DO NOT WRITE YOUR NAME OR KAUST ID NUMBER ON THIS PAGE OR ANY OTHER PAGE

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YOU ARE ALLOWED TO SUBMIT SOLUTIONS TO ONLY FIVE PROBLEMS

EXAM ID NUMBER:________

COURSE NUMBER: EE 202

PROBLEM: 1

EE 202 Monolothic Amplifier Circuits

Make any reasonable assumptions and/or approximations whenever appropriate.

Question 1: 20 Marks

1) In Fig. 1.1, Vo is equal to [3 marks]

(a) 0 (b) VDD/√4

(c) VDD/4 (d) VTH

2) In Fig. 1.2, given that the transistor is biased such that gm = 10mS, the voltage gain (Av) is approximately equal to [3 marks]

(a) 50 (b) 5

(c) 25 (d) All answers are wrong

3) In Fig. 1.3, the output resistance (Rout) is approximately equal to [4 marks]

(a) roN(1+gmN/gmP) (b) roN(1+gmP/gmN)

(c) roN(1+gmNroP) (d) 2roN

4) For the circuit given in Fig. 3

- Show that the output resistance (Rout) is approximately equal to ro2(gm2ro1)(gm3ro3). [6 marks]
- Find the voltage gain (Av). [4 marks]

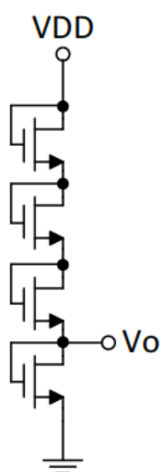

Fig. 1.1

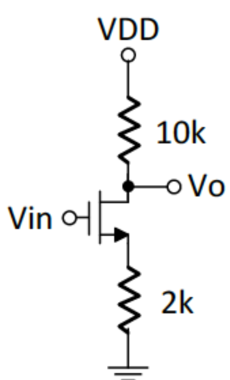

Fig. 1.2

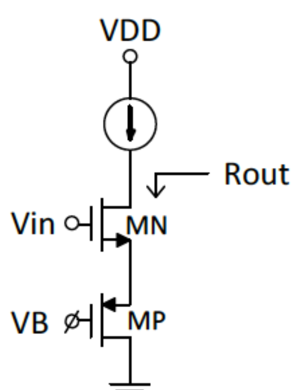

Fig. 1.3

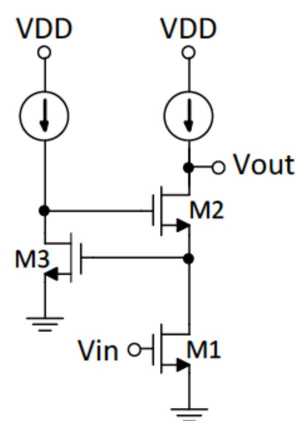

Fig. 3

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EXAM ID NUMBER:_______

COURSE NUMBER: EE 202

PROBLEM: 2

EE 202 Monolothic Amplifier Circuits

Make any reasonable assumptions and/or approximations whenever appropriate.

Question 2: 20 Marks

1) In Fig. 1.4, the product of the amplifier voltage gain (Av) and bandwidth (BW) is independent of [5 marks]

(a) gm (b) RD

(c) CL (d) All answers are wrong

2) In Fig. 1.5, Rout1 (note the arrow direction) is approximately given by [4 marks]

(a) 1/gm1 (b) ro1//(1/gm2)

(b) ro1//ro2 (d) ro1

3) In Fig. 1.5, Rout2 (note the arrow direction) is approximately given by [4 marks]

(a) ro2(gm1.ro1) (b) ro2(gm2.ro1)

(c) ro2 (d) ro2(gm2/gm1)

4) For the circuit given in Fig. 2:

- Find the output resistance (Rout). [4 marks]
- Find the voltage gain (Av). [3 marks]

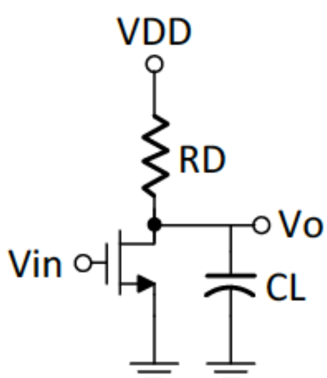

Fig. 1.4

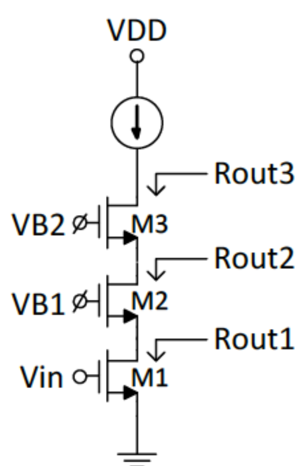

Fig. 1.5

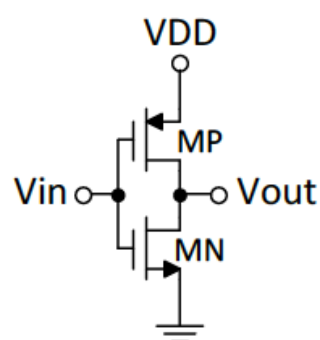

Fig. 2

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EXAM ID NUMBER:________

COURSE NUMBER: EE 203

PROBLEM: 1

EE 203: Solid State Device Laboratory

1. An ion implanter with an accelerating voltage of 50 kV is used to implant the following ions into Si to an ion dose of 10^{15} ions/cm^2:

(1) B^+; (2) B^{2+}; (3) B_2^+.

(a) Calculate the **velocities** of these ions if they are accelerated through the 50 kV potential in the ion implanter and to estimate the **vertical straggles, ΔR_P**, and **maximum concentrations, N_P**, of the boron profile in each case using the full Gaussian approximation. [3 types of species × 3 parameters × 2 points = 18 points]

(b) If the Si substrate is n-type doped with a background concentration of 10^{16}/cm^3, explain qualitatively which ion above will give the deepest junction depth. [2 points]

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COURSE NUMBER: EE 203

PROBLEM: 2

2. You are doing the step of poly-silicon gate lithography and etching in the lab. The poly-silicon is 350 nm with a variation of ±10% across the wafer and the etch rate of poly-silicon in Si etchant also has a ±10% variation.

a) How much over-etch in percentage of etch time is required to ensure all poly-silicon on the wafer is removed? [4 points]

b) The mask has four NMOS devices with varying gate lengths, 4 µm, 6 µm, 8 µm and 10 µm. Assume that there is no patterning error during the lithography, i.e., the photoresist patterns have exactly the same sizes as the drawings on the mask. Calculate the worst-case shortest gate lengths on the wafer obtained after the over-etch calculated in a) for each of the four devices. (Assume that Si etchant does not etch the underlying thin oxide.) [4 devices × 4 points = 16 points]

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EXAM ID NUMBER:________

COURSE NUMBER: EE 208

PROBLEM: 1

Q1:

This question is regarding **edge emitting** InGaN/GaN LED that emits at 450nm. The power-current characteristics of the LED can be expressed as:

$P_{act}=h\upsilon(J/qd)\beta_{sp}\tau_n[p_o+n_o+(\tau_n J/qd)]$.

a. Using the equation above, show that: (i) under low injection, the emission power (P_{act}) is directly proportional to the injection current density (J), and (ii) under high injection, P_{act} is direct proportional to J^2.

[4 points]

b. Sketch the light-current (L-I) curve of the LED under high and low injection.

[2 points]

c. Identify the (i) spontaneous emission and (ii) amplified spontaneous emission (ASE) regions on the L-I curve.

[2 points]

d. Compared to the low injection, would you expect to see blue or red-shift in peak emission wavelength if the device is operated under high current injection. Why?

[2 points]

e. Suggest methods to increase the emission power of the LED.

[2 points]

f. Comparing the 450nm InGaN/GaN with a 1550nm InGaAs/InP-based LED, would you expect to see:
   i. larger or smaller threshold voltage. Why?
   ii. differential resistance. Why?
   iii. withstand a higher or lower injection power. Why?
   iv. being able to operate at higher or lower temperature from a GaN-based LED? Why?

[5 points]

g. Discuss the advantages and disadvantages of surface emitting vs. edge-emitting LEDs.

[3 points]

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COURSE NUMBER: EE 208

PROBLEM: 2

Q2:

This question is about the edge emitting InGaN/GaN semiconductor lasers.

a. Comment on the feasibility of incorporating a graded-index separate confinement double heterostructure (GRIN-SCH) design blue (450nm) InGaN/GaN lasers.

[4 points]

b. Why the use of quantum-well structure is essential for room temperature lasing in InGaN/GaN lasers? Comment.

[4 points]

c. Why $E_{InGaN(Bulk)} \neq E_{InGaN(QW)}$? Comment.

[4 points]

d. Explain how do you extract (i) slope efficiency (external quantum efficiency), internal quantum efficiency (η_i), mirror loss (α_m), internal loss (α), threshold gain (g_{th}), Γg_o, transparency current (J_t), and threshold current density at infinite length (J_o) from Fabry-Perot lasers with different lengths.

[4 points]

e. Suggest methods to improve (i) the threshold current, (ii) output power, and (iii) internal quantum efficiency of the laser.

[4 points]

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EXAM ID NUMBER:________

COURSE NUMBER: EE 221

PROBLEM: 1

Problem 1 (20 points)

Assume that an electric field given by

$$\mathbf{E}^i(x) = E_0(\hat{a}_y + \hat{a}_z)e^{-jk_0x},\ k_0 = \omega\sqrt{\varepsilon_0\mu_0}\ ,\ -\infty < x < 0,\ -\infty < y,z < \infty,$$

is incident on a dielectric planar half space of uniaxial metamaterial ($0 < x < \infty, -\infty < y,z < \infty$) with

$$\bar{\varepsilon} = \begin{bmatrix} \varepsilon' & 0 & 0 \\ 0 & \varepsilon' & 0 \\ 0 & 0 & -\varepsilon' \end{bmatrix} \text{ and } \mu = -\mu', \text{ where } \varepsilon' > 0 \text{ and } \mu' > 0.$$

Find expressions of reflected and transmitted electric fields, $\mathbf{E}^r(x)$ and $\mathbf{E}^t(x)$.

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COURSE NUMBER: EE 221

PROBLEM: 2

Problem 2 (20 points): Consider a perfect electrically conducting waveguide with a rectangular cross section extends from $x=0$ to $x=\sqrt{3}a$ and from $y=0$ to $y=a$. Assume that the waveguide modes are propagating in $+\hat{a}_z$ direction and the waveguide is filled with a homogenous dielectric with permittivity ε and permeability μ.

(a) (8 points) Write down the expressions for the electric fields of the TM modes. Use boundary conditions. You do not need to derive the constants at the beginning of the expressions. (Full credit will be given for the correct spatial dependence.)

(b) (8 points) Assuming the modes ordered based on their on their cut-off frequencies (from the lowest one to the highest one). Find the first six TM modes.

(c) (4 points) Assume that the frequency of operation is $2f_c$, where f_c is the cut of frequency of the dominant mode (the mode with the lowest cut-off frequency). Assume that the amplitude of TM_{22} mode's electric field at point $\{x,y,z\}=\{0.5a,0.5a,10a\}$ is E_0. Find the amplitude of the same field at point $\{x,y,z\}=\{0.5a,0.5a,10a+l\}$ in terms of a, l, and E_0.

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EXAM ID NUMBER:________

COURSE NUMBER: EE 231

PROBLEM: 1

Qualifier questions

1) In the plane at z=0, the disturbance of a monochromatic field of wavelength λ reads as follows:

$$V(x, y, z = 0) = Ae^{ik_1 x} + e^{-r^2}$$

with A and B complex constants, R a real constant, $r = \sqrt{x^2 + y^2}$ and $k = 2\pi/\lambda$. Propagate the field at a generic distance z and write the expression of the resulting disturbance V(x,y,z).

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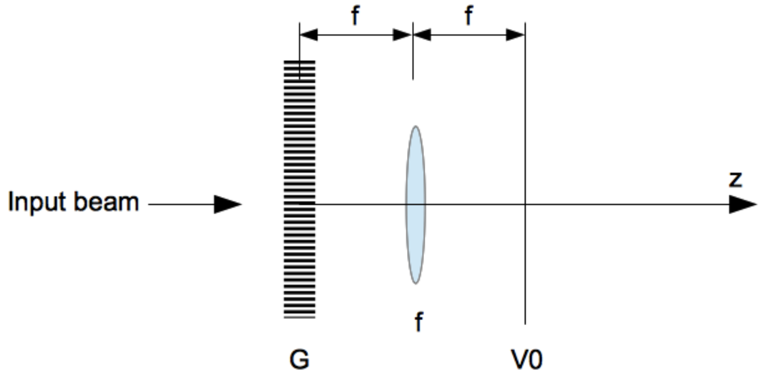
COURSE NUMBER: EE 231

PROBLEM: 2

2) An input plane wave characterized by the following disturbance field $V(x, y, z = 0) = Ae^{ik_1 x}$ is launched in the following system:



characterized by a grating G and a thin lens of focal f. The grating has the following transfer function T(x)=cos(4πx/L)^2.
Calculate the intensity I=|V0|^2.