

## Exercises

The following exercises may be used.

1. The following table lists data points for the decay rate (in counts/s) of a radioactive source:

<i>Time</i> (s)	<i>Rate</i> (s <sup>-1</sup> )	<i>Time</i> (s)	<i>Rate</i> (s <sup>-1</sup> )	<i>Time</i> (s)	<i>Rate</i> (s <sup>-1</sup> )
0.6	18.4	2.0	3.02	3.6	1.72
0.8	10.6	2.4	2.61	4.0	1.61
1.2	8.04	2.8	2.08	4.2	1.57
1.6	6.10	3.0	1.50	4.3	1.85

- Plot the data using an appropriate set of axes, and determine over what range of times the rate obeys the decay law  $R = R_0 e^{-t/\tau}$ .
  - Estimate the value of  $R_0$  from the plot.
  - Estimate the value of  $\tau$  from the plot.
  - Estimate the value of the rate you expect at  $t = 6$  s.
2. An experiment determines the gravitational acceleration  $g$  by measuring the period  $T$  of a pendulum. The pendulum has an adjustable

length  $L$ . These quantities are related as

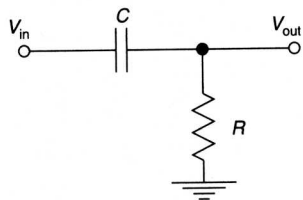
$$T = 2\pi \sqrt{\frac{L}{g}}$$

A researcher measures the following data points in some arbitrary units.

Data point	$L$	$T$
1	0.6	1.4
2	1.5	1.9
3	2.0	2.6
4	2.6	2.9
5	3.5	3.4

One of these data points is obviously wrong. Which one?

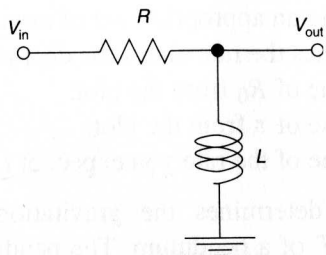
3. Consider the following simple circuit:



Let the input voltage  $V_{in}$  be a sinusoidally varying function with amplitude  $V_0$  and angular frequency  $\omega$ .

- Calculate the gain  $g$  and phase shift  $\phi$  for the output voltage relative to the input voltage.
- Plot  $g$  and  $\phi$  as a function of  $\omega/\omega_0$  where  $\omega_0 = 1/RC$ . For each of these functions, use the combination of linear or logarithmic axes for  $g$  and for  $\phi$  that you think are most appropriate.

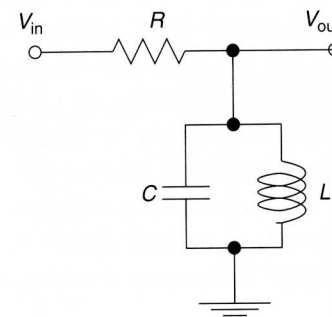
4. Consider the following simple circuit:



Let the input voltage  $V_{in}$  be a sinusoidally varying function with amplitude  $V_0$  and angular frequency  $\omega$ .

- Calculate the gain  $g$  and phase shift  $\phi$  for the output voltage relative to the input voltage.
- Plot  $g$  and  $\phi$  as a function of  $\omega/\omega_0$  where  $\omega_0 = R/L$ . For each of these functions, use the combination of linear or logarithmic axes for  $g$  and for  $\phi$  that you think are most appropriate.

5. Consider the following not-so-simple circuit:



- What is the gain  $g$  for very low frequencies  $\omega$ ? What is the gain for very high frequencies? Remember that capacitors act like dead shorts and open circuits at high and low frequencies, respectively, and inductors behave in just the opposite way.
- At what frequency do you suppose the gain of this circuit is maximized?
- Using the rules for impedance and the generalized voltage divider, determine the gain  $g(\omega)$  for this circuit and show that your answers to (a) and (b) are correct.

6. Suppose that you wish to detect a rapidly varying voltage signal. However, the signal is superimposed on a large DC voltage level that would damage your voltmeter if it were in contact with it. You would like to build a simple passive circuit that allows only the high-frequency signal to pass through.

- Sketch a circuit using only a resistor  $R$  and a capacitor  $C$  that would do the job for you. Indicate the points at which you would measure the input and output voltages.

