Engineering Services (Main)
Examination, 2026

वियोज्य *DETACHABLE*

ELECTRICAL ENGINEERING
Paper I

Time Allowed : Three Hours	Maximum Marks : 300

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions 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, **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 notations have 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 or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.

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

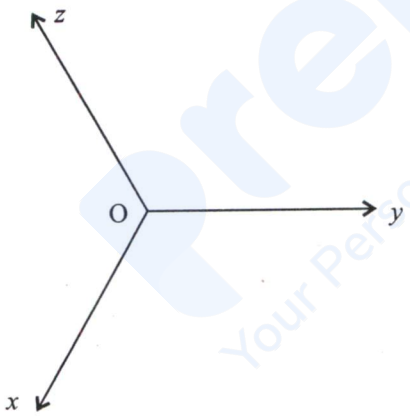
SECTION 'A'

1.(a) (i) Let A be an $n \times n$ invertible matrix and λ be an eigenvalue of A. Show that $\lambda^{-1}|A|$ is an eigenvalue of Adj(A), where $|A|$ denotes the determinant of A and Adj(A) denotes the adjoint matrix of A.

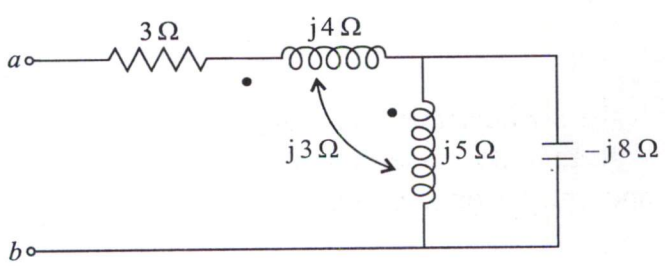
(ii) Let A and B be two 4×4 matrices such that the three eigenvalues of AB-BA are -1, 1 and 2. Then find determinants of AB-BA and Adj(AB-BA). 6+6=12

1.(b)(i) A material has a linear absorption coefficient of $5{\cdot}91 \times 10^4$ m^{-1} for photons of a particular wavelength. Determine the thickness of the material required to absorb 99·9% of the photons. 6

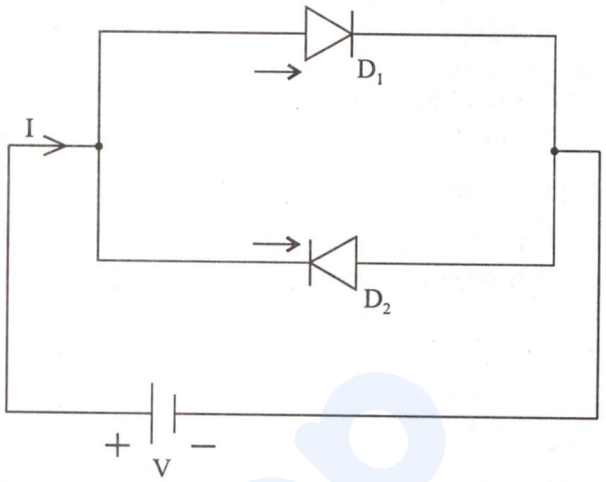
1.(b)(ii) Draw an orthorhombic unit cell and within that cell a [1 2 $\bar{1}$] direction. Take the coordinate system as shown below, with origin point as O. 6



1.(c) For the coupled circuit shown in figure, find the input impedance at terminals ab. 12



1.(d) (i) Two diodes D_1 and D_2 are connected as shown. Assuming that the two diodes are identical and are made of Germanium, determine the expression for I-V relation of the circuit. 6



(ii) A depletion, N-channel MOSFET has two points on its $I_D - V_{GS}$ Curve :

$V_{GS} = 0$ at $I_D = 12$ mA, and
$V_{GS} = -6V$ at $I_D = 0$.

Determine the value of V_{GS} at the point which will provide highest trans-conductance gain for small signals. 6

1.(e) A single phase 230 V, energy meter has a constant of 600 revolutions per kWh. The meter is correctly adjusted.

(i) Determine the disc speed in RPM for a current of 4·85 A at 0·9 lagging power factor.

(ii) If the lag adjustment is changed so that the voltage flux is leading the applied voltage at 84°, determine the error introduced at a power factor of 0·6 lagging and unity. Comment on the results. 12

2.(a)(i) A parallel plate capacitive transducer uses plates of area 600 mm^2 which are separated by a distance 0·3 mm. Calculate the value of capacitance when the dielectric is air.

(A) Calculate the change in capacitance if a linear displacement reduces the distance between the plates to 0·2 mm. Also calculate the ratio of per unit change of capacitance to per unit change of displacement.

(B) Suppose a mica sheet 0·01 mm thick is inserted in the gap. Calculate the value of capacitance now when the distance between the plates is 0·3 mm and change in capacitance when the linear displacement of the plates reduces the distance to 0·2 mm. Also calculate the ratio of per unit change in capacitance to per unit change in displacement. The dielectric constant of mica is 8. 12

2.(a)(ii) A piezo-electric transducer has a capacitance of 1200 pF and a charge sensitivity of 50×10^{-3} c/m. The connecting cable has a capacitance of 200 pF while the oscilloscope used for readout has a readout input impedance of 1 MΩ with a parallel capacitance of 50 pF.

(A) What is the sensitivity (V/m) of the transducer alone ?

(B) What is the high frequency sensitivity (V/m) of the entire measuring system ?

(C) What is the lowest frequency that can be measured with 5 per cent amplitude error by the entire system ? 8

2.(b)(i) A peripheral device transmits data packets of 1024 bytes each. Each byte is represented in ASCII and the system uses 7-bit Hamming Code for error detection and correction.

Compute :

(A) the total number of bits required to transmit one packet with Hamming Code applied.

(B) if the transmission line has a bit error rate (BER) of 1×10^{-6}, estimate the probability that a packet arrives with at least one error and

(C) Discuss how the choice of Hamming code impacts latency *Vs* reliability in this system. 10

2.(b)(ii) A system uses segmentation with paging.

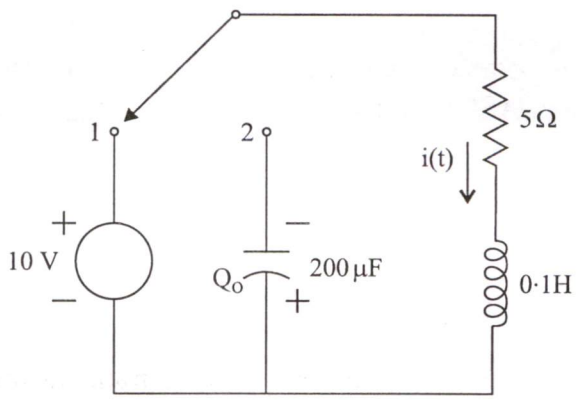
Virtual address	=	32 bits
Segmentation	:	8 segments per process
Each segment max size	=	4 MB
Page size	=	4 kB

(A) Break down the virtual address into segment number, page number and offset.

(B) Calculate the number of bits required for each field and

(C) If a process uses 3 segments (sizes : 2 MB, 1 MB and 512 kB), compute the total number of pages allocated. 10

2.(c) In the series RLC circuit shown in figure, the capacitor has an initial charge $Q_0 = 1$ mC and the switch is in position 1 long enough to establish the steady state. Find the transient current which results when the switch is moved from position 1 to 2 at $t = 0$. 20



3.(a) (i) Show that two similar matrices have the same characteristic polynomial.

(ii) Let E and F be two independent events. Show that E^C (complement of E) and F^C (complement of F) are also independent.

(iii) Let X be a random variable of continuous type with the probability density function (p.d.f.)

$$f(x)=\begin{cases} x & 0 \leq x < 1 \\ \frac{1}{2} & 1 \leq x < 2 \\ 0 & \text{Otherwise} \end{cases}$$

Find the cumulative distribution function (c.d.f.) of X and $P(1 \leq X < 2)$.

6+6+8=20

3.(b)(i) For a Ceramic compound, mention the two characteristics of the component ions that determine the crystal structure. Further, demonstrate that the minimum cation-to-anion radius ratio for a coordination number of 8 is 0·732. Assume a cubic unit cell. Show the various steps along with the schematic diagram. 10

3.(b)(ii) Explain with the help of diagrams how the electron structure of an isolated atom differs from that of a solid material. 5

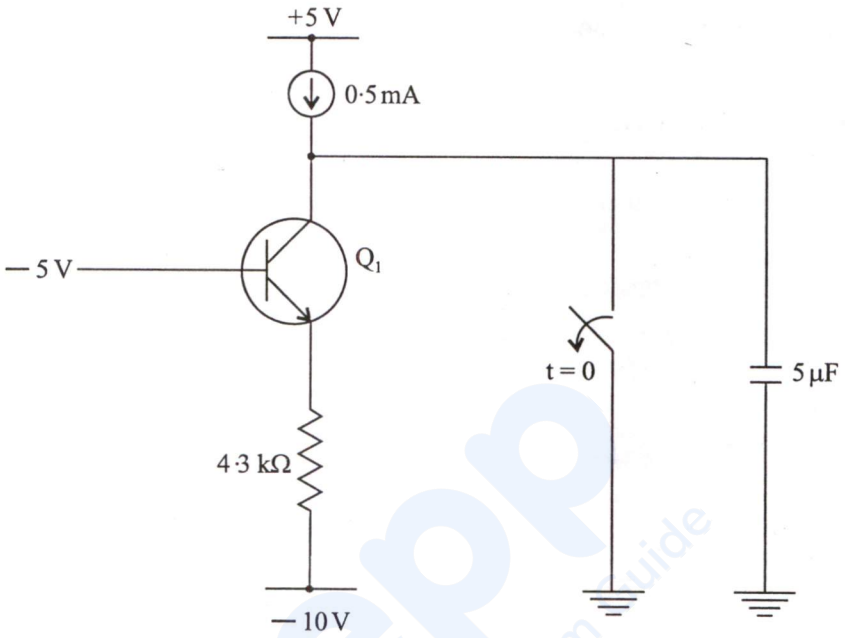
3.(b)(iii) What is Fermi level ? Compare the position of Fermi level in metals, semiconductors and insulators with the help of energy band diagrams. 5

3.(c)(i) For a MOSFET with threshold voltage of 400 mV and working in saturation, the gate-to-source voltage (V_{GS}) is 900 mV, and the drain current is 1 mA.

When the V_{GS} is changed to 1400 mV, and assuming that the MOSFET is operating at saturation and neglecting any channel width modulation effect, determine the drain current. 10

3.(c)(ii) A capacitor is connected at the output of a BJT circuit with a switch, as shown. The BJT (Q_1) has $\beta = \infty$, $V_{BE_{on}} = 0{\cdot}7$ V, $V_{CE_{(sat)}} = 0{\cdot}7$ V.

The switch, initially closed, is opened at time $t = 0$. Find the time t_1 at which Q_1 leaves the active region. 10



4.(a)(i) What is a voltage ratio box ? Explain its construction and working. 8

4.(a)(ii) Describe with the help of suitable diagrams, how a DC potentiometer can be used for

(A) Calibration of a voltmeter

(B) Calibration of an ammeter. 12

4.(b)(i) A 10 Gbps link with Round Trip Time (RTT) = 45 ms, Maximum Transfer Unit (MTU) = 1500 bytes. Using Transmission Control Protocol (TCP) sliding window with window size = 256 kB, sender must transfer a 6 GB file.

Compute :

(A) Bandwidth-Delay Product (BDP)

(B) Max throughput based on window

(C) Transfer time and

(D) Required window to saturate 10 Gbps. 10

4.(b)(ii) A server has 16 cores and schedules as follows :

Batch jobs : 40 jobs @ 2×10^9 instructions each
Time slice : 5 ms
Context switch : 15 µs
CPU = 3 GHz, issue = 2 IPC.
All jobs run CPU-bound.

Find :

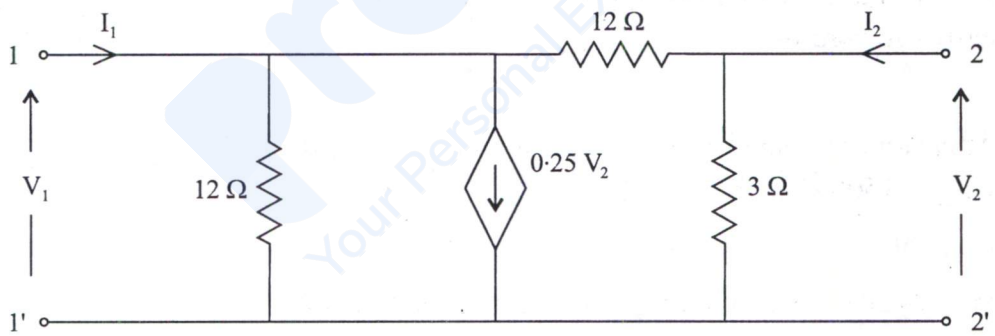
(A) Execution time per job

(B) Switch overhead fraction

(C) Total time to complete all 40 jobs

(D) CPU utilization 10

4.(c)(i) Find the hybrid parameters of the circuit shown in figure. 10



4.(c)(ii) Design a T and TT section constant-K high pass filter having cut-off frequency of 15 kHz and nominal impedance $R_o = 600\ \Omega$.

Also find

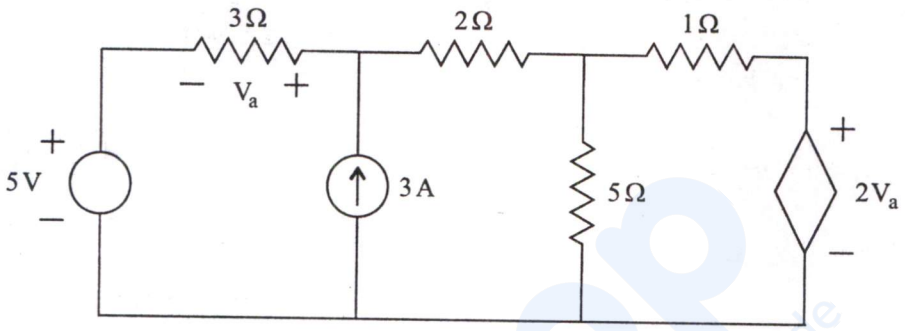
(A) its characteristic impedance and phase constant at 25 kHz and

(B) attenuation at 5 kHz. 10

SECTION 'B'

5.(a) Two point charges $-5\ \mu C$ and $6\ \mu C$ are located at (3, –1, 4) and (0, 4, –2) respectively. Find the potential at (1, 0, 1), assuming zero potential at infinity. 12

5.(b) Find V_a using superposition theorem in the circuit shown in figure. 12

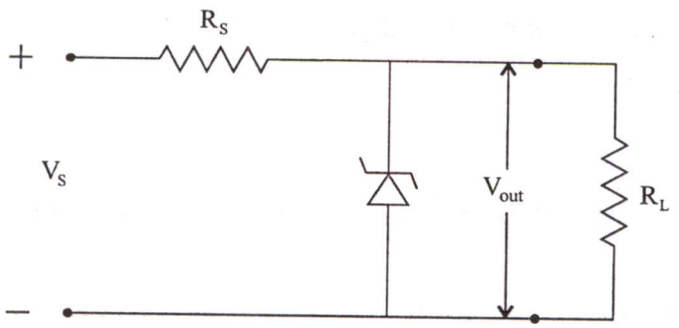


5.(c)(i) A zener diode with a breakdown voltage of 100 V is used as a voltage regulator as shown in figure.

Determine the range of load resistances over which the circuit gives a constant V_{out} if $R_s = 1500\ \Omega$ and $V_s = 150$ V.

Assume that the maximum rated current is 100 mA.

Further, if R_L is fixed at 10 kΩ, over what range of input voltages does the circuit regulate ? 6



5.(c)(ii) The bandwidth of a single-stage amplifier extends from 10Hz to 100 kHz. Determine the lower cut-off frequency where the voltage gain is down by 1 dB from its mid-band value. 6

5.(d) (i) For which pairs of values (a, b), the system

$$\begin{aligned} x + y + az &= 1 \\ x + ay + z &= 4 \\ ax + y + z &= b \end{aligned}$$

of linear equations has infinitely many solutions.

(ii) Let $A = \begin{bmatrix} 3 & -2 \\ 1 & 0 \end{bmatrix}$. Find an invertible matrix P and a diagonal matrix D such that $P^{-1}AP = D$. Also, find a matrix B such that $B^2 = A$. 6+6=12

5.(e) A weather station stores hourly temperature readings for 24 hours shown below. Due to interference, readings that exceed $\pm 80°C$ are considered faulty and must be replaced with the average of the nearest non-faulty neighbours. The hourly temperature readings for 24 hours are :

25, 28, 30, 29, 88, 32, 35, 36, 37, 90, 40, 42, 43, 44, 45, 50, 51, 55, 60, 78, –95, 75, 72, 70

Write a C program to

(i) Filter faulty readings and

(ii) Print final corrected readings. 12

6.(a)(i) The circuit for measurement of resistance and self-inductance of an iron cored coil is as follows :

arm ab : unknown impedance
arm bc : a pure resistance R_3
arm cd : a lossless capacitor C_4
arm da : a capacitor C_2 in series with resistance R_2

Under balanced conditions :

$R_3 = 10\ \Omega$, $R_2 = 842\ \Omega$, $C_2 = 0{\cdot}135\ \mu F$ and $C_4 = 1\ \mu F$.

Calculate the value of resistance and self inductance of the coil at a supply frequency of 100 Hz. Also draw the phasor diagram under balanced condition. The supply is connected between points *a* and *c*. 10

6.(a)(ii) Explain why Anderson's bridge is preferred over Maxwell's bridge for precise measurement of inductance, especially at audio frequencies. Discuss the practical limitations of component selection, accuracy considerations and frequency response characteristics of both bridges. 10

6.(b) (i) Find the absolute maximum and the absolute minimum values of the function

$$f(x) = \sin x(1 + \cos x),\ 0 \leq x \leq 2\pi.$$

(ii) Using Residue theorem, evaluate the integral $\oint_c \frac{4-3Z}{Z^2-Z} dZ$ counter clockwise around any simple closed path C such that :

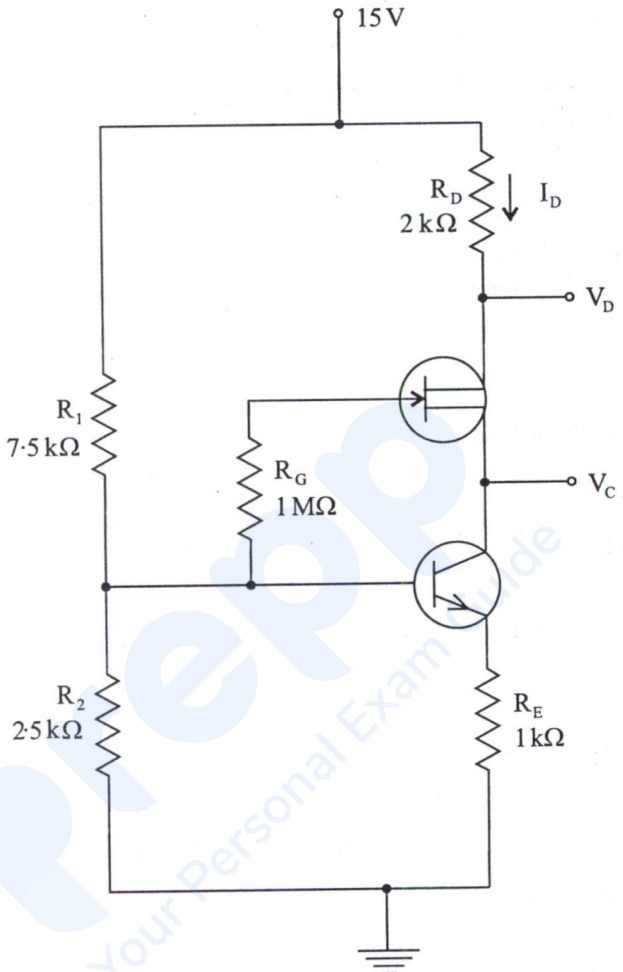
(A) 0 and 1 are inside C
(B) 0 is inside but 1 outside
(C) 1 is inside but 0 outside
(D) 0 and 1 are outside. 10+10=20

6.(c) A Y-connected load $Z_A = 10\angle 0°\ \Omega$, $Z_B = 10\angle 60°\ \Omega$ and $Z_C = 10\angle -60°\ \Omega$ is connected to a three phase, three wire ABC system having RMS value of line voltage 208 V. Considering V_{BC} as reference, obtain

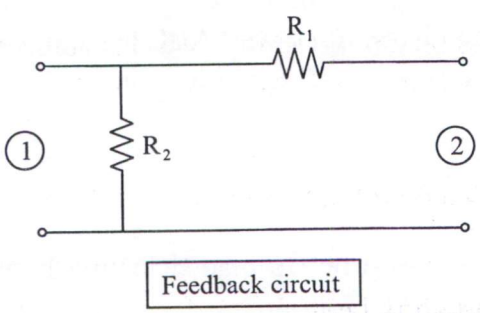
(i) Line currents 14

(ii) The readings of wattmeters placed in line B and C. (Line A is the potential reference for both meters). 6

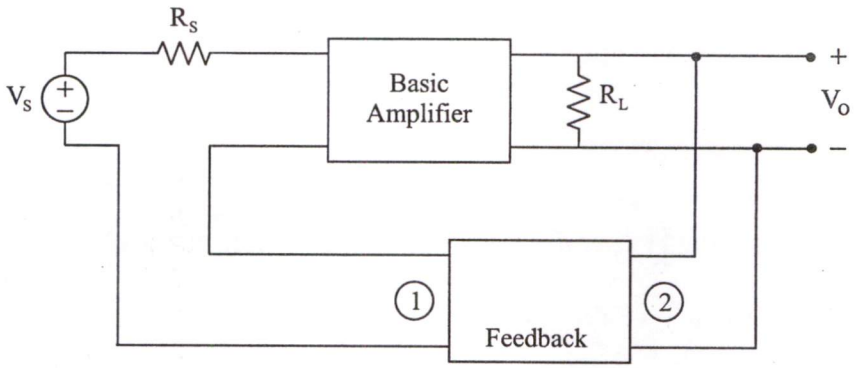
7.(a)(i) For a circuit as shown below, determine the values of voltages V_D and V_C. Assume $\beta = 100$, $V_{BE} = 0{\cdot}7$ V, saturation drain current of JFET is 10 mA and pinch off voltage is –5 V. 10



7.(a)(ii) A series-shunt feedback amplifier utilizes the feedback circuit as shown below :



For reference, the amplifier configuration is as shown below :



Find expressions for the *h*-parameters of the feedback circuit.

If $R_1 = 1\ k\Omega$ and $\beta = 0{\cdot}01$, what are the values of all four *h*-parameters and their units ? 10

7.(b)(i) Derive a relation between the relative permeability and the magnetic susceptibility of a material. 8

7.(b)(ii) What is quantum confinement ? Explain its effect on the electronic properties of nanomaterials. How does reducing size affect the bandgap of semiconductor nanomaterials ? Also, discuss the effect of nanoscale dimensions on electrical conductivity. 12

7.(c) How modern processors exploit Instruction-Level Parallelism (ILP).

(i) Explain with examples how data hazards, control hazards and structural hazards limit ILP.

(ii) Propose architectural solutions for each hazard type and

(iii) Analyze Trade-offs between hardware complexity and performance gains. 20

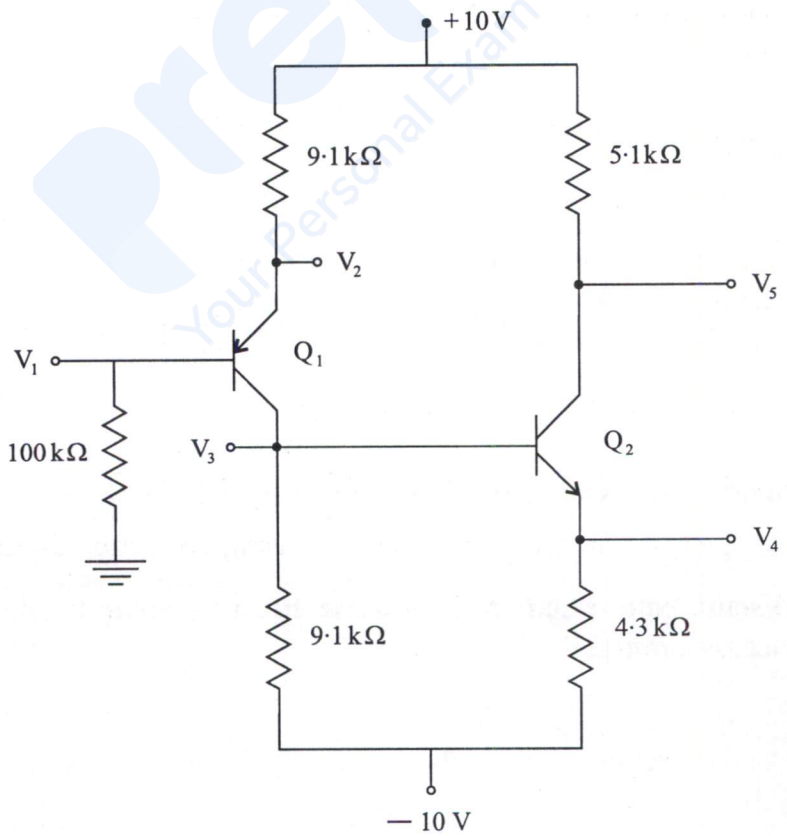
8.(a) (i) Find the Fourier series expansion of the following periodic function with period 2π.

$$f(x) = \begin{cases} \pi & -\pi < x < 0 \\ \pi - x & 0 \leq x < \pi, \end{cases}$$

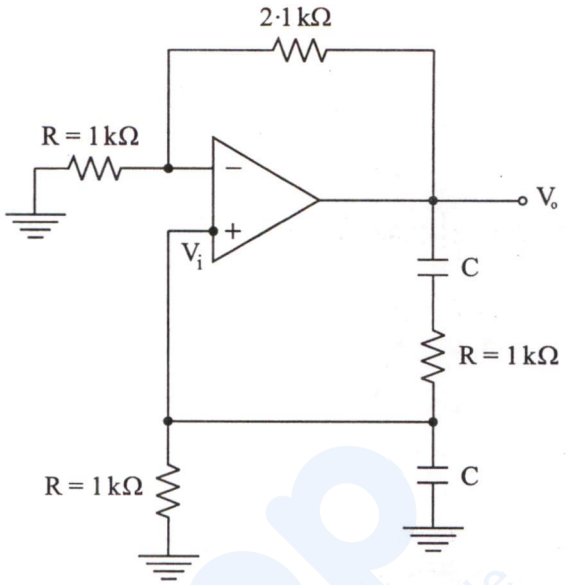
$$f(x + 2\pi) = f(x).$$

(ii) Evaluate $\iint_E y\,dx\,dy$, where E is the region bounded by the line $y = x$ and the parabola $y = 4x - x^2$. 12+8=20

8.(b)(i) For the circuit shown below, find the values of node voltages V_1, V_2, V_3, V_4 and V_5, for $\beta = \infty$ and also for $\beta = 100$. 10



8.(b)(ii) For the sinusoidal oscillator shown in figure, determine the value of C required for oscillations of frequency 1 kHz. 10



8.(c) A 3-phase power system uses instrument transformers for measurement and protection.

A Current Transformer (CT) with ratio 1000 : 5 is connected to measure line current.

A Potential Transformer (PT) with ratio 11 kV/110 V is connected to measure the voltage.

The actual line current is 800 A and the actual line voltage is 6·6 kV.

The CT has a ratio error of +1% and a phase angle error of 20 minutes (lagging). The PT has a ratio error of –0·5% and phase angle error of 10 minutes (leading). The Wattmeter connected to the secondary side reads 350 W.

(i) Compute the true power in the line using correction factors and

(ii) Discuss how ratio and phase angle errors affect accuracy in protective relays and metering.

Assume load power factor as unity. 20