Engineering Services (Main) Examination - 2025

NESP–O–ENTE

ELECTRONICS AND TELECOMMUNICATION 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.

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

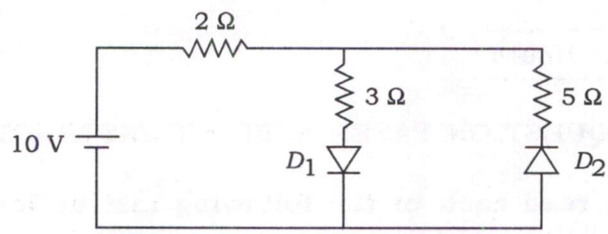
Answers must be written in **ENGLISH** only.

Values of constants which may be required :

Electron charge	=	$-1{\cdot}6\times10^{-19}$ coulomb
Free space permeability	=	$4\pi\times10^{-7}$ henry/m
Free space permittivity	=	$\frac{1}{36\pi}\times10^{-9}$ farad/m
Velocity of light in free space	=	3×10^{8} m/s
Boltzmann's constant	=	$1{\cdot}38\times10^{-23}$ J/K
Planck's constant	=	$6{\cdot}626\times10^{-34}$ J-s
Mass of electron	=	$9{\cdot}1\times10^{-31}$ kg

Section—A

1. *(a)* Find the current flowing in the circuit as given in the figure, where two ideal diodes are connected in parallel :



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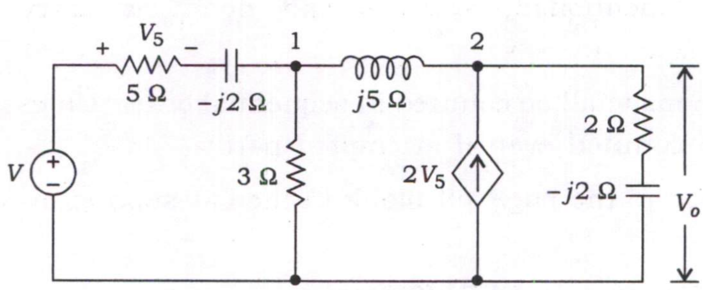
(b) A certain d.c. motor has $R_A = 1{\cdot}3\ \Omega$, $I_A = 10$ A, and produces a back e.m.f. $E_A = 240$ V, while operating at a speed of 1200 r.p.m. Determine the voltage applied to the armature, the developed torque and the developed power. 12

(c) Consider a unit cell of simple cubic structure. Find the angle between the normals to pair of planes whose Miller indices are *(i)* [1 0 1] and [0 1 0], and *(ii)* [2 1 1] and [1 0 1]. 12

(d) For the circuit shown in the figure, calculate the value of the voltage V which gives $V_o = 5\angle 0°$ volts :



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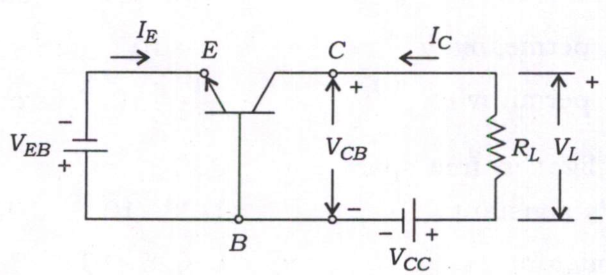
(e) Shown below is an *n-p-n* transistor biased in the active region :



Assume that the emitter is much more heavily doped than the base.

(i) Plot the potential variation across the emitter and collector junction.

(ii) Plot the minority carrier concentration in each section of the transistor.

(iii) Show how this transistor configuration works as an amplifier.

(iv) Plot the collector current against base to emitter voltage for a silicon transistor when it is varied from – 0·4 V to + 0·8 V. Indicate the cutoff, active and saturation regions.

(v) From the transistor characteristics, write the analytical expressions for the collector current and the emitter current.

(vi) Show how these equations are used to replace the *n-p-n* transistor with two back diodes in shunt with two dependent current sources. 12

2. *(a)* *(i)* The magnetic field of the earth is approximately 3×10^{-5} T (tesla). At what distance from a long-distance wire carrying a steady current of 10 A is the field equal to 10 percent of the earth's field? Suggest at least two ways to help reduce the effect of electric circuits on the navigation compass in a boat or an airplane. 12

(ii) A typical deep cycle battery (used for electric trolling motors for fishing boats) is capable of delivering 12·6 V and 10 A for a period of 10 hours. How much charge flows through the battery in this interval? How much energy does the battery deliver? 8

(b) During a laboratory experiment, a student tried to build an inverting amplifier as shown in Fig. (i). The student accidentally reversed the connection of the two input terminals and obtained the circuit of Fig. (ii). The student was greatly surprised that the circuit no longer behaved as expected. Calculate the gain in both the cases and explain the stability of both the circuits. Assume open-loop gain of op-amp as 2×10^5, $R_i = \infty$, $R_o = 0$ and stray capacitance of 1 pF across the input terminals :

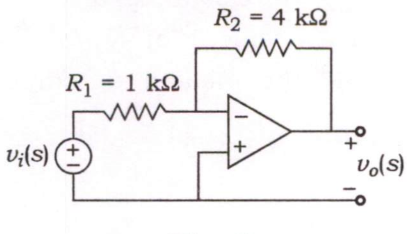


Fig. (i)

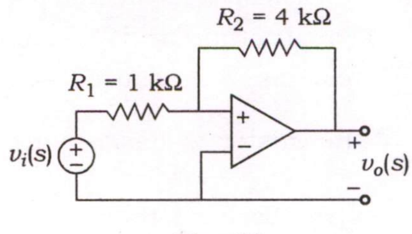


Fig. (ii)

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(c) The state equation of a linear time-invariant system is expressed by

$$\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} [r(t)]$$

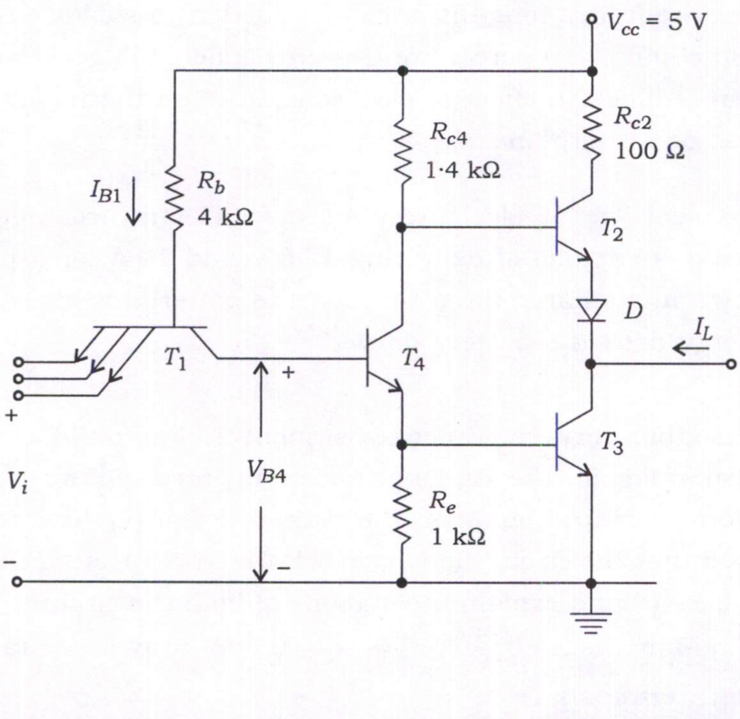
(i) Calculate the state transition matrix.

(ii) Find the state vector $x(t)$ for $t \geq 0$, when $r(t) = u(t)$.

Assume the initial state to be zero. 10+10=20

3. *(a)* Explain the operation of the TTL gate circuit shown below, clearly mentioning the roles of the transistors T_2 and T_4, and the diode D.

Assume that when all the inputs are at logic 1, the transistors T_3 and T_4 are both in saturation :



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(b) *(i)* A thermistor, having $\beta = 3100$ K, has a resistance of 1050 Ω at 20 °C. The thermistor is used for the measurement of temperature and the resistance measured is 2300 Ω. Find the measured temperature if the thermistor is described by the relation $R = R_0 \exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$ where the symbols have their standard meanings. 10

(ii) The following are the data for a Hay's bridge :

$R_1 = 1\ \text{k}\Omega \pm 1$ part in 10 K, $R_2 = 16 \cdot 8\ \text{k}\Omega \pm 1$ part in 10 K,

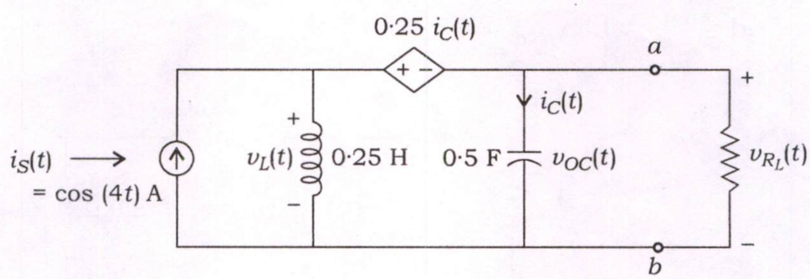
$R_3 = 833 \pm 0 \cdot 25\ \Omega$, $C = 1 \cdot 43 \pm 0 \cdot 001\ \mu\text{F}$

The supply frequency is $50 \pm 0 \cdot 1$ Hz and the bridge's balanced conditions are

$$L = \frac{CR_1R_2}{1+\omega^2C^2R_3^2} \quad \text{and} \quad R = \frac{R_1R_2R_3C^2\omega^2}{1+\omega^2C^2R_3^2}$$

Calculate the values of L and R of the coil, and their limits of error. 10

(c) Find the Thevenin's equivalent of the circuit shown in the figure if $\omega = 4$ rad/s. Also determine the voltage $v_{R_L}(t)$, when a $1 \cdot 2\ \Omega$ load is connected to terminals a–b :



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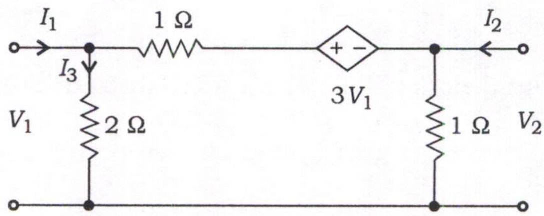
4. (a) Consider that a double-heterojunction LED emitting at a peak wavelength 1400 nm has radiative and non-radiative recombination times of 20 ns and 80 ns respectively. The drive current is 30 mA and the refractive index of the light source material is 3·0. Calculate the power emitted from the device. 20

(b) A spherical nanoparticle has diameter of 10 nm. Determine the surface area to volume ratio and explain how this property affects the behaviour of nanomaterials compared to bulk materials. 20

(c) (i) A CR tube has an anode-screen distance of 30 cm. The accelerating potential is 1 kV. The tube is placed with its axis vertical. Find the maximum deflection of the spot due to the earth's magnetic field having $B = 0 \cdot 018 \times 10^{-3}\ \text{Wb/m}^2$. 10

(ii) Calculate the Y-parameters for the network shown in the figure :



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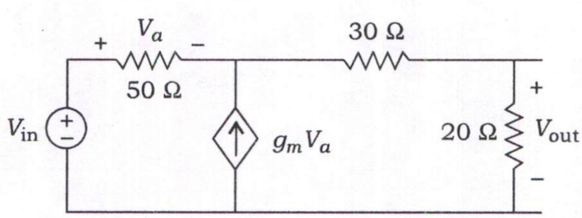
SECTION—B

5. (a) Derive a relation for the value of the capacitor for frequency error compensation of a moving-iron voltmeter in terms of its parameters and the series resistance. 12

(b) For the circuit shown in the figure, find $\frac{V_{out}}{V_{in}}$ in terms of the parameter g_m. Then find $\frac{V_{out}}{V_{in}}$, when $g_m = 2$:



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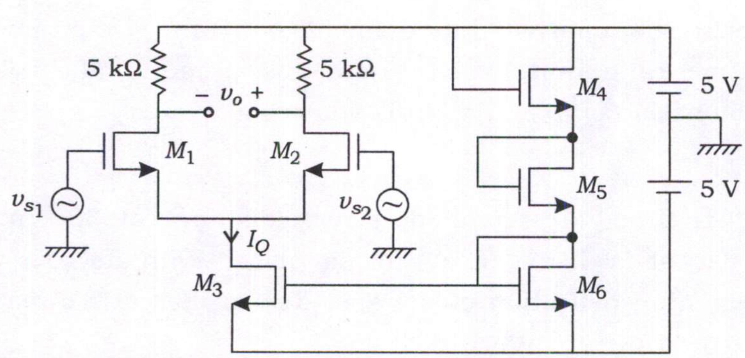
(c) For the circuit shown in the figure, all the MOSFETs are identical. Assume $\mu_n C_{ox} = 0{\cdot}1\ \text{mA/V}^2$, $V_{tn} = 1\ \text{V}$, $\lambda = 0$ and $I_Q = 1\ \text{mA}$. Calculate $\frac{W}{L}$ ratio and voltage gain $A_d = \frac{v_o}{v_{s_1} - v_{s_2}}$:



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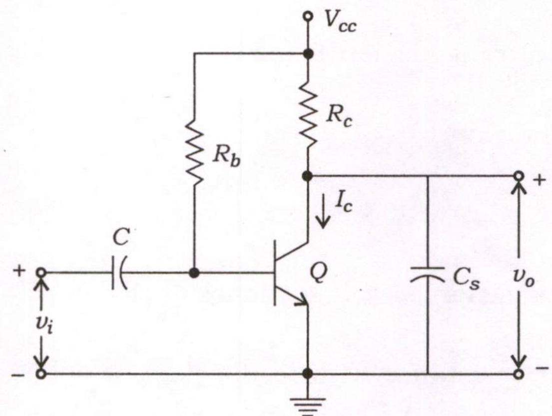
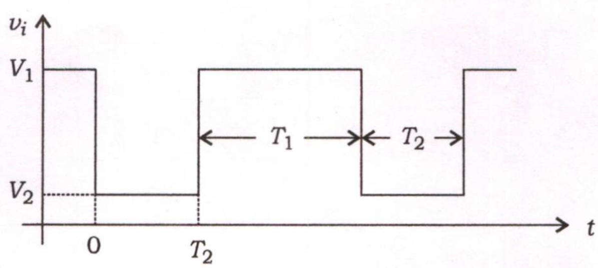
(d) Design a J-K counter for states 1, 2, 4, 5, 7, 8, 10, 11, ... What would happen if the circuit were turned ON and the first state it entered was a don't care state? 12

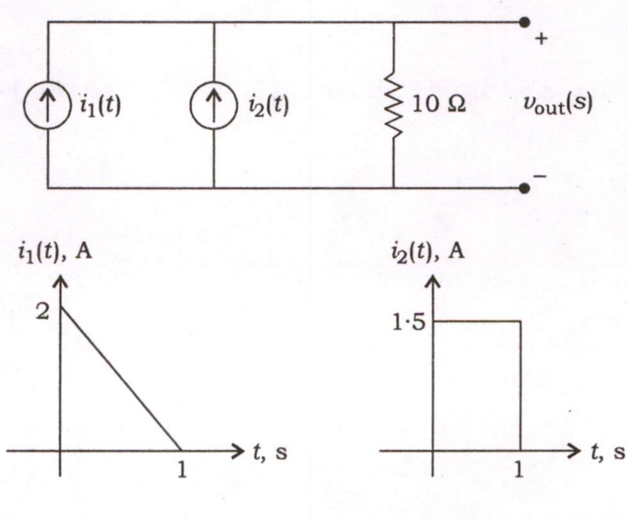
(e) The transistor Q acts as a switch in the given circuit for the applied input v_i that varies with time as shown below :





Plot the variation of the collector current I_c and the output voltage v_o, assuming that the time constants are small compared to T_1 or T_2. 12

6. (a) The circuit of the figure has two sources of excitation $i_1(t)$ and $i_2(t)$. Compute $v_{out}(s)$:



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(b) Consider the circuit given below with the following parameters :

$R_{c_1} = 3$ K, $R_{c_2} = 500\ \Omega$, $R_e = 50\ \Omega$, $R' = R_s = 1 \cdot 2$ K, $h_{fe} = 50$, $h_{ie} = 1 \cdot 1$ K and $h_{re} = h_{oe} = 0$

Analyze the circuit for—

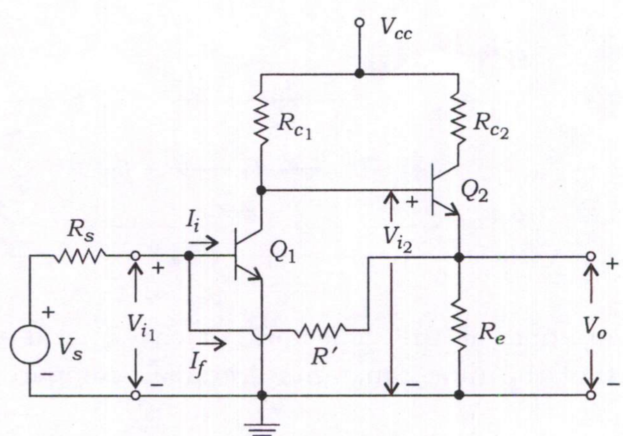
(i) reverse transmission factor, β;

(ii) transfer gain;

(iii) voltage gain with feedback;

(iv) input resistance with feedback;

(v) output resistance with feedback.



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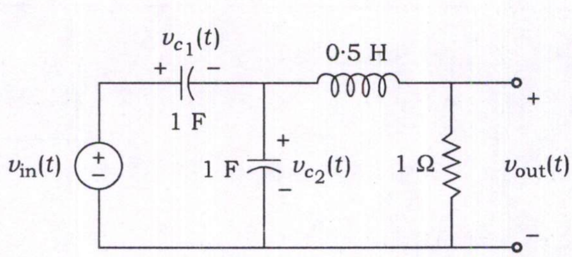
(c) Consider the circuit in which $v_{in}(t) = 5u(t)$ V, $v_{c_1}(0^-) = 3$ V, $v_{c_2}(0^-) = 0$ V and $i_L(0^-) = 2$ A. Find $v_{out}(t)$:



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7\. *(a)* *(i)* A first-order thermometer is used for the measurement of temperature of air cycling at a rate of 1 cycle every 5 minutes. The time constant of the thermometer is 20 seconds. Calculate the attenuation of the indicated temperature in percent. If the temperature undergoes a sinusoidal variation of 20 °C, calculate the indicated variation in temperature. 10

(ii) Compare and contrast Type–I and Type–II superconductors based on the following parameters :

(1) Magnetic field behaviour

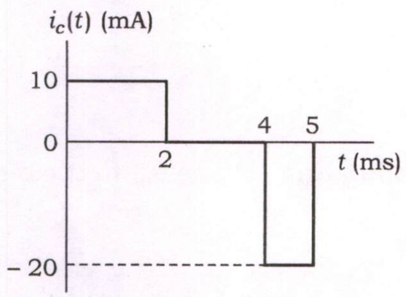
(2) Critical magnetic field

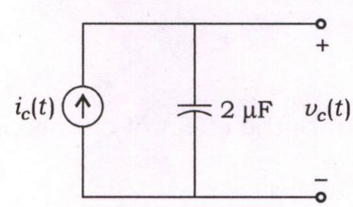
(3) Material examples

(4) Meissner effect

(5) Applications 10

(b) The current through a 2 μF capacitor is shown in the figure. At $t = 0$, the voltage is zero. Sketch the voltage and power waveform with respect to the time (scaled voltage and power) :





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(c) *(i)* A piezoelectric ceramic disc of thickness $t = 2$ mm and area $= 1 \cdot 5 \times 10^{-4}$ m^2 is subjected to a compressive force of $F = 50$ N applied perpendicular to its faces. The material has the following properties :

- Piezoelectric coefficient = 300×10^{-12} C/N
- Relative permittivity = 1200
- Volume permittivity = $8 \cdot 854 \times 10^{-12}$ F/m

Determine the following :

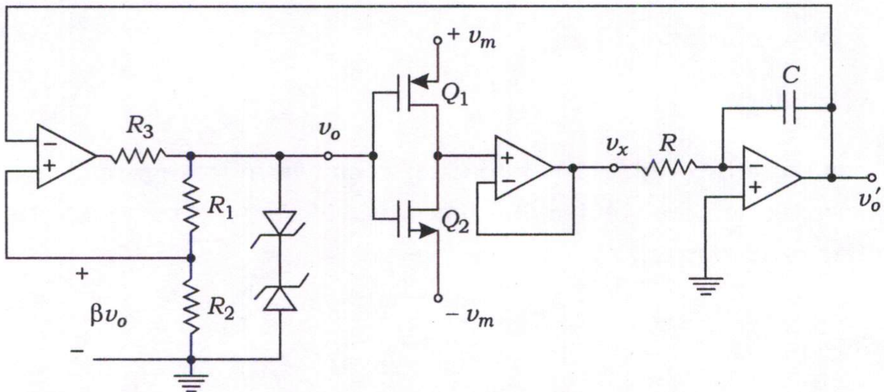
(1) Charge generated on electrodes due to applied force

(2) Capacitance of the piezoelectric disc

(3) Voltage generated across the ceramic disc 10

(ii) For a 2-port network, express Z-parameters in terms of inverse hybrid parameters. 10

8. *(a)* Explain the working of each stage of the voltage-controlled oscillator circuit shown below :

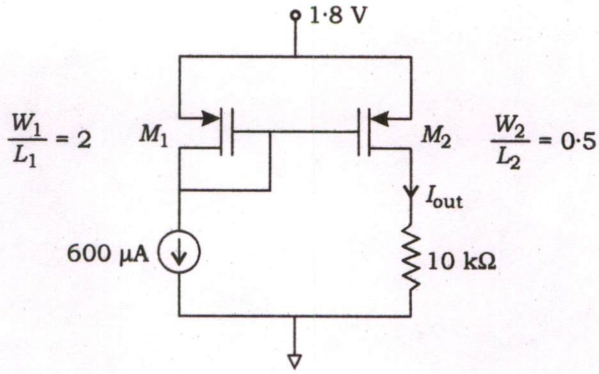


Evaluate the effect of change in modulating voltage v_m to the output frequency. 20

(b) Use a decoder to design a binary-to-hexadecimal character generator. The outputs of the character generator are to be connected via current limiting resistors to a common anode seven-segment display. Assume that the inputs are positive logic signals. 20

(c) *(i)* A voltage $50 + 25 \sin \omega t$ volts is applied to a series R-L circuit having a resistance of $10\ \Omega$ and inductance of 0·1 H. A wattmeter is connected in the circuit to measure power. Calculate the reading of the wattmeter if $\omega = 100\pi$ rad/s. 10

(ii) For the circuit shown in the figure, find I_{out}. Assume $\mu_n C_{ox} = 250\ \mu A/V^2$ and $V_{tn} = 0 \cdot 4$ V for both the MOSFETs :



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