Note for students: Always derive equations present in the lecture slides & verify them. They may be true only for specific condition.

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11.31

ESC201 **Major Quiz-I** **11/02/2025**

Total Marks: 8 **Time: 30 minutes**

Instructions

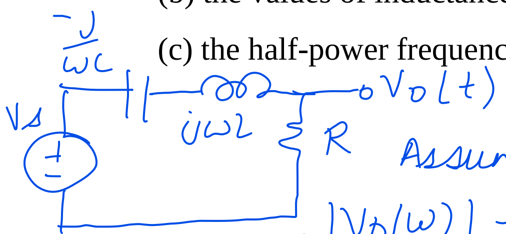
- **Please write your name and roll number first.**
- **Read the question carefully and answer it in the question paper itself.**

1) After a crushing defeat in the Delhi elections, IIT Alumnus Mr. Arvind Kejriwal wants to tune into the "Mann ki Baat" program by our Prime Minister on the Vividh Bharti (AIR) FM at a frequency of 105.4 MHz. Mr. Kejriwal wants to design a filter which may pass the content of Vividh Bharti channel while attenuating (rejecting) the adjacent FM radio channels Radio Nasha (107.2 MHz) and FM Rainbow Lucknow (100.7 MHz) by at least -60 dB. Since he spent a lot of money during the election campaign, he can only afford a resistor of 50 Ω, a variable inductor and a variable capacitor to design this filter. Can you please help Mr. Kejriwal design this filter using the R, L, and C components and find out:

(a) the quality factor (Q) of this filter. **(2 marks)**

(b) the values of inductance and capacitance needed. **(2 marks)**

(c) the half-power frequencies. **(1 mark)**



$|H(\omega)| = \left|\frac{V_o(\omega)}{V_s(\omega)}\right| = \frac{R}{\sqrt{R^2+(\omega L-\frac{1}{\omega C})^2}}$

Assuming $V_s = 1V$ & $Q = \frac{\omega_0 L}{R}$;

$|V_o(\omega)| = \frac{1}{\sqrt{1+\boxed{\frac{\omega_0^2}{\omega^2}}Q^2\left(\frac{\omega^2}{\omega_0^2}-1\right)^2}}$

Equation in lecture slide approximates it as "1" Give full marks even if students ignored it

if $\omega \sim \omega_0$,

$|V_o(\omega)| \cong \frac{\omega_0^2}{Q(\omega^2-\omega_0^2)}$ 0.5

$\Rightarrow \boxed{|V_o(\omega)| \cong \frac{\omega_0}{2Q(\omega-\omega_0)}}$

for -60 dB attenuation at nearest frequency; 0.5 if nearest is satisfied, farther one will always be attenuated by <-60 dB [give full marks even if they found Q for both ω & used larger one]

In this case $\omega_0 = 2\times\pi\times105.4$ MHz, $= 662.24$ MHz 0.5

$\omega_{near} = \omega = 2\times\pi\times107.2$ MHz $= 673.55$ MHz.

0.5 At $\omega = \omega_{near}$; $|V_o(\omega)| = 0.001$

$\Rightarrow 0.001 = \frac{662.24}{2Q\ 11.31} \Rightarrow \boxed{Q \cong 29,276.74}$

0.5

(b) $Q = \frac{\omega_0 L}{R} \Rightarrow L = \frac{RQ}{\omega_0} = 2.2\times10^{-3}$ H

$\omega_0^2 = \frac{1}{LC}$ 0.5

or $Q = \frac{1}{\omega_0 RC} \Rightarrow C = \frac{1}{\omega_0 RQ} = 1.03\times10^{-15}$ F 0.5 0.5

Give full marks even if they use $\omega_0^2 = \frac{1}{LC}$ or derive ω_1 & ω_2

(c) $B = \omega_2-\omega_1 = \frac{R}{L}$ or $Q = \frac{\omega_0}{B} \Rightarrow B = 0.02$ MHz 0.5

$\omega_1 \cong \omega_0 - \frac{B}{2} = 662.21$ MHz 0.5 $\omega_2 \cong \omega_0 + \frac{B}{2} = 662.26$ MHz

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2) Draw the Bode magnitude plot for the following transfer function:

$$H(j\omega) = \frac{(Last\ 2\ digits\ of\ your\ roll\ no.)(j\omega)^3(j\omega+100)^2}{(1+j\omega)^2(j\omega+10)(j\omega+1000)^2}$$

(3 marks)

$$H(j\omega) = (K) \times (j^2) \times j\left(\frac{\omega}{1}\right)^3 \times \left(1+\frac{j\omega}{100}\right)^2 \times 10^4 \times \frac{1}{\left(1+j\frac{\omega}{1}\right)^2} \times \frac{1}{10\left(1+\frac{j\omega}{10}\right)} \times \frac{1}{\left(1+\frac{j\omega}{1000}\right)^2} \times \frac{1}{10^6}$$

0.5

$$= \left(\frac{-K}{10^3}\right) \times \boxed{j\left(\frac{\omega}{1}\right)^3} \times \boxed{\left(1+\frac{j\omega}{100}\right)^2} \times \boxed{\frac{1}{\left(1+j\frac{\omega}{1}\right)^2}} \times \boxed{\frac{1}{\left(1+\frac{j\omega}{10}\right)}} \times \boxed{\frac{1}{\left(1+\frac{j\omega}{1000}\right)^2}}$$

0.5 0.5 0.5 0.5 0.5

$20\log_{10}\left(\left|\frac{K}{10^3}\right|\right)$ dB ← |H(jω)| (dB)

let this be α