ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING

PAPER-I

Time Allowed: **Three Hours** Maximum Marks: **300**

Question Paper Specific Instructions

Please reach each of the following instruction carefully before attempting questions:

*There are **EIGHT** questions divided in **TWO** sections.*

*Candidate has to attempt **FIVE** questions in all*

*Questions **No.1** and **5** are **compulsory** and out of the remaining, any **THREE** are to be attempted choosing at least **ONE** question from each section.*

The number of marks carried by a question/part is indicated against it.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.

Unless otherwise mentioned, symbols and rotations carry their usual standard meanings.

Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page of portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

*Answers must be written in **ENGLISH** only.*

Values of constants which may be required:

Electron charge	$= -1.6 \times 10^{-19}$ Coulomb
Free space permeability	$= 4\pi \times 10^{-7}$ Henry/m
Free space permittivity	$= \left(\frac{1}{36\pi}\right) \times 10^{-9}$ Farad/m
Velocity of light in free space	$= 3 \times 10^{8}$ m/sec
Boltzmann constant	$= 1.38 \times 10^{-23}$ J/K
Planck's constant	$= 6.626 \times 10^{-34}$ J-s

SECTION-A

1. **(a)** **(i)** An InGaAs photodiode operation at $1.3\,\mu m$ is limited by background radiation giving $I_B = 10^{-7}$ A. The responsivity of the diode is 0.74 A/W at $1.3\,\mu m$. Find the minimum detectable power of this photodiode if the bandwidth of the device is 10 MHz and load resistance is 10 MHz and load resistance is $R_L = 10^7\,\Omega$.

(ii) An nMOS transistor has a threshold voltage (V_t) of 0.4 V and a supply voltage $V_{DD} = 1.2$ V. A circuit designer is evaluating a proposal to reduce V_t by 100 mV to obtain faster transistor. By what factor would the sub-threshold leakage current increase at room temperature at $V_{gs} = 0$?

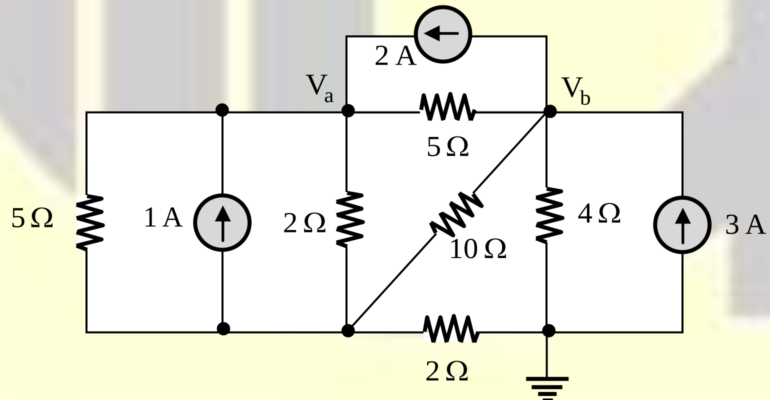
Assume n = 1.4.

[6 + 6 Marks]

(b) Design a two-sided limiting circuit using a resistor, two diodes and two power supplies to feed a $1\,k\Omega$ load with nominal limiting levels of ±3V. Use voltage drop of 0.7V for each diode when conducting. In the non-limiting region, the circuit voltage gain should be at least 0.95 V/V.

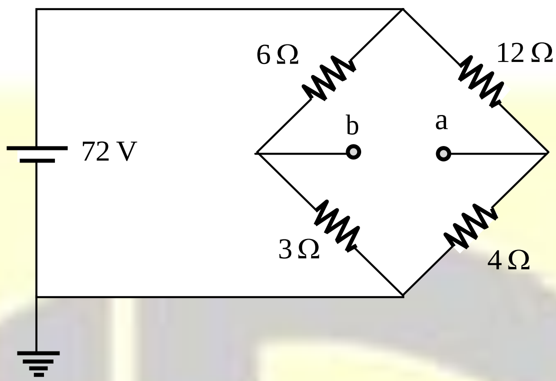
[12 Marks]

(c) Find the node voltages V_a and V_b for the circuit shown in the figure using node voltage analysis. Also, find the current through $5\,\Omega$ resistor:



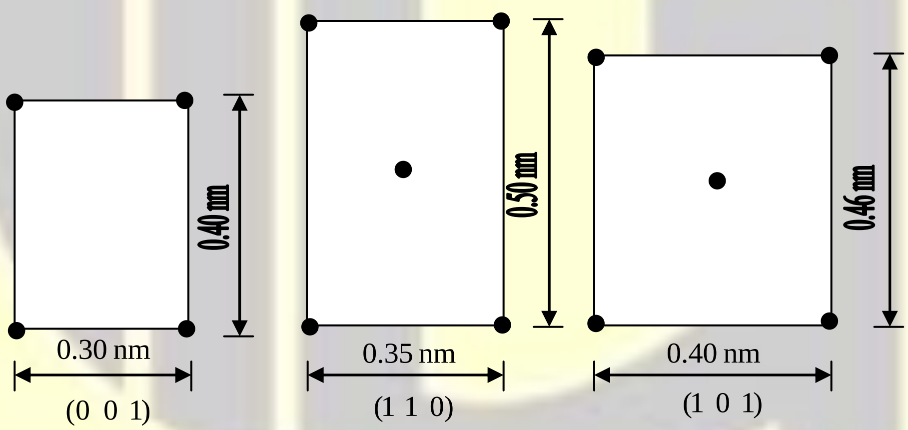
[12 Marks]

(d) Find the Thevenin equivalent circuit for the network shown below. Also, find the current through the load resistor of 10 ohms, if connected across the terminal a-b of the Thevenin equivalent circuit:



[12 Marks]

(e) The following figures shows three different crystallographic planes for a unit cell of a hypothetical material. For each plane, the circles represent only those atoms contained within the unit cell, where circles are reduced from their actual diameter/size. Identify the unit cell and the crystal system it belongs to:

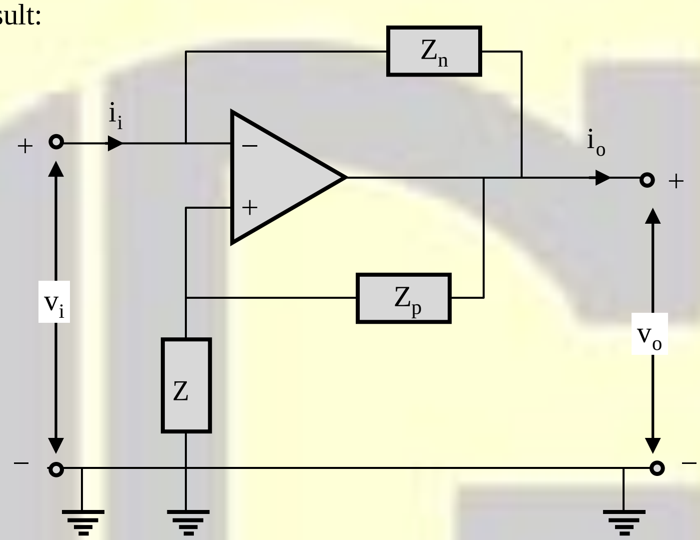


[12 Marks]

2. **(a)** **(i)** Why are boron and phosphorus almost universally employed for p-type and n-type impurities in silicon?

(ii) The diffusion coefficients for copper in aluminum at 500°C and 600°C are $4.8\times10^{-14}\,m^2/s$ and $5.3\times10^{-3}\,m^2/s$, respectively. Determine the approximate time at 500°C that will produce the same diffusion result as a 10-hour heat treatment at 600°C.

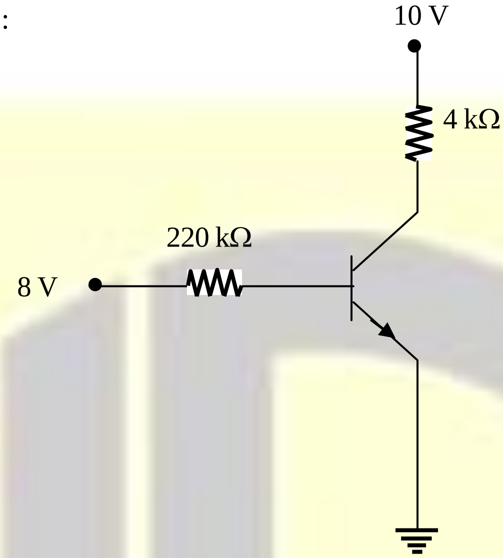
(iii) Find the driving-point impedance to the right of the input terminals of the given circuit. Comment on the result:



[10 + 5 +5 Marks]

(b) **(i)** Derive the Fermi level position in an intrinsic semiconductor in terms of E_c, E_v and effective masses of electron $\left(m_n^*\right)$ and hole $\left(m_p^*\right)$. Hence, calculate the position of the intrinsic Fermi level with respect to the centre of the band gap in silicon at T = 300 K. Given that $m_n^* = 1.08\,m_0$ and $m_p^* = 0.56\,m_0$. Here, m_0 is rest mass of the electron.

(ii) Calculate the currents and voltages in the circuit given below. Also, calculate the power dissipated in the transistor. The transistor parameters are $\beta = 100, V_{BE(ON)} = 0.7V$, $V_{CE(sat)} = 0.2\ V$:



[10 + 10 Marks]

(c) **(i)** Predict the crystal structure and compute the theoretical density for FeO.

Given

Ionic radius of $Fe^{++} = 0.077$ nm

Ionic radius of $O^{--} = 0.140$ nm

Atomic weight of Fe = 55.845 g/mole

Avogadro's number = $6.022 \times 10^{23} / \text{mole}$

(ii) How are ceramic products fabricated? Explain the role of powder pressing and sintering in the fabrication of ceramic products.

[10 + 10 Marks]

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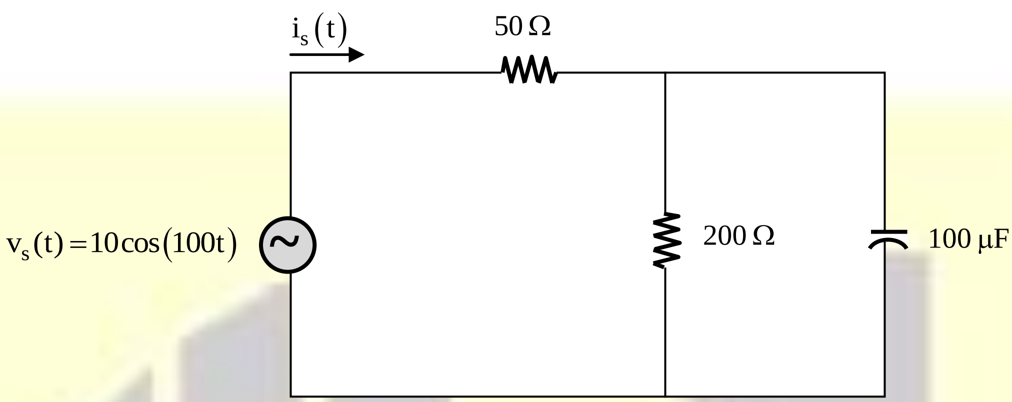
3. **(a)** **(i)** Determine the source current $i_s(t)$ for the circuit shown in the figure using phasor analysis method:



(ii) A customer's plant has two parallel loads connected to the power utility's distribution lines. The first load consists of 50 kW of heating and is resistive. The second load is a set of motors that operate at 0.86 lagging power factor. The motor's load is 100 kVA. Power is supplied to the plant at 10000 volts r.m.s. Determine the total current flowing from the utility's lines into the plant and the plant's overall power factor.

[10 + 10 Marks]

(b) **(i)** Draw the power flow diagrams of a DC generator and a DC motor.

(ii) A 250 Vshunt motor on no load runs at 1000 r.pm. and takes 5A. The total armature and shunt field resistances are respectively $0.2\,\Omega$ and $250\,\Omega$. Calculate the speed when loaded and taking a current of 50A, if the armature reaction weakens the field by 3%.

[10 + 10 Marks]

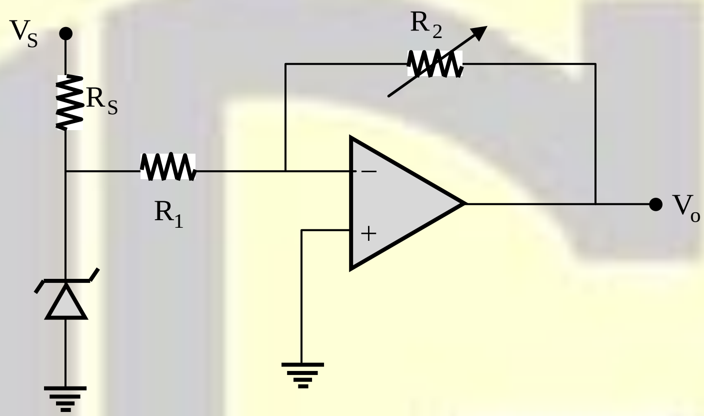
(c) **(i)** Derive an expression for electrical conductivity of an intrinsic semiconductor and compute the room temperature intrinsic carrier concentration for gallium arsenide. [Given, the room temperature electrical conductivity for gallium arsenide is $3\times10^{-7}(\Omega m)^{-1}$. The electron and hole mobilities are $0.80\,m^2/V\text{-s}$ and $0.04\,m^2/V\text{-s}$, respectively]

(ii) Discuss Matthiessen's rule and explain the influence of the factors affecting resistivity of metals.

[10 + 10 Marks]

4. **(a)** **(i)** The recombination process in an LED at 300 K is dominated by bulk radiative, SRH and auger processes. The mean lifetime of carriers due to radiative, SRH and auger processes are 5 ns, 10 ns and 25 ns, respectively. Estimate the quantum efficiency of the LED in absence of surface recombination. What is the bandwidth of this LED?

(ii) Find the maximum allowed voltage of V_S in the given adjustable output voltage regulator circuit. The Zener diode specifications limit the maximum current through Zener diode to $I_{Z_{max}}$:



[10 + 10 Marks]

(b) **(i)** State the applications of synchronous motors. Compare synchronous motor with induction motor.

(ii) Compare with neat sketches squirrel-cage and slip-ring three-phase induction motor with reference to construction, performance and applications.

[10 + 10 Marks]

(c) **(i)** What is magnetic anisotropy? Explain the importance of magnetic anisotropy in transformer cores.

(ii) What are the different synthesis strategies for producing nanoparticles? Classify them on the basis of physical methods, chemical synthesis and mechanical processes.

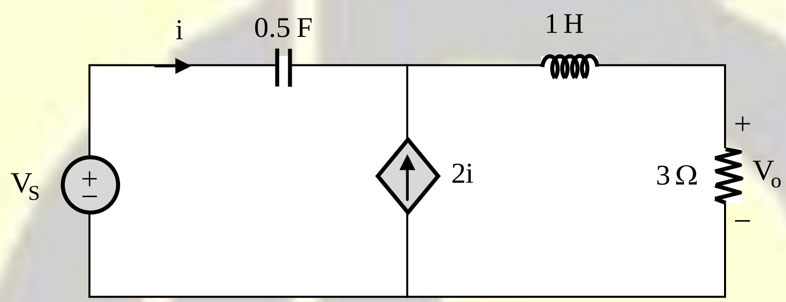
[10 + 10 Marks]

SECTION-B

5. **(a)** Draw the block diagram of digital data acquisition system and explain the essential function of each block and component.

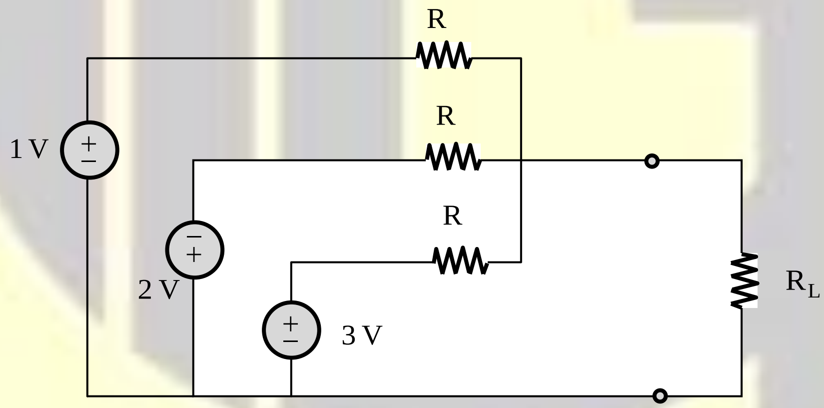
[12 Marks]

(b) Obtain the transfer function $H(s)=\frac{V_o}{V_S}$ for the circuit given below:



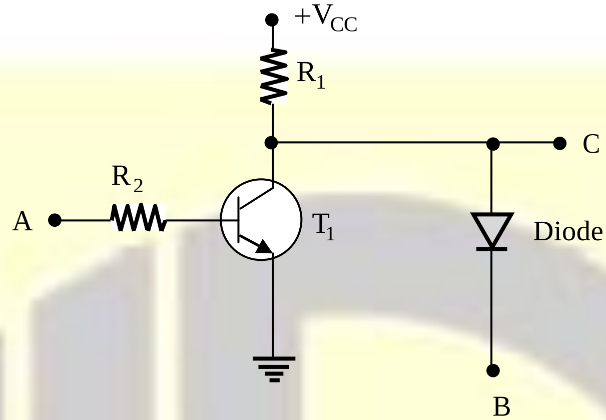
[12 Marks]

(c) For the given circuit, find the value of R, if the maximum power delivered to the load is 3 mW:



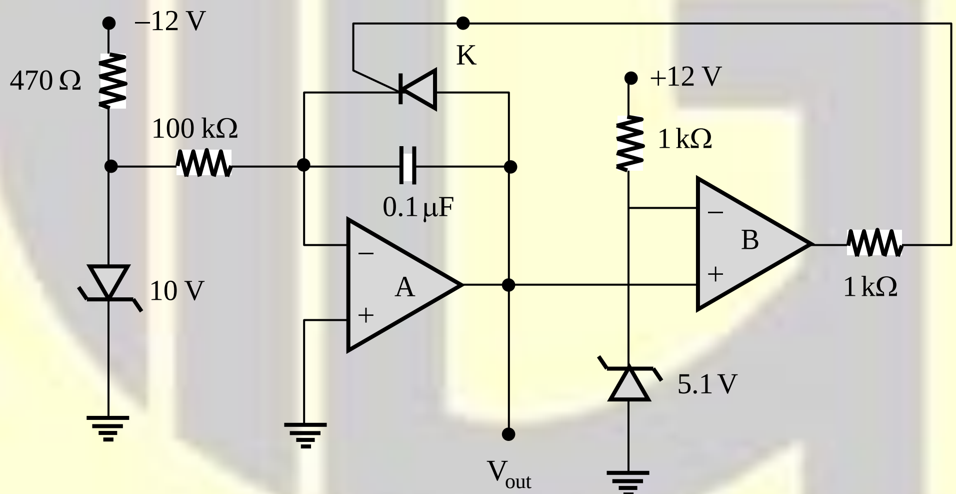
[12 Marks]

(d) The transistor T_1 has negligible collector-to-emitter saturation voltage as shown in the figure below. Also, the diode drops negligible voltage when conducting. If the power supply is +5V, A and B are digital signals with V_{CC} as logic 1 and 0V as logic 0, find the Boolean expression for output C:



[12 Marks]

(e) Explain the operation of the circuit shown below. Include a description of its output waveform, including its amplitude and period:



The device which is connected in parallel to the capacitor can be considered a controlled diode which conducts in one direction only, when triggered by a positive trigger at the control input K, and stops conducting when a negative trigger is applied or if the forward bias to it is removed, similar to an SCR.

Assume that the capacitor is uncharged initially.

[12 Marks]

6. **(a)** **(i)** Define noise. Explain with examples the generated noise, conducted noise and radiated noise. Describe the techniques used for reducing the magnitude of the above-mentioned categories of noise.

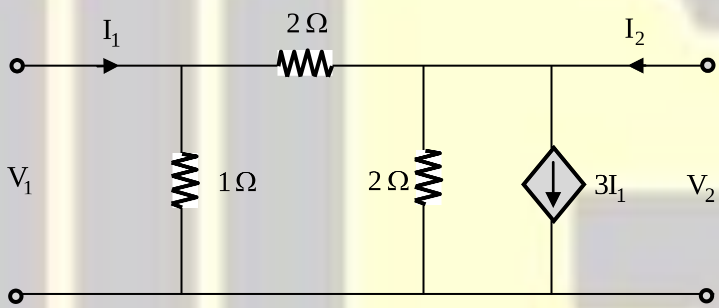
(ii) An amplifier whose bandwidth is 100 kHz has a noise power spectrum density input of 7×10^{-21}J. If the input resistance is $50\,\text{k}\Omega$ and the amplifier gain is 100, what is the noise output voltage?

[10 + 10 Marks]

(b) Describe in brief the different methods used for measurement of medium resistances.

[20 Marks]

(c) Find the Z parameters of the network given below:

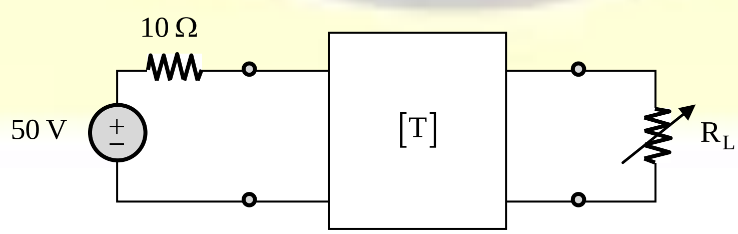


[20 Marks]

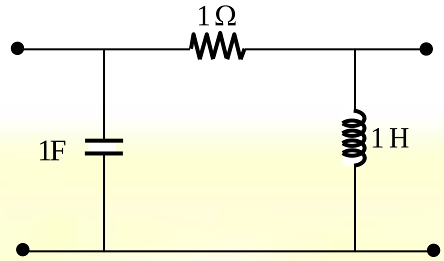
7. **(a)** **(i)** The ABCD parameters of the two-port network in the given figure are

$$\begin{bmatrix} 4 & 20\,\Omega \\ 0.1\,\text{S} & 2 \end{bmatrix}$$

The output port is connected to a variable load for maximum power transfer. Find R_L and the maximum power transferred.



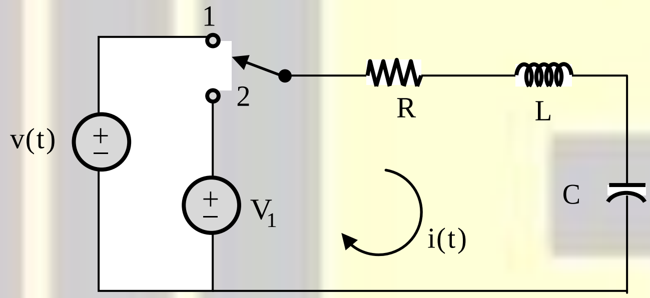
(ii) Find the T network equivalent to the π network given in the figure in s-domain using Laplace transform:



Find the element values for s = j1.

[15 + 5 Marks]

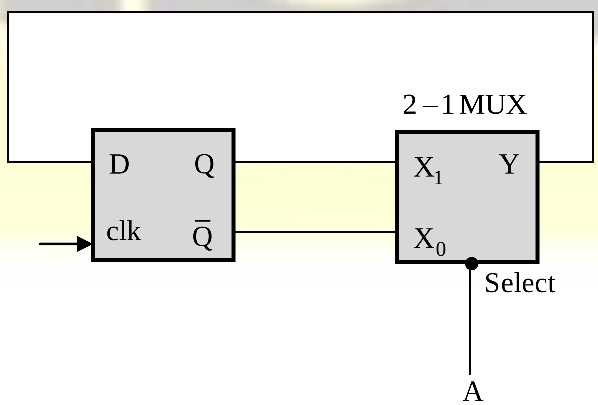
(b) The switch is moved from position 1 to 2 at t = 0 in the following circuit. The initial conditions are specified as $i_L(0_+) = 2A$, $v_C(0_+) = 2V$. Find the current i(t) for t > 0, assuming L = 1 H, $R = 3\,\Omega$, $C = 0.5\,F$ and $V_1 = 5V$. Use Laplace transform method:



[20 Marks]

(c) **(i)** Derive the expressions for the current gain g and the input impedance Z_{in} for a common-collector amplifier. Show the all necessary steps, starting with the circuit diagram (equivalent circuit model) for the derivation.

(ii) Draw the state transition diagram for the logic circuit shown below:



[10 + 10 Marks]

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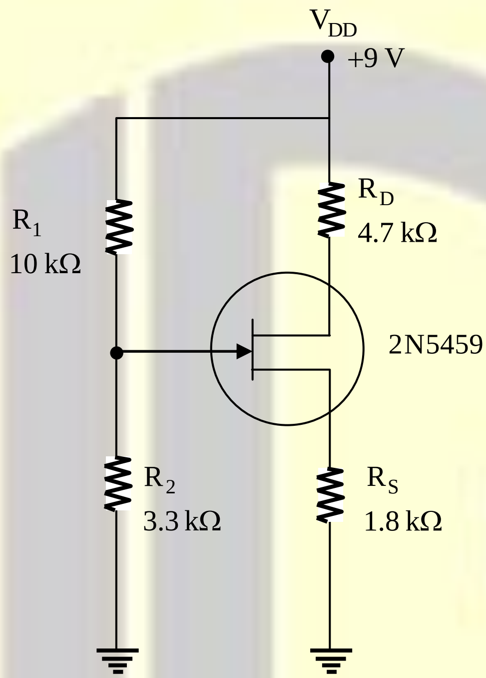
8. **(a)** **(i)** An analog switch uses an n-channel MOSFET with $V_{GS(th)} = 4V$. A voltage of +8V is applied to the gate. Determine the maximum peak-to-peak input signal that can be applied, if the drain-to-source voltage drop is neglected.

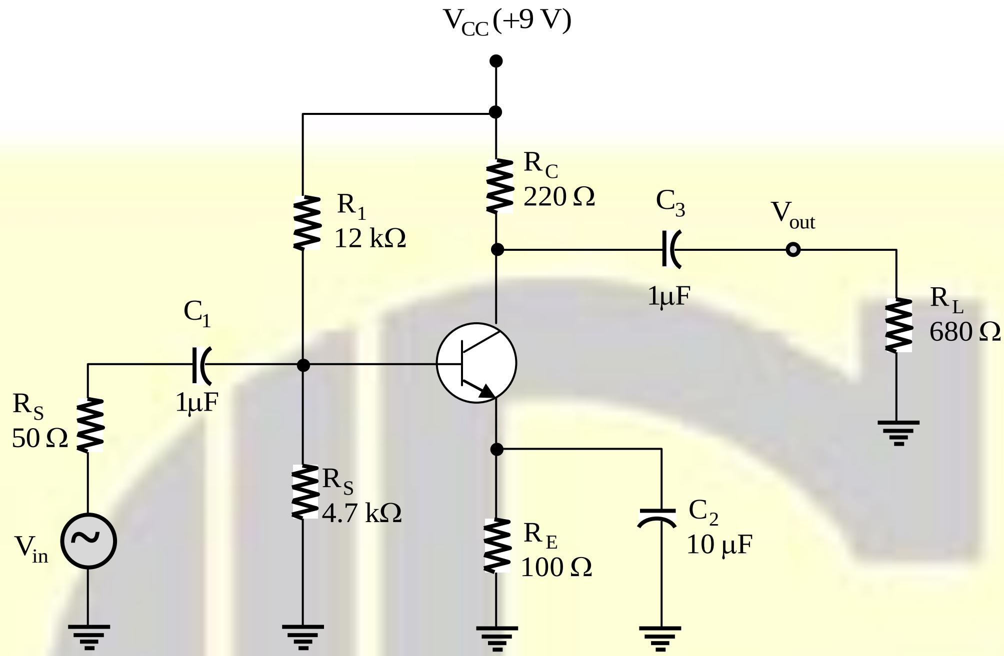
Also determine the minimum frequency of the pulses applied to the MOSFET gate, if this switch is used to sample a signal with a maximum frequency of 15 kHz.

(ii) Determine the maximum I_D and V_{GS} for the circuit given below:



[10 +10 Marks]

(b) Determine the lower cut-off frequency of the amplifier shown in the figure:



Given, $\beta_{dc} = \beta_{ac} = 125, C_{be} = 25\text{ pF and } C_{bc} = 10\text{ pF}$.

Thus, also calculate the voltage gain A_V at lower cut-off frequency.

[12 Marks]

(c) **(i)** Derive the expressions for stress in an element subjected to biaxial stress.

(ii) A simple tension member having an area of 100 mm^2 is subjected to a load of 3000 kg. Strain of 1520 and –544 microstrain are measured in the axial and transverse directions, respectively. Determine the value of Young's modulus and Poisson's ratio.

[10 + 10 Marks]
