ECE137B Final Exam

There are 5 problems on this exam and you have 3 hours.
There are pages 1-19 in the exam: please make sure all are there.

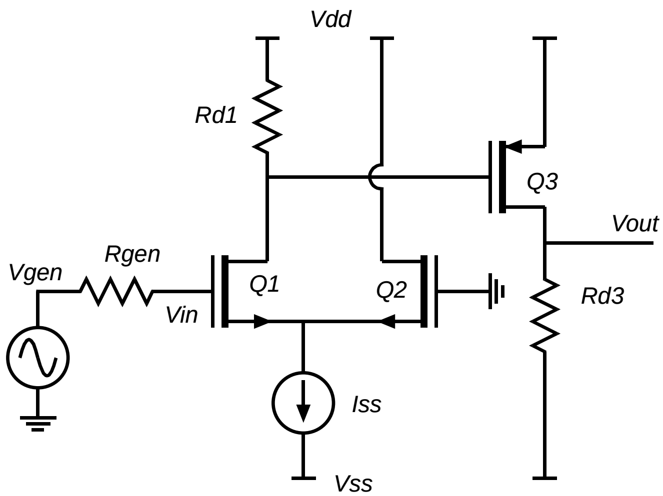
Do not open this exam until told to do so
Show all work:
Credit will not be given for correct answers if supporting work is not shown.
Class Crib sheets and 3 pages of your own notes permitted.
Don't panic.

Time function	LaPlace Transform
$\delta(t)$	1
U(t)	1/s
$e^{-\alpha t}\cdot U(t)$	$\frac{1}{s+\alpha}$ or $\frac{1/\alpha}{1+s/\alpha}$
$e^{-\alpha t}\cos(\omega_d t)\cdot U(t)$	$\frac{s+\alpha}{(s+\alpha)^2+\omega_d^2}$
$e^{-\alpha t}\sin(\omega_d t)\cdot U(t)$	$\frac{\omega_d}{(s+\alpha)^2+\omega_d^2}$

Problem	points	possible	Problem	points	possible
1a			3a		
1b			3b		
1c			4		
1d			5a		
2a			5b		
2b					

Name: ___________________________________

Problem 1, 25 points
method of first-order and second-order time constants



Q1, Q2, and Q3 have $v_{sat}c_{ox}W_g$ = 10 mS, $|V_t|$=1 volts, and λ =0 V^{-1} .
Vdd and Vss are +/- 4 Volts.
Rgen=50 kOhm and Iss=4 mA.

Q1 has
$C_{gs} = 10C_{gd}$ =31.8 fF.
Q2 has
$C_{gs} = 10C_{gd}$ =31.8 fF.
Q3 has
$C_{gs} = 0$, C_{gd} =63.6 fF.

Part 1, 4 points

Q1 and Q2 are to be biased at 2 mA drain current, Q3 is to be biased at 4mA drain current and Vout is to be at zero volts DC.

Find Rd1 and Rd3

Rd1=____________ Rd3=______________

b

Part b, 5 points

Find the mid-band value of Vout/Vgen.
Vout/Vgen=________________________

Part c, 4 points

Find the f_τ of transistors Q1 and Q3.

Q1: f_τ =____________________ Q3: f_τ =____________________

b

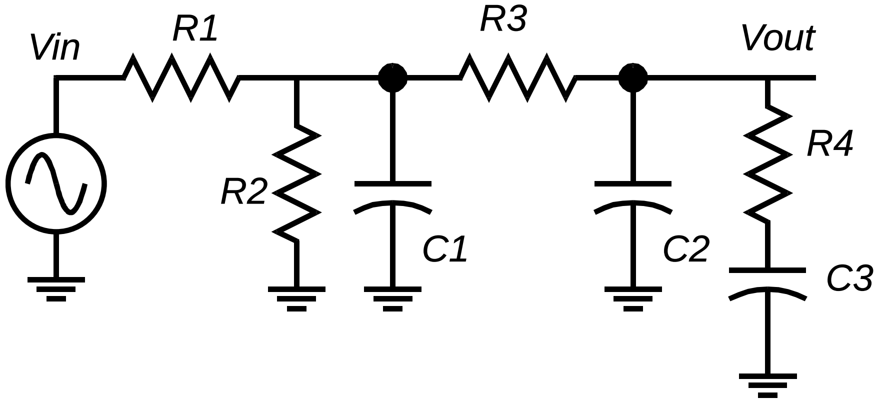
Part d, 12 points

Using MOTC, you will find the frequency, in Hz (not rad/sec), of the ***two*** major poles in the transfer function. The degeneration approximation may help.

capacitor 1: Cgs of transistor 1 (possibly the degernerated Cgs)	capacitor 2: Cgd of transistor 1	capacitor 3: Cgd of transistor 3
$R_{11}^{0} =$ ____________	$R_{22}^{0} =$ ____________	$R_{33}^{0} =$ ____________
$R_{22}^{1} =$ ____________	$R_{33}^{1} =$ ____________	$R_{33}^{2} =$ ____________
$f_{p1} =$ ____________	$f_{p2} =$ ____________	

b

Problem 2: 20 points
method of time constants analysis



R1=1 KOhm R2=2 KOhm R3=3 KOhm R4=4 KOhm
C1= 1 nF C2=2nF C3=3 nF

<u>Part a, 15 points</u>
Using MOTC, find the transfer function Vout(s)/Vgen(s). Give the answer in standard form $\frac{V_{out}(s)}{V_{gen}(s)} = \left.\frac{V_{out}}{V_{gen}}\right|_{DC} \frac{1+b_1 s + b_2 s^2 + ...}{1 + a_1 s + a_2 s^2 + ...}$

HINT: $b_1 = R_4 C_2$ and $0 = b_2 = b_3 = \cdots$

$R_{11}^0 =$________________ $R_{22}^0 =$________________ $R_{33}^0 =$________________

$R_{22}^1 =$________________ $R_{33}^1 =$________________ $R_{33}^2 =$________________

$\left.\frac{V_{out}}{V_{gen}}\right|_{DC} =$________________ $a_1 =$________________ $a_2 =$________________

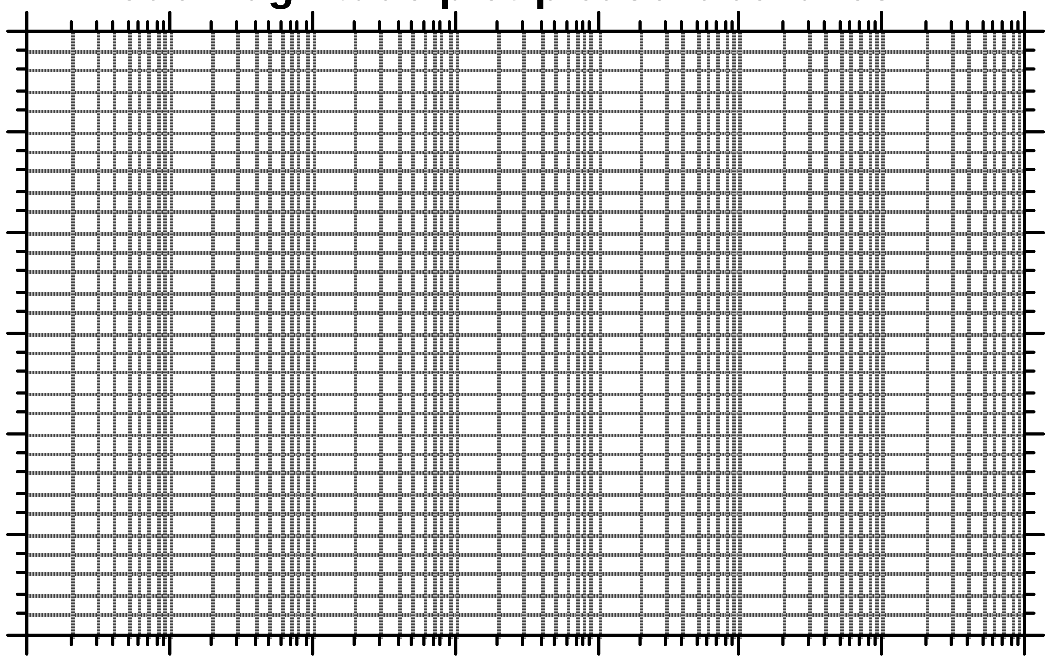
b

Part b, 5 points

Draw a Bode Plot (Straight-line asymptotes) of the circuit transfer function Vout/Vgen, labeling all pole and zero frequencies and labeling the slopes of all asymptotes.

Bode Magnitude plot-please label axes

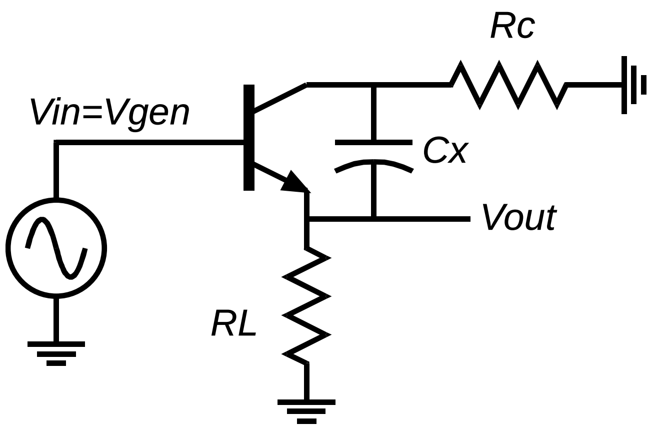
dB



Frequency

Problem 3 20 points

Nodal analysis and transistor circuit models



Above is the AC small signal representation of transistor circuit.

Rc= 2000 Ohms. RL= 10,000 Ohms. The transistor is biased at 2 mA DC emitter current, so that re=13Ohms. C_x =20 fF

τ_f =0 ps, $C_{be,depl}$ = 0 fF, C_{cb} =0 fF, β =infinity, V_A =infinity volts.

<u>Part a, 7 points</u>

Draw an accurate small-signal equivalent circuit model of the circuit above, with the transistor represented by the hybrid-pi model

b

Part b, 13 points

Using NODAL ANALYSIS, find the transfer function Vout(s)/Vgen(s).

The answer must be in standard form $\frac{V_{out}(s)}{V_{gen}(s)} = \left.\frac{V_{out}}{V_{gen}}\right|_{DC} \frac{1+b_1 s+b_2 s^2+...}{1+a_1 s+a_2 s^2+...}$

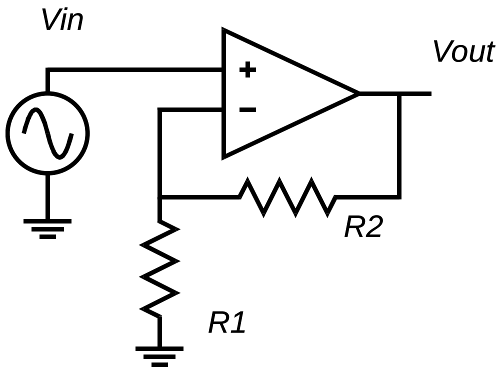
HINT: Think carefully; how many nodal equations are really needed here

$\left.\frac{V_{out}}{V_{gen}}\right|_{DC} =$ ____________________ , $a_1 =$ ____________________ , $a_2 =$ ____________________

$b_1 =$ ____________________ , $b_2 =$ ____________________

(note that a3, a4, ..., b3,b4, ... are all zero)

Problem 4 20 points
negative feedback



The amplifier has a differential gain of $4 \bullet 10^5$. R1=1 kOhm, R2=39 kOhm. The op-amp has infinite differential input impedance and zero differential output impedance.

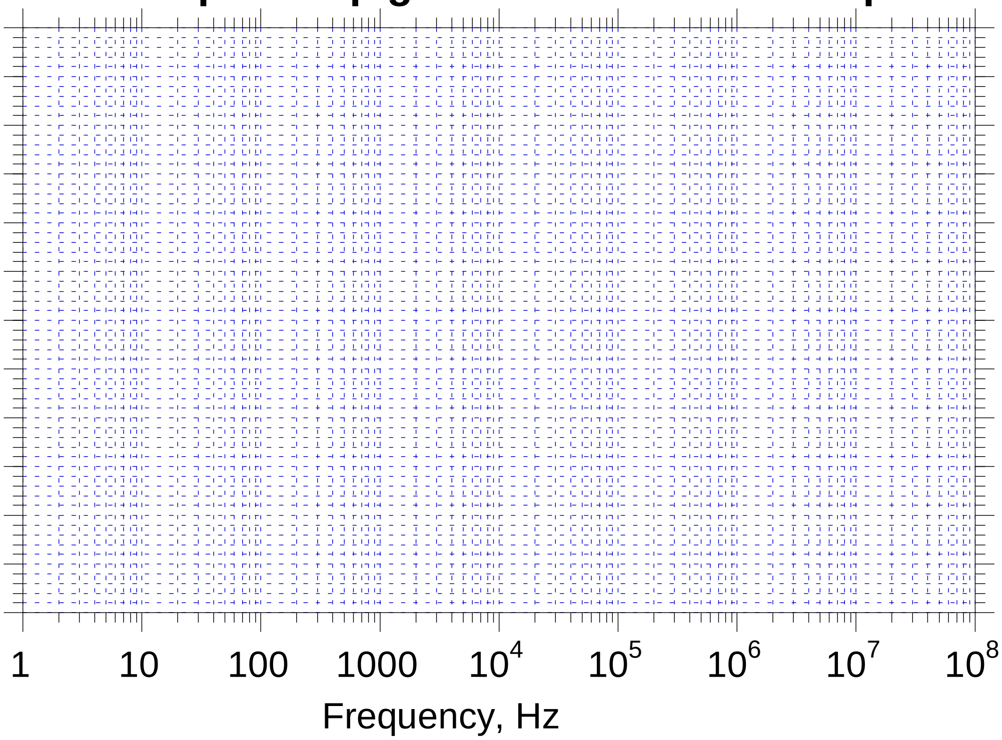
The differential amplifier has poles in its open-loop transfer function at 100 Hz, 1 kHz, & 1 MHz. It has a single zero in its transfer function at 10 kHz.

Using the Bode plot on the next page, plot the open-loop gain (A_d or A_{ol}), the inverse of the feedback factor $(1/\beta)$, closed loop gain (A_{CL}), and determine the following:

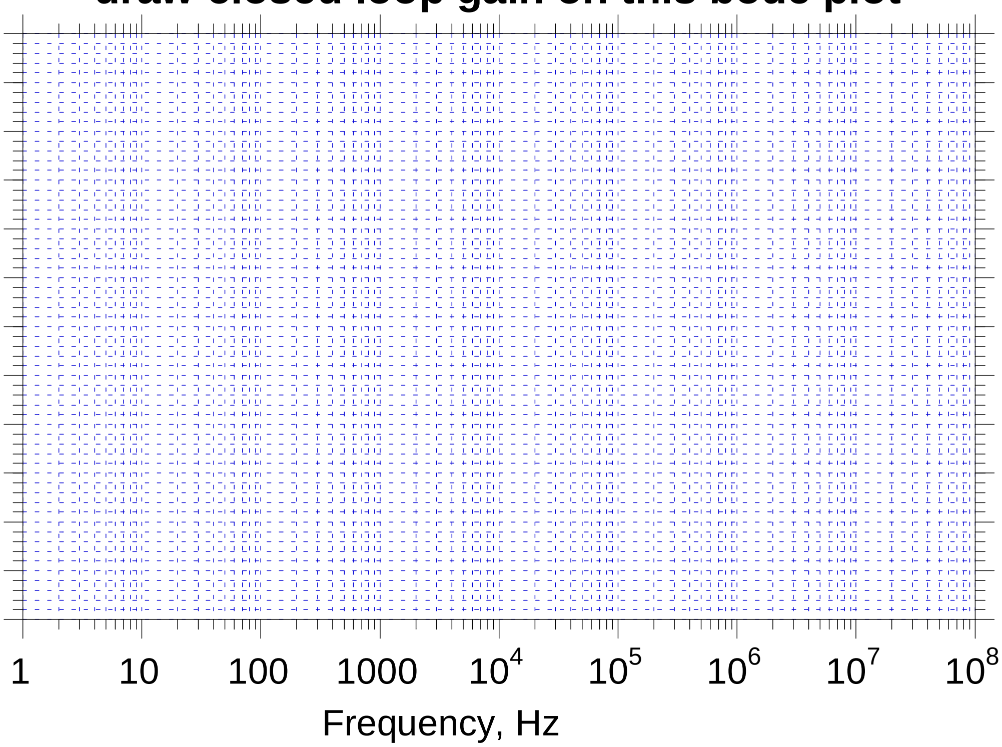
Loop bandwidth=_______________ phase margin=___________________
Vout/Vgen at DC=____________________

b

Draw open loop gain and 1/beta on this plot



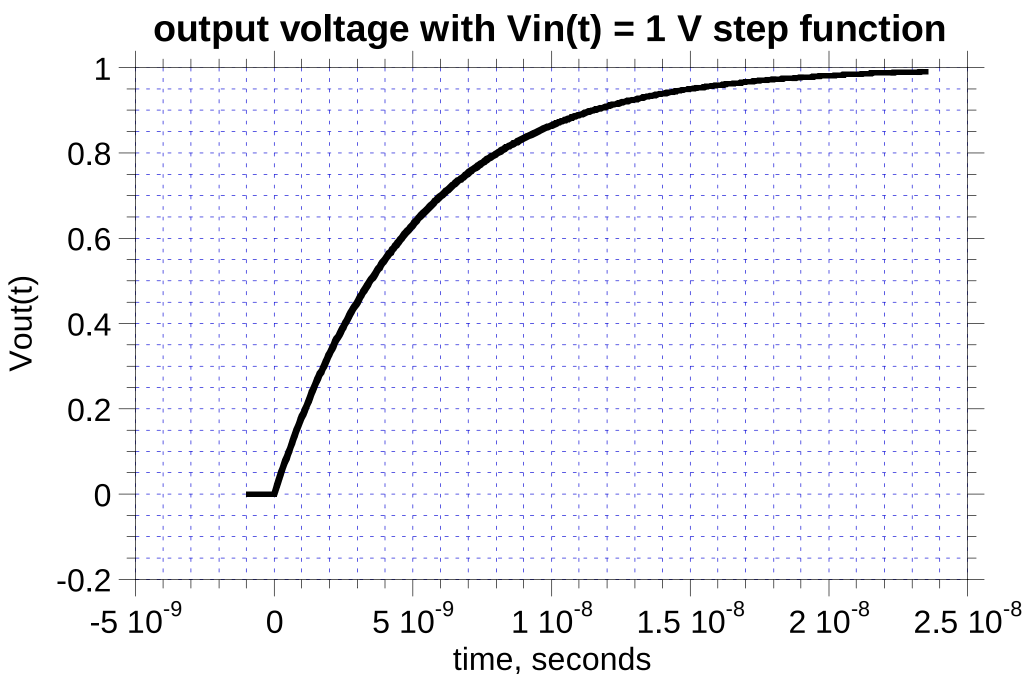
draw closed loop gain on this bode plot



Problem 5 15 points
transfer functions

Part a, 5 points

A transistor circuit has a step response (input is a 1-V step function) as shown.

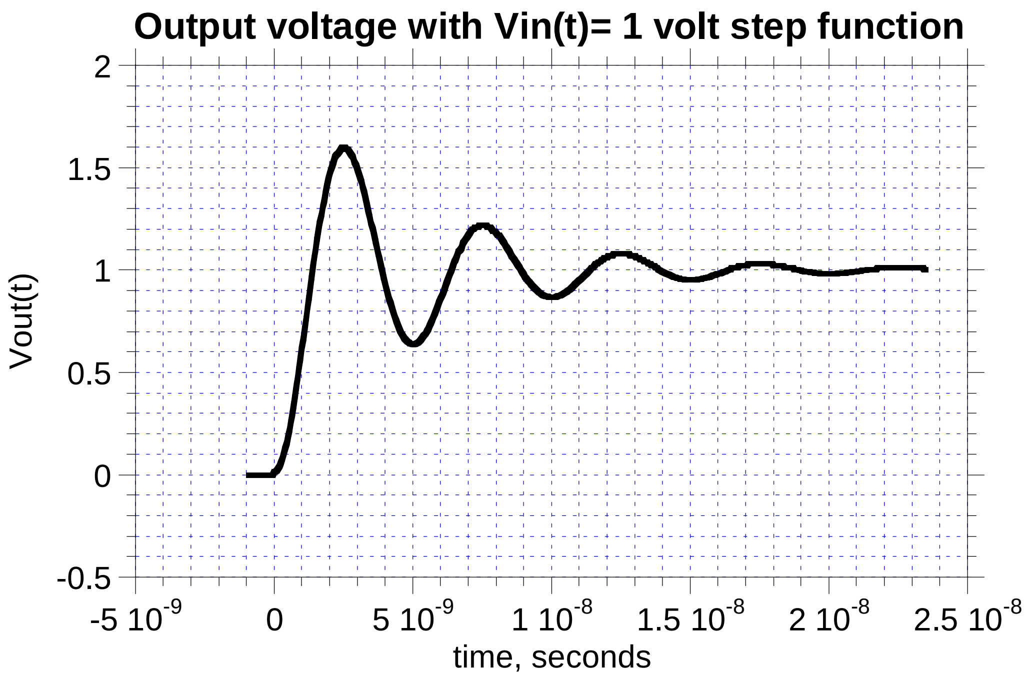


What is the circuits' 3-dB bandwidth ? f_{3dB} = ________________________________

b

Part b, 10 points

Another transistor circuit has a step response (input is a 1-V step function) as shown.

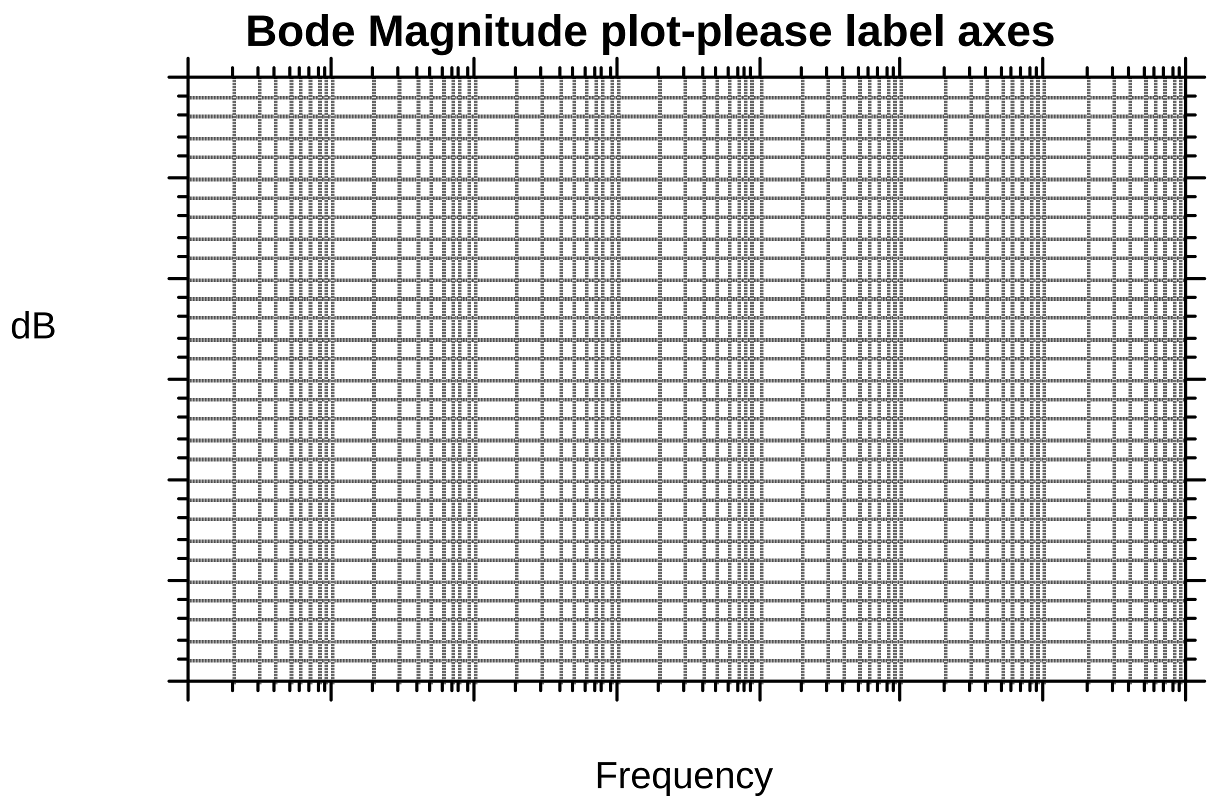


This is clearly a second-order response.

Approximately what is the damped resonant frequency ? f_n = ________________

Estimate the damping factor ? ζ = ____________ (35% accuracy is fine here)

Sketch the transfer function below, labeling both axes, key slopes, and key frequencies.



b