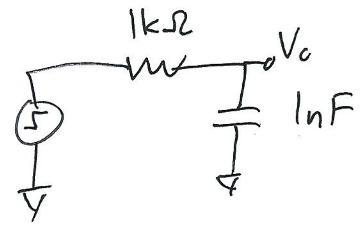
EE140 HW 1

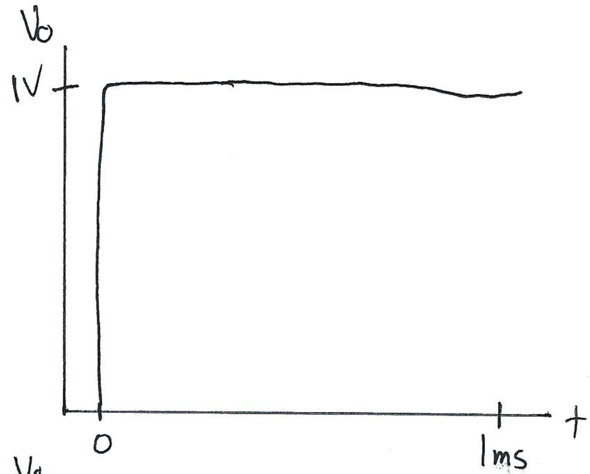
(1)



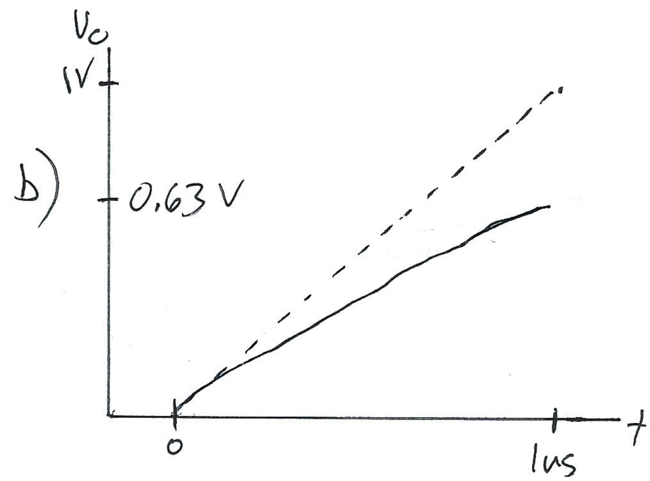
$\tau = 1\,\mu s$

$V_o = 1 - \exp(-t/\tau)$

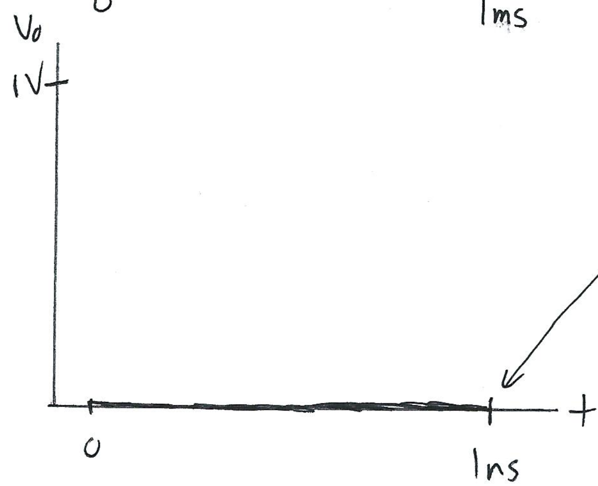
a)



b)



c)



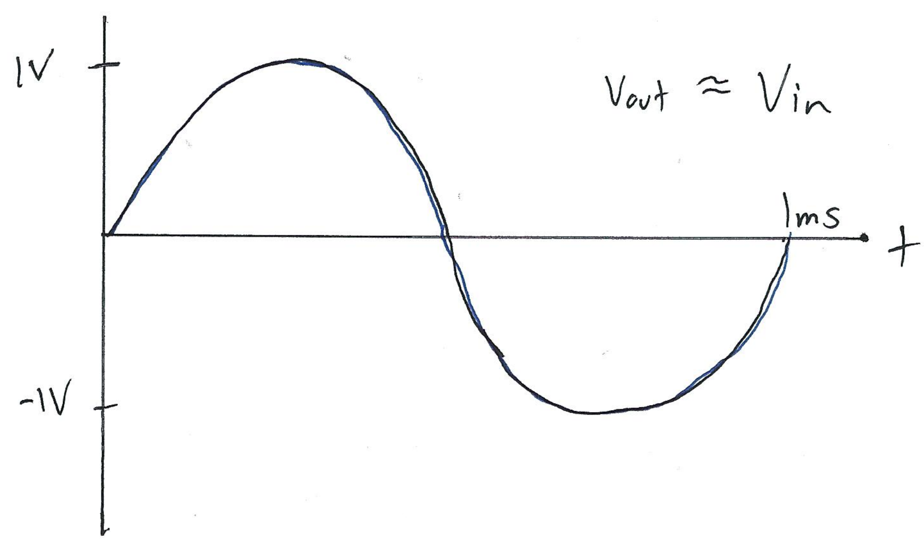
After 1ns $V_o = 0.001\,V$

(2) Rough sketches by hand, no calculator

3dB frequency = 1Mrad/s ÷ 2π ≈ 165 kHz

a)

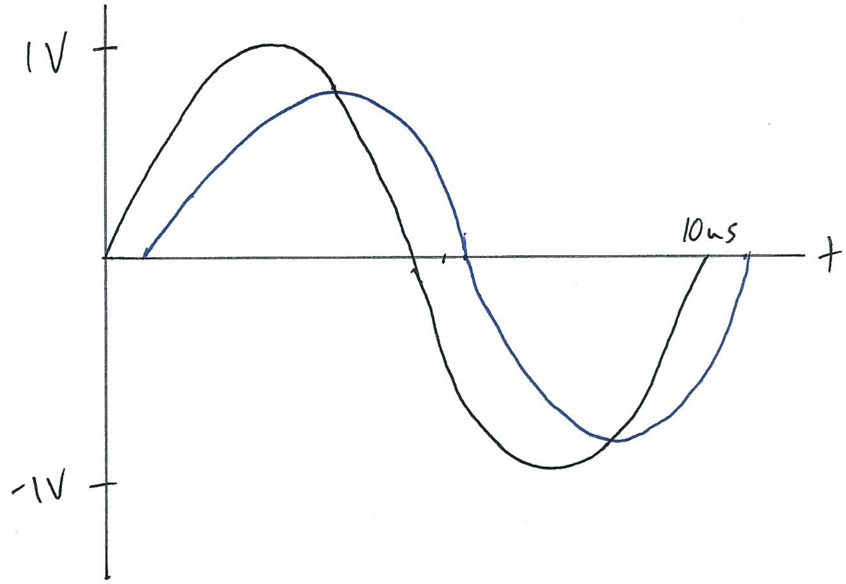
1kHz



$V_{out} \approx V_{in}$

b)

100kHz

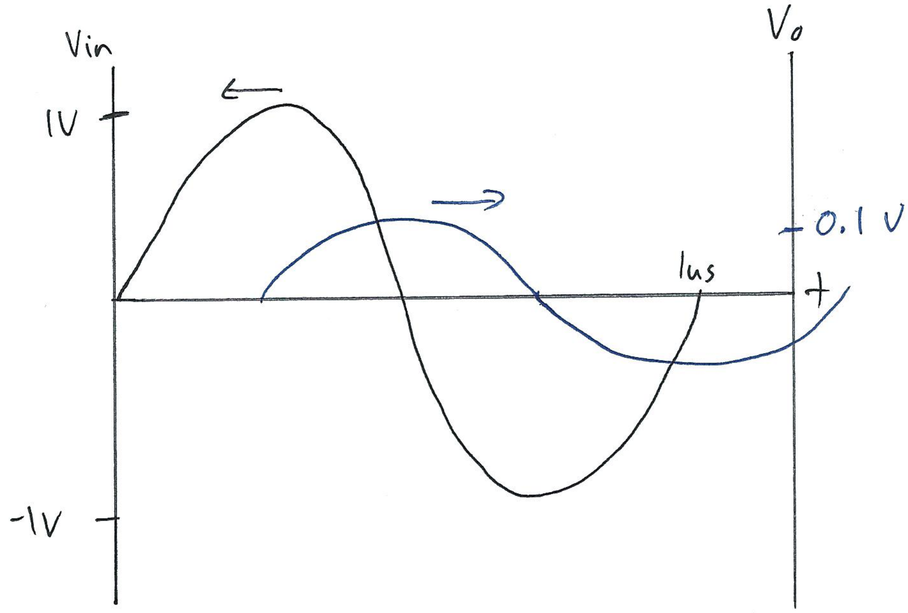


Slightly below cutoff, so amplitude slightly bigger than 0.5 and phase $\angle$ 45°

(Actual answer $0.85 \angle -32°$)

c)

1MHz

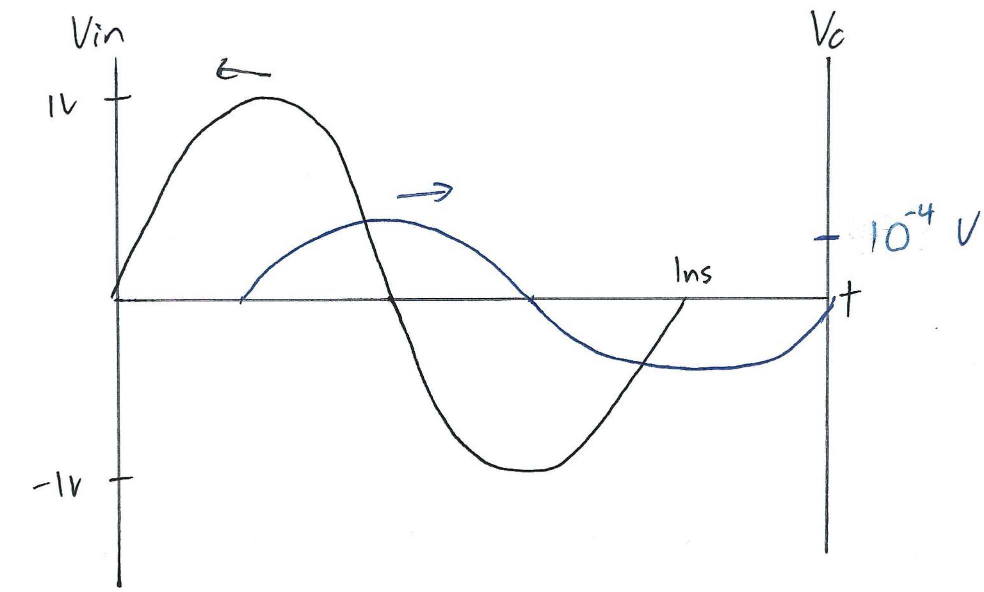


$\approx \frac{1}{10}$ amplitude

& 90° phase shift

d)

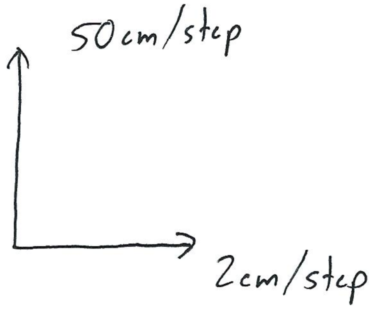
1GHz



$\approx \frac{1}{10^4}$ amplitude

& 90° phase shift

(3)

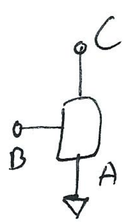


10 steps north is 500 cm higher elevation

To return to original altitude, must then walk

$$\frac{500\ \text{cm}}{2\ \text{cm/step}} = 250 \text{ steps west}$$

(4)



$$I_c = f(V_{ba}, V_{ca})$$

a) $I_c + i_c = f(V_{BA} + v_{ba}, V_{CA} + v_{ca})$

b) 2D Taylor:

$$f(x+\Delta x, y+\Delta y) = f(x,y) + f_x'(x,y)\Delta x + f_y'(x,y)\Delta y + \dots$$

$$I_c + i_c = \underbrace{f(V_{BA}, V_{CA})}_{\text{This is } I_c} + \underbrace{\left.\frac{\partial f}{\partial V_{BA}}\right|_{V_{BA}, V_{CA}}}_{\text{call } g_b} \cdot v_b + \underbrace{\left.\frac{\partial f}{\partial V_{CA}}\right|_{V_{BA}, V_{CA}}}_{\text{call } g_c} \cdot v_c$$

$$i_c = g_b v_b + g_c v_c$$

c) $i_c = 0 \qquad 0 = g_b v_b + g_c v_c$

$$v_c = \frac{-g_b}{g_c} v_b$$

d) Call north the "b" direction and east "c" direction,

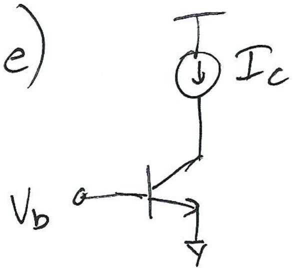
v_b is then # of steps north, v_b is # steps east,

g_b is altitude per step north, g_c is altitude/step east,

$$v_c = \frac{-g_b}{g_c} v_b = \frac{-50}{2} \cdot 10 = -250 \text{ steps east}$$

(-east = west)

e)



$$I_c = I_S \left(1 + \frac{V_{CE}}{V_A}\right) \exp\left(\frac{V_{BE}}{V_T}\right)$$

$$I_{c,\text{taylor}} = I_c + \left.\frac{\partial I_c}{\partial V_{BE}}\right|_{V_{BE}, V_{CE}} \cdot v_{be} + \frac{\partial I_c}{\partial V_{CE}} \cdot v_{ce} + \cancel{\ldots}$$

$$I_{c,\text{taylor}} = I_c + \left[\frac{I_S}{V_T} \exp\left(\frac{V_{BE}}{V_T}\right) + \frac{I_S}{V_T}\frac{V_{CE}}{V_A} \exp\left(\frac{V_{BE}}{V_T}\right)\right] \cdot v_{be} + \frac{I_S}{V_A} \exp\left(\frac{V_{BE}}{V_T}\right) \cdot v_{ce}$$

$$I_c + i_c = I_c + \frac{I_c}{V_T} v_{be} + \frac{I_c}{V_A} v_{ce}$$

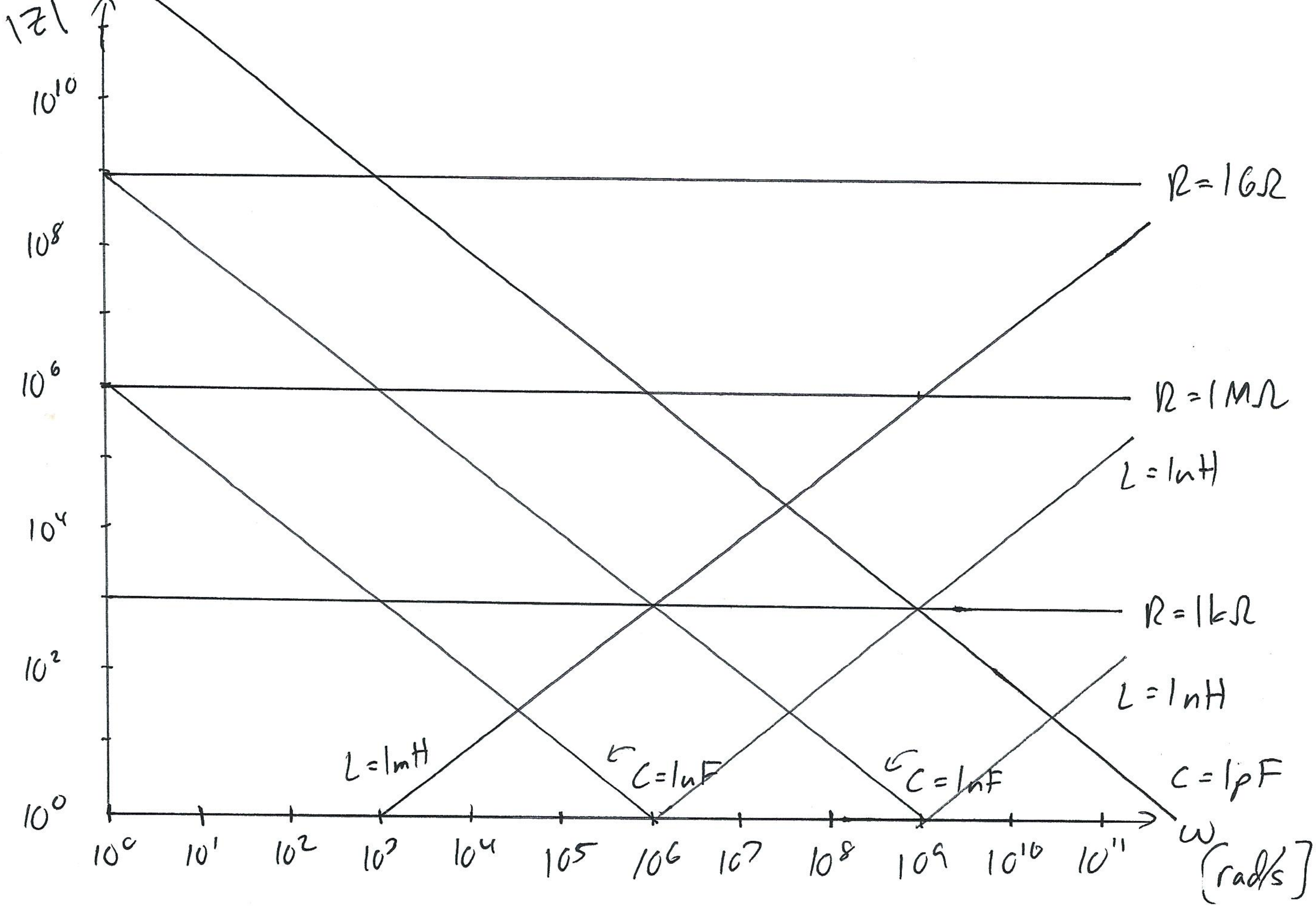
$i_c = 0$

$$v_{ce} = \frac{\frac{-I_c}{V_T} v_{be}}{\frac{I_c}{V_A}}$$

$$\boxed{v_{ce} = \frac{-V_A}{V_T} v_{be}}$$

(5)

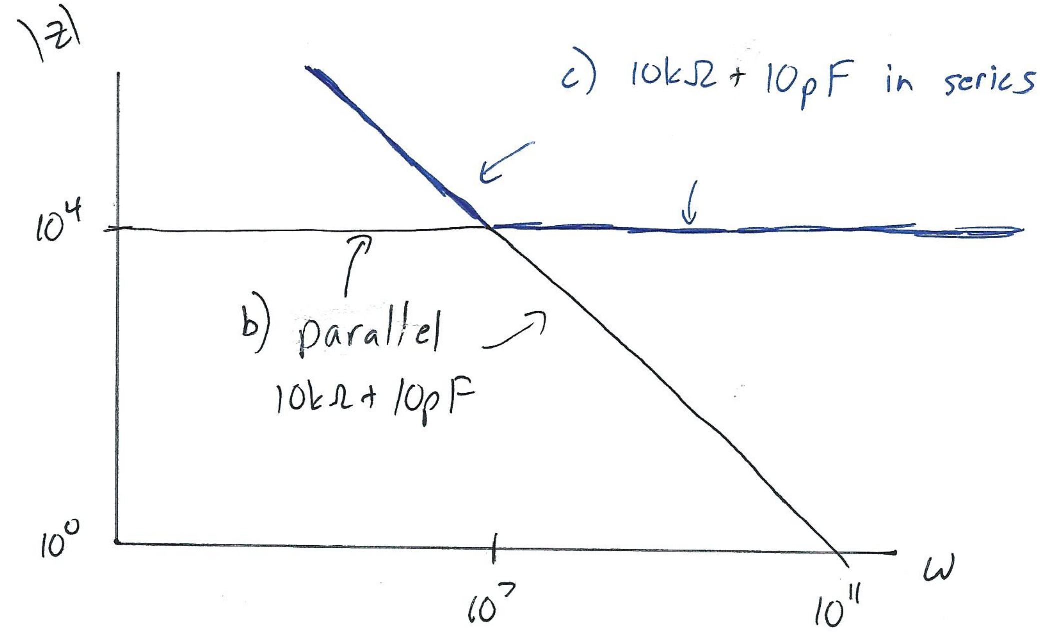
a)



|Z|
10^10
10^8
10^6
10^4
10^2
10^0
R = 1GΩ
R = 1MΩ
L = 1µH
R = 1kΩ
L = 1nH
L = 1mH
C = 1µF
C = 1nF
C = 1pF
10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^10 10^11
ω [rad/s]

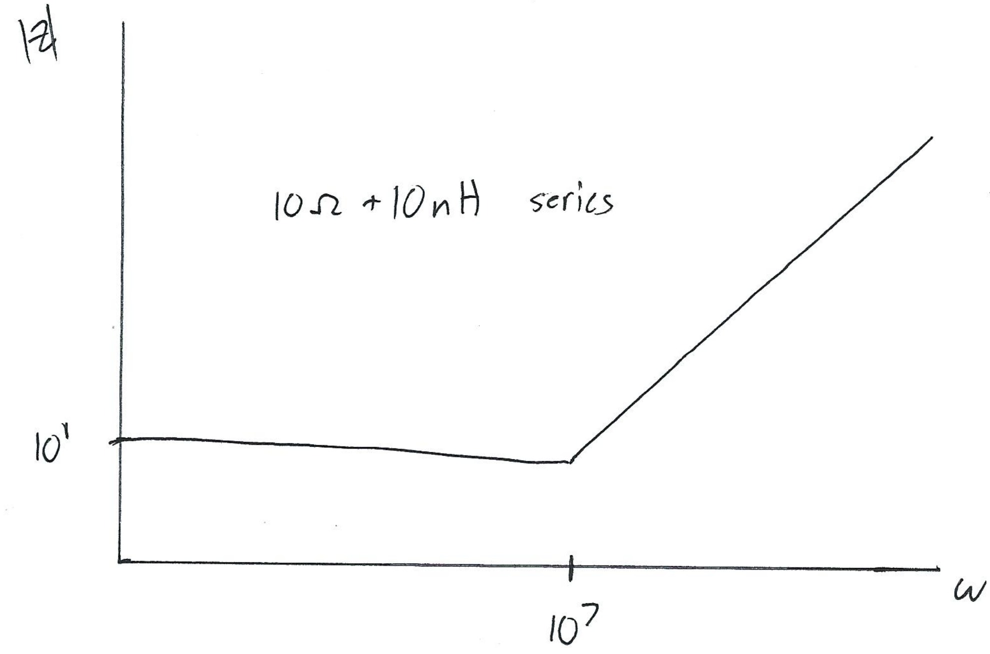
b)

c)

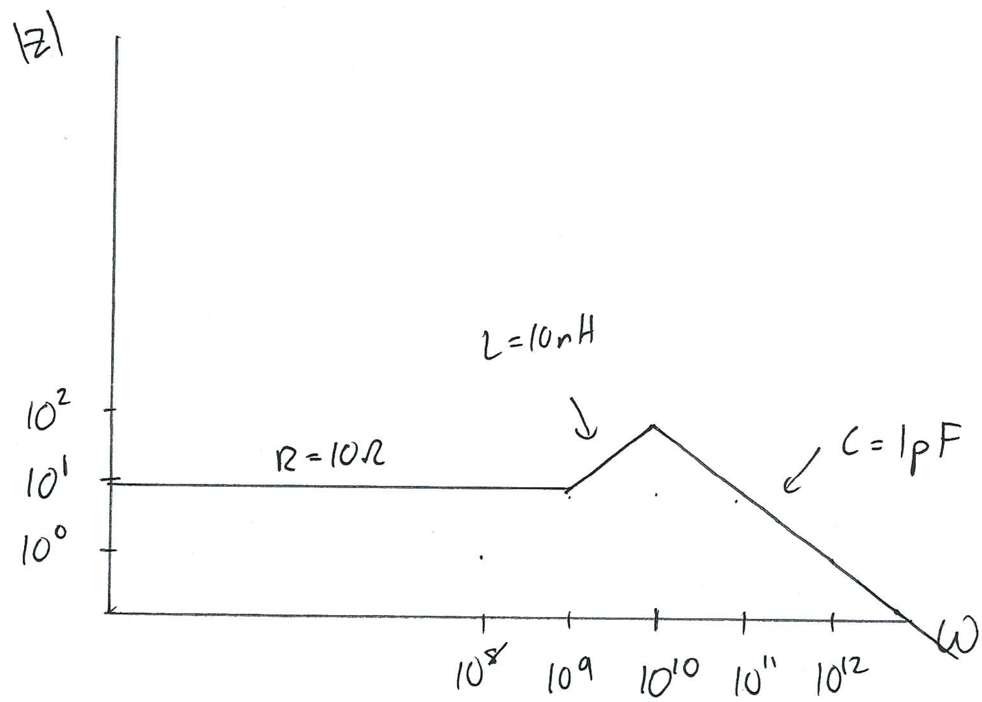


|Z|
c) 10kΩ + 10pF in series
10^4
b) parallel
10kΩ + 10pF
10^0
10^7
10^11
ω

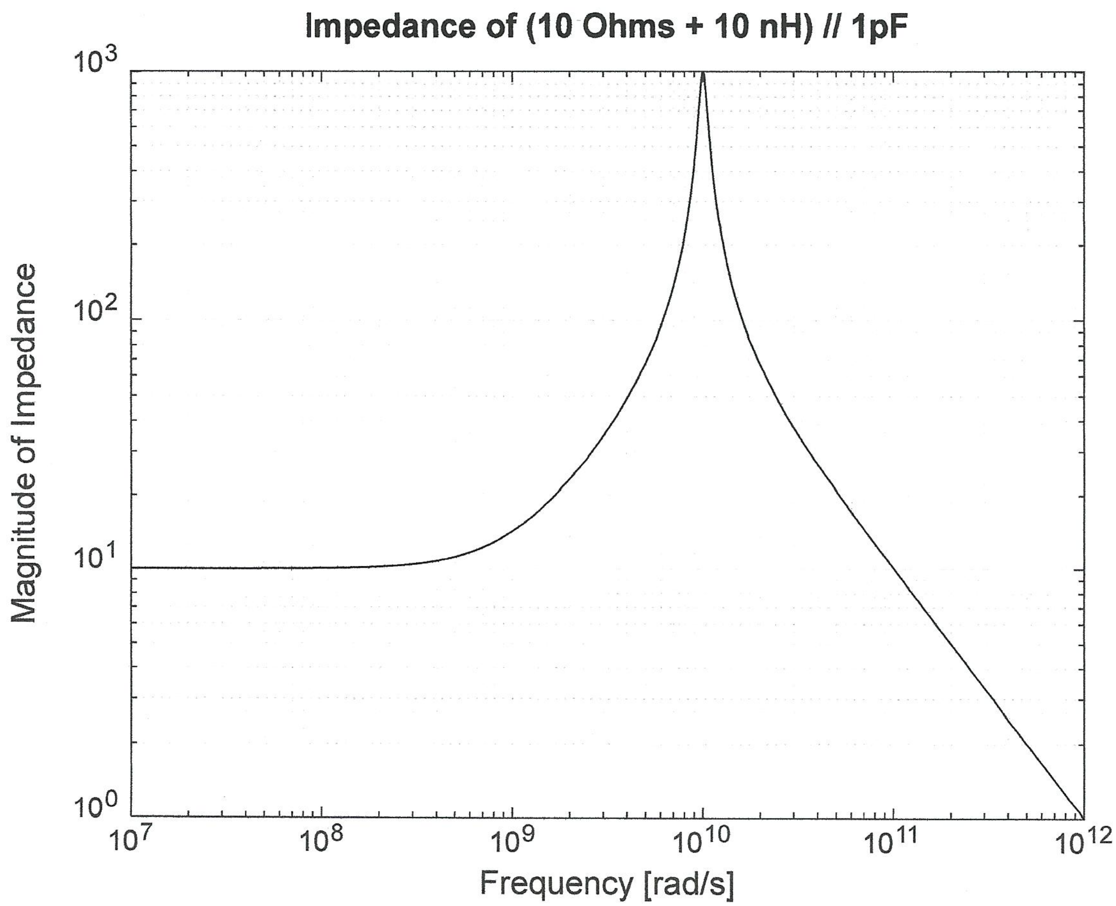
d)



e)



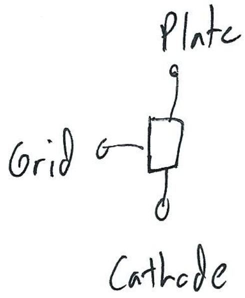
Note that our straight line approximation ignores the "peaking" in this second order response. See following plot for what it actually looks like.



$$Q = \frac{\omega_o * L}{R} = 10$$

Note that the impedance peaks to a value Q times higher than that predicted by our straight line impedance approximation.

(6)



$$g_m = \frac{\Delta I_{plate}}{\Delta V_{grid}}$$

$$r_o = \frac{\Delta V_{plate}}{\Delta I_{plate}}$$

$$g_m = \frac{100\,mA - 200\,mA}{-75\,V + 52\,V} = 4.35\,mS$$

$$r_o = \frac{3500\,V - 750\,V}{100\,mA - 50\,mA} = 55\,k\Omega$$

$$A_v = -g_m r_o = -239.3\ V/V$$

Could also estimate from the slope of grid vs plate voltage curve at bias point.

$$A_v = \frac{\Delta V_{plate}}{\Delta V_{grid}} \approx \frac{-1000}{4} = -250\ V/V$$

HW1 Rubric
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1) 6 pts
-- 2 pts per plot

2) 12 pts total
-- 3 pts per plot, 1 pt for correct amplitude, 1 pt for correct phase shift, 1 pt for labeling axis

3) 4 pts
-- half for attempt, +4 for correct answer

4) 10 pts
-- 2 pts for each item

5) 17 pts
-- a) 1 pt for each component
-- b) through e) 2 pts each

6) 6 pts
-- 2 pts each for gm,ro,Av
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55 pts total