

# Practice

## Physics 261 Final Exam

**The final exam will be worth ~140 points.**




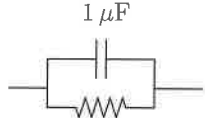
Remember to show your work.

This practice exam emphasizes what we have learned since Exam 2. The real final will be comprehensive, so you should also review the homework, previous exams, and practice exams from the whole semester. Pay special attention to what you missed on Exams 1 and 2!

Name: Solutions

I've tried to make these clear—  
but let me know if you have questions.

5. (15 points) For each circuit element, write the value of the impedance  $Z$  at  $\omega = 1000$  rad/sec ( $f = 159$  Hz). Also fill in the high and low frequency limits of  $Z$ .

	Impedance, $Z$ ( $\Omega$ )		
	$\omega = 1000$	$\omega \rightarrow 0$	$\omega \rightarrow \infty$
$1 \text{ k}\Omega$ 	$1 \text{ k}\Omega$	$1 \text{ k}\Omega$	$1 \text{ k}\Omega$
$1 \mu\text{H}$ 	$j \times 10^3 \Omega$	$0$	$\infty$
$1 \mu\text{F}$ 	$-j \times 10^3 \Omega$	$\infty$	$0$
$1 \mu\text{F}$  $1 \text{ k}\Omega$	$\frac{1}{2}(1-j) \text{ k}\Omega$	$1 \text{ k}\Omega$	$0$

$$Z_L = j\omega L = j \times 10^3 \text{ Hz} \times 10^{-6} \text{ H}$$

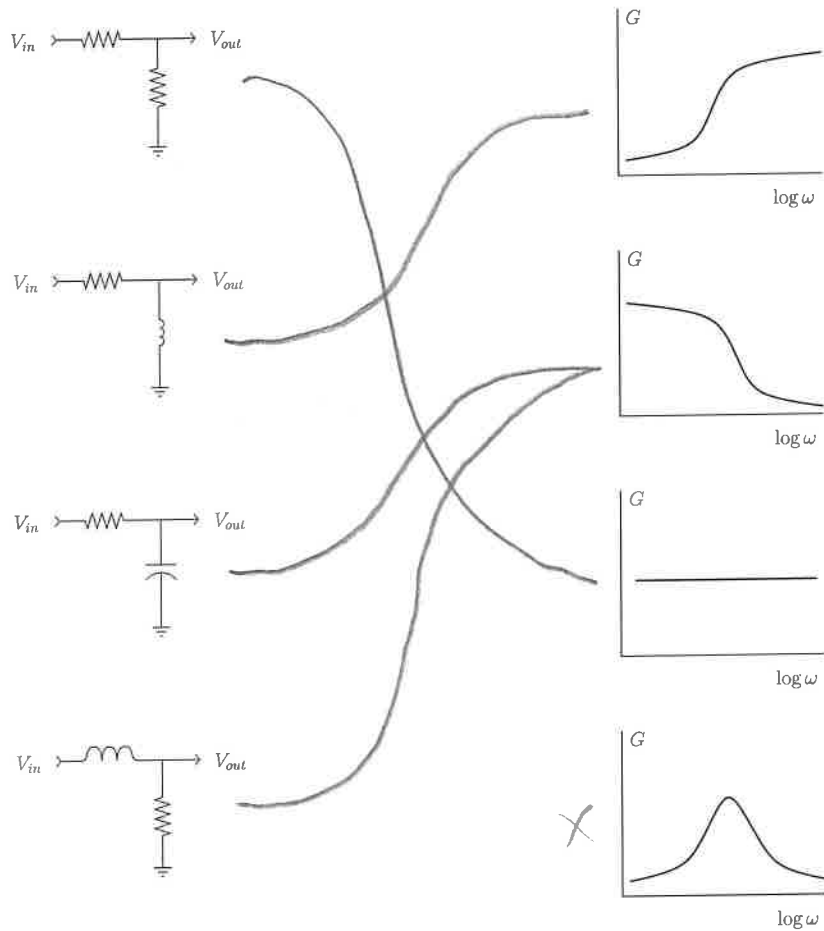
$$Z_C = \frac{-j}{\omega C} = -j / (10^3 \text{ Hz})(10^{-6} \text{ F})$$

$$Z = \frac{1}{j\omega C + \frac{1}{R}} = \frac{1 \Omega}{j \times 10^{-3} + 10^{-3}} = \frac{1 \text{ k}\Omega (1-j)}{(1+j)(1-j)} = \frac{(1-j) \text{ k}\Omega}{2}$$

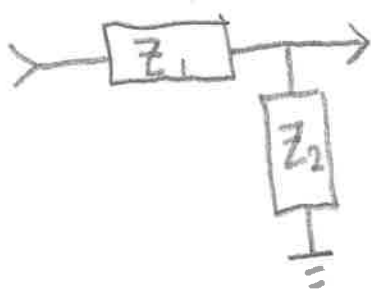
3. (12 points) Choose the correct gain function for each circuit. There may be duplicates.

No dependence<sup>(a)</sup>  
on  $\omega$ !

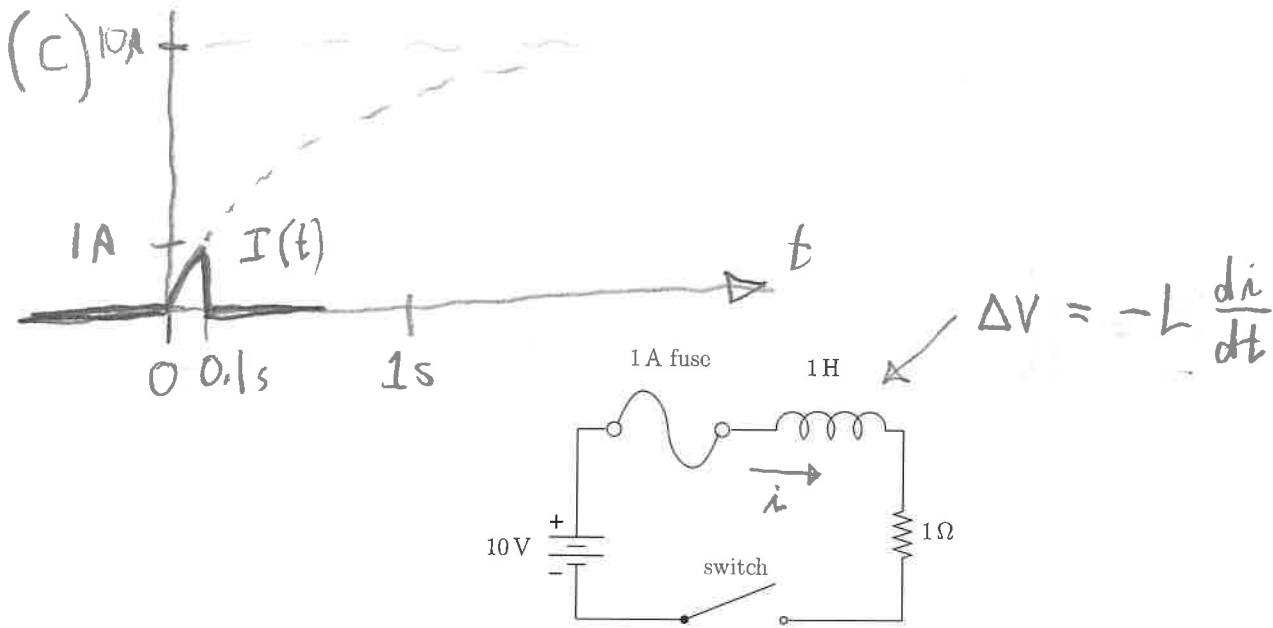
At high  $\omega$ ,  
the capacitor  
is a wire  
and the  
inductor is  
a broken  
wire. At low  
 $\omega$ , the roles  
reverse.



General Picture:



$$V_{out} = \frac{Z_2}{Z_1 + Z_2} V_{in}$$



7. (15 points) At time  $t = 0$ , the switch is closed. As soon as the current reaches 1 A, the fuse will “blow”, which means that the conductor will melt, breaking the circuit (until that happens, the fuse acts as a wire).

- Write the current  $i(t)$  for the inductor, assuming the fuse hasn't blown yet.
- At what time does the fuse blow?
- Sketch  $i(t)$  from  $t = 0$  to a bit after the fuse blows.
- What happens to the voltage across the inductor when the fuse blows?

→ Sudden voltage spike, trying to maintain current.

(a) KVL:  $10V - L \frac{di}{dt} - 1\Omega i = 0$

$i(0) = 0$        $i(\infty) = \text{const} \Rightarrow \frac{di}{dt} \rightarrow 0,$

So  $i(\infty) = \frac{10V}{1\Omega} = 10A$

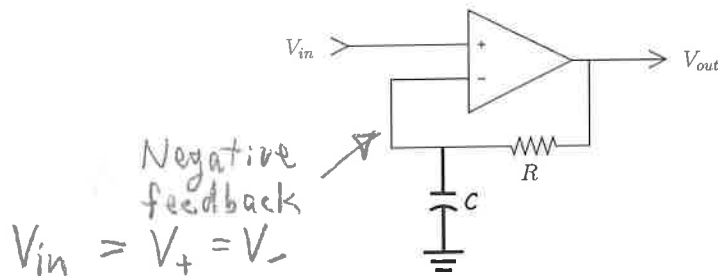
$\tau = L/R = 1H/1\Omega = 1s$

$i(t) = [i(0) - i(\infty)] e^{-t/\tau} + i(\infty)$

$i(t) = 10A (1 - e^{-t/1s})$

(b)  $1A = 10A (1 - e^{-t/1s}) \Rightarrow \frac{9}{10} = e^{-t/1s} \Rightarrow t = -1s \cdot \ln(0.9)$   
 $\approx 0.1s$   
 (recall  $\ln(1+x) \approx x$  for small  $x$ , so  $\ln(0.9) = \ln(1-0.1) \approx -0.1$ )

7. (18 points) Don't panic! Analyze as you would any op amp circuit with negative feedback, and assume the input voltage signal has some frequency  $\omega$ .



- (a) Find  $V_{out}$  as a function of  $V_{in}$  and  $\omega$ .  
 (b) Find the magnitude of the gain.  
 (c) Find the phase. Does the output voltage lead or lag the input?

$$(a) \quad V_{in} = V_- = V_{out} \times \frac{Z_c}{R + Z_c} = V_{out} \times \frac{-j/\omega C}{R - j/\omega C}$$

$$V_{out} = \frac{R - j/\omega C}{-j/\omega C} V_{in} = (1 + j\omega RC) V_{in}$$

$$(b) \quad G = |1 + j\omega RC| = \sqrt{1 + \omega^2 R^2 C^2}$$

$G(\omega)$  \*

$$(c) \quad \tan \phi = \frac{\omega RC}{1}$$

$$0 < \phi < \frac{\pi}{2}$$

Output Leads input.

\* This is not a practical circuit. gain  $\rightarrow \infty$  at high frequencies!