bandgap makes switch use sensitive to high frequency spikes and transients

→ Example: SiC (Silicon Carbide), GaN (Gallium Nitride).

(C) Isolation requirement ~~of~~ in driver circuit wrt converter circuit digram.

Q7 (E) MOSFET: Metal Oxide Semiconductor Field Effect Transistor

IGBT: Insulate Gate Bipolar Transistor

BJT: Bipolar Junction Transistor

SCR: Silicon Controlled Rectifier

IGCT: Integrated Gate Commutated Thyristor

GTO: Gate Turn-off Thyristor.

Q7 (D). (i) Day-to Day life.

- Power Bank. (charge phones)
- Solar photovoltanic
- HVDC (High voltage Direct current).

(ii) Emerging Applications

- Electric vehicles (TESLA)
- Electric submarine
- Electric Aircrafts.