Quiz II — ECSE 1010 — Fall 2015

Name ________________________________

Part A (20 Points)

1. (3 Pts) _________
2. (3 Pts) _________
3. (4 Pts) _________
4. (3 Pts) _________
5. (4 Pts) _________
6. (3 Pts) _________

Part B (80 Points)

1. (10 Pts) _________
2. (5 Pts) _________
3. (10 Pts) _________
4. (15 Pts) _________
5. (10 Pts) _________
6. (10 Pts) _________
7. (15 Pts) _________
8. (5 Pts) _________

Total __________________

Draw circuit diagrams for all problems, especially as you simplify the circuits.

Be sure to fully annotate plots, even when the problem does not ask you to do this.

Show all of your work

At least skim through the entire quiz before you begin and then start with the problems you know best.

Note that some questions involve using things you have learned in new ways and some involve some minor new information. Focusing on what you know will make the problems easier to solve.

The proctor will only answer clarification questions where wording is unclear or where there may be errors/typos. No other questions will be responded to.

Note: ***In Part B, we will drop your lowest problems totaling 15 points. That is, either a 15 point problem or a 10 point and a 5 point problem, whichever does your grade the most good. Thus, if there is a problem that you find particularly difficult, leave it until the end and invest your efforts on the remainder of the quiz. Basically, you begin the quiz with 15 free points and go up from there.***

Northeast Blackout – 9 November 1965

The New York Times.

POWER FAILURE SNARLS NORTHEAST; 800,000 ARE CAUGHT IN SUBWAYS HERE; AUTOS TIED UP, CITY GROPES IN DARK

The **Northeast blackout of 1965** was a significant disruption in the supply of electricity on Tuesday, November 9, 1965, affecting parts of Ontario, Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Pennsylvania and Vermont. Over 30 million people and 80,000 square miles (207,000 km^2) were left without electricity for up to 13 hours. The cause of the failure was human error that happened days before the blackout. Maintenance personnel incorrectly set a protective relay on one of the transmission lines from a Niagara generating station in Queenston, Ontario. The safety relay, which was to trip if the current exceeded the capacity of the transmission line, was set too low.

An aircheck of NY City radio station WABC reveals disc jockey Dan Ingram doing a segment of his afternoon drive time show, during which he notes that a record he's playing sounds slow, as do the subsequent jingles played during a commercial break. Ingram quipped that the record "was in the key of R." The station's music playback equipment used motors that got their speed timing from the frequency of the powerline, normally 60 Hz. Comparisons of segments of the hit songs played at the time of the broadcast, minutes before the blackout happened, in this aircheck, as compared to the same song recordings played at normal speed reveal that approximately six minutes before blackout the line frequency was 56 Hz, and just two minutes before the blackout that frequency dropped to 51 Hz. As another recording plays in the background – again at a slower-than-normal tempo – Ingram mentions that the lights in the studio are dimming, then suggests that the electricity itself is slowing down, adding, "I didn't know that could happen". New York City was dark by 5:27 p.m. Power restoration was uneven. Most generators had no auxiliary power to use for startup. Parts of Brooklyn were repowered by 11:00pm, the rest of the borough by midnight. The entire city was not returned to normal power supply until nearly 7:00 a.m. the next day. Power in western New York was restored in a few hours, thanks to the independent generating plant at Eastman Kodak Company in Rochester which stayed online throughout the blackout. It provided auxiliary power to restart other generators in the area which, in turn, were used to get all generators in the blackout area going again.

Following the blackout, measures were undertaken to try to prevent a repetition. Reliability councils were formed to establish standards, share information, and improve coordination amongst electricity providers. The task force that investigated the blackout found that a lack of voltage and current monitoring was a contributing factor to the blackout, and recommended improvements. The Electric Power Research Institute helped the electric power industry develop new metering and monitoring equipment and systems, which have become the modern SCADA systems in use today. Source: Wikipedia

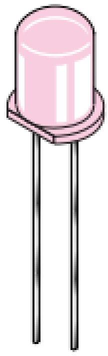
IR LED Specs (Excerpts)

FAIRCHILD SEMICONDUCTOR

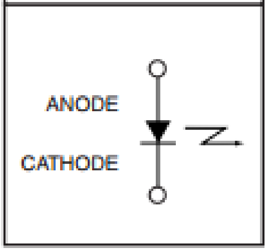
QED121/122/123
PLASTIC INFRARED LIGHT EMITTING DIODE

FEATURES

- λ= 880 nm
- Chip material = AlGaAs
- Package type: T-1 3/4 (5mm lens diameter)
- Matched Photosensor: QSD122/123/124
- Narrow Emission Angle, 18°
- High Output Power
- Package material and color: Clear, peach tinted, plastic



SCHEMATIC



ELECTRICAL / OPTICAL CHARACTERISTICS (T_A =25°C)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN	TYP	MAX	UNITS
Peak Emission Wavelength	I_F = 20 mA	λ_{PE}	—	880	—	nm
Emission Angle	I_F = 100 mA	Θ	—	±9	—	Deg.
Forward Voltage	I_F = 100 mA, tp = 20 ms	V_F	—	—	1.7	V
Reverse Current	V_R = 5 V	I_R	—	—	10	µA
Radiant Intensity QED121	I_F = 100 mA, tp = 20 ms	I_E	16	—	40	mW/sr
Radiant Intensity QED122	I_F = 100 mA, tp = 20 ms	I_E	32	—	100	mW/sr
Radiant Intensity QED123	I_F = 100 mA, tp = 20 ms	I_E	50	—	—	mW/sr
Rise Time	I_F = 100 mA	t_r	—	800	—	ns
Fall Time		t_f	—	800	—	ns

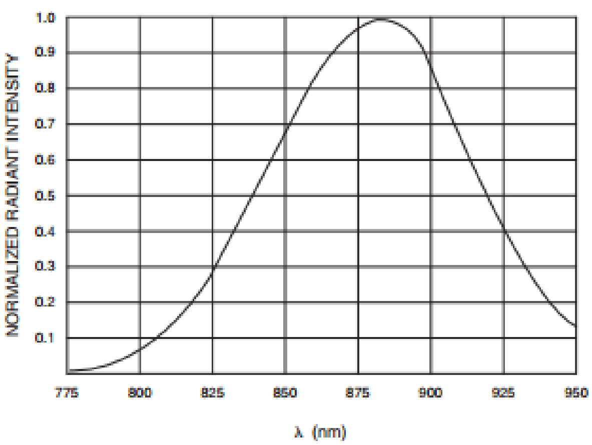
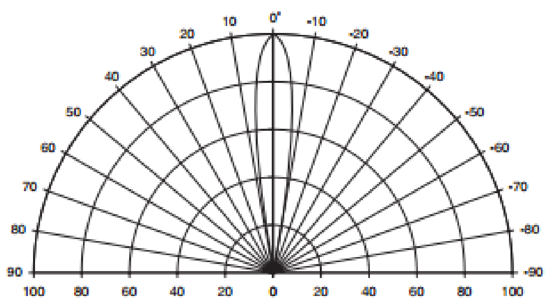


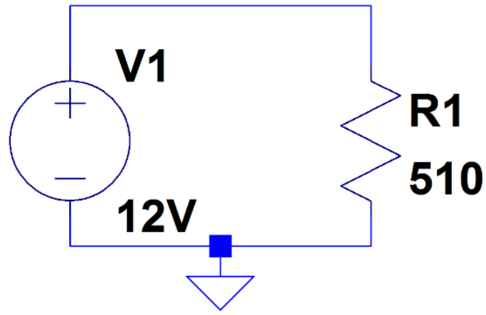
Fig. 4 Normalized Radiant Intensity vs. Wavelength

Fig. 5 Radiation Pattern



Part A: Multiple Choice (20 Points)

1. (3 Pts) Ohm's Law: What is the current I passing through the resistor R1 due to the voltage source V1? *Circle the correct answer and show your work*
   a. .235mA
   b. 61.2mA
   c. 2.35mA
   d. 6.12mA
   e. 23.5mA
   f. .612mA



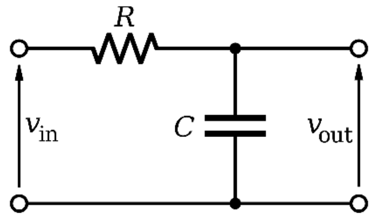
2. (3 Pts) Power to Resistor: What is the power delivered to the resistor in the circuit of question 1? *Circle the correct answer and show your work.*
   a. 28.2mW
   b. 2.82W
   c. 282mW
   d. 734mW
   e. 73.4mW
   f. 7.34W

3. (4 Pts) Decibels – For a simple voltage divider with R_1 = 10kΩ and R_2 = 50kΩ, and the output taken across R_2, find the number of decibels (dB) for the output to input ratio. Both the magnitude and sign must be correct. *Circle the correct answer and show your work.*
   a. 16
   b. -16
   c. .8
   d. -.8
   e. 1.6
   f. -1.6
   g. 8
   h. -8

4. (3 Pts) Radians vs Degrees – The column on the left lists a series of angles in radians and the column on the right lists the same angles in degrees, but not in the same order. *Draw a line connecting the angle in radians with its counterpart in degrees. An example is shown.*

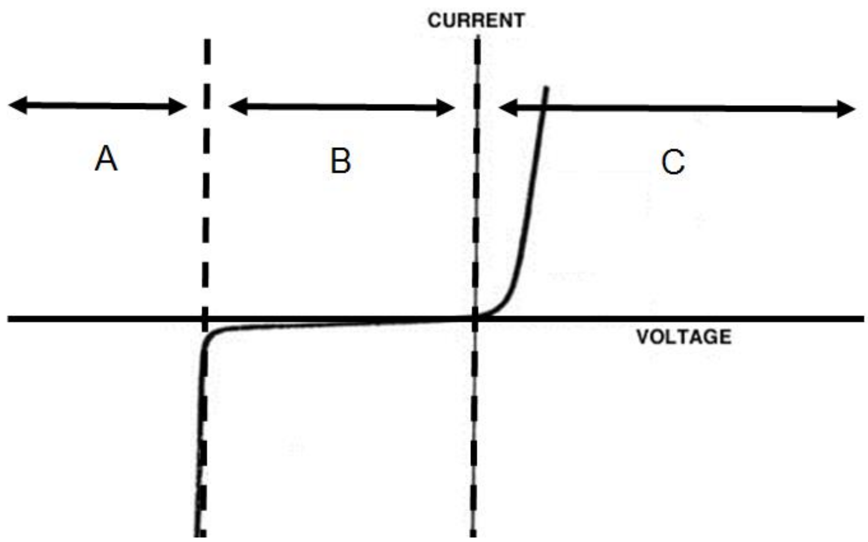
a. –π	h. 0
b. –π/2	i. 90
c. –π/4	j. -45
d. 0	k. 180
e. π/4	l. -180
f. π/2	m. 45
g. π	n. -90

5. (4 Pts) Filters – One of the most characteristic points in an RC or RL filter, is the corner frequency. For the simple RC filter shown in the figure, what is the phase shift at its corner frequency? *Circle the correct answer. Hint: Write the transfer function and simplify it at the corner frequency.*



   a. -180°
   b. -90°
   c. -45°
   d. 0°
   e. 45°
   f. 90°
   g. 180°

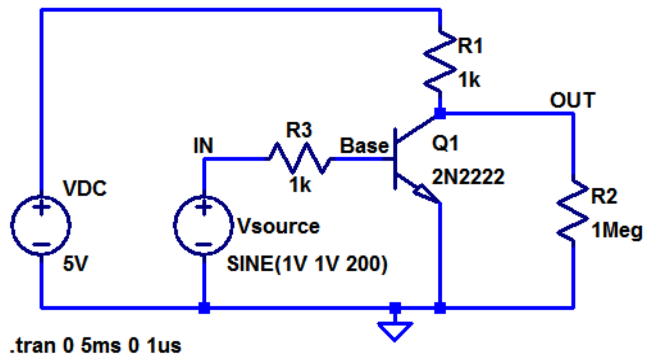
6. (3 Pts) Diode Operating Regions – There are three voltage ranges shown in the realistic diode I-V curve below: the Breakdown Region, The Forward Bias Region and the Reverse Bias Region. Identify which region is which by writing the name of the region under the letter A, B or C on the figure.

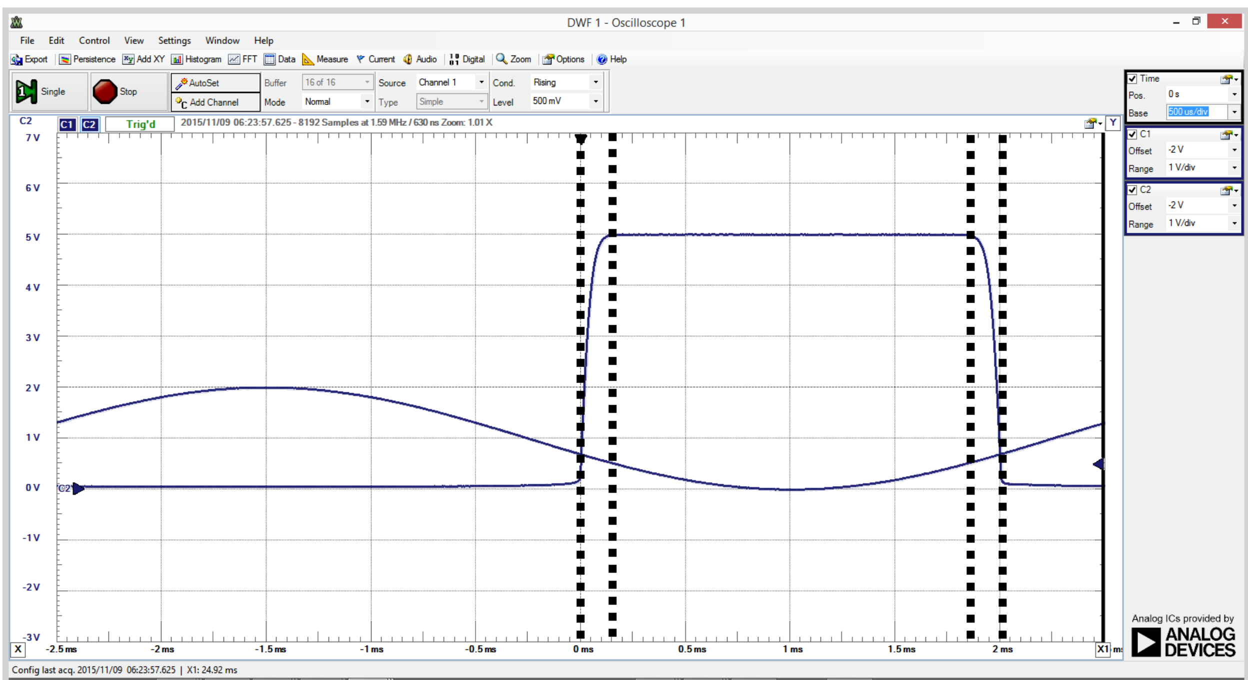


Part B (80 Points) ***See note on front page.***

Problem 1 (10 Points) – Transistor as a Switch

The figure below shows the entire screen for the experiment done to demonstrate how transistors can be used as switches. The circuit for the experiment is shown at the right. Three regions are marked by dashed lines in the figure: where the non-sinusoidal voltage is near zero, where it is near 5V and where it transitions between 0V and 5V. *On the plot, neatly label which signal is the input voltage V(IN), which is the output voltage V(OUT), the time period where the transistor switch is ON and the time period where the transistor switch is OFF. (2.5 Pts each)*





Problem 2 (5 Points) – Wiring the Transistor Circuit

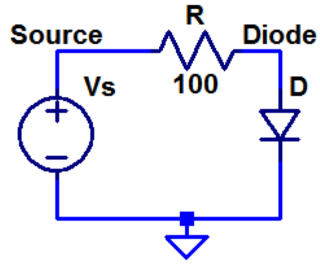
Two voltage sources are used in the transistor circuit: Vsource and VDC.

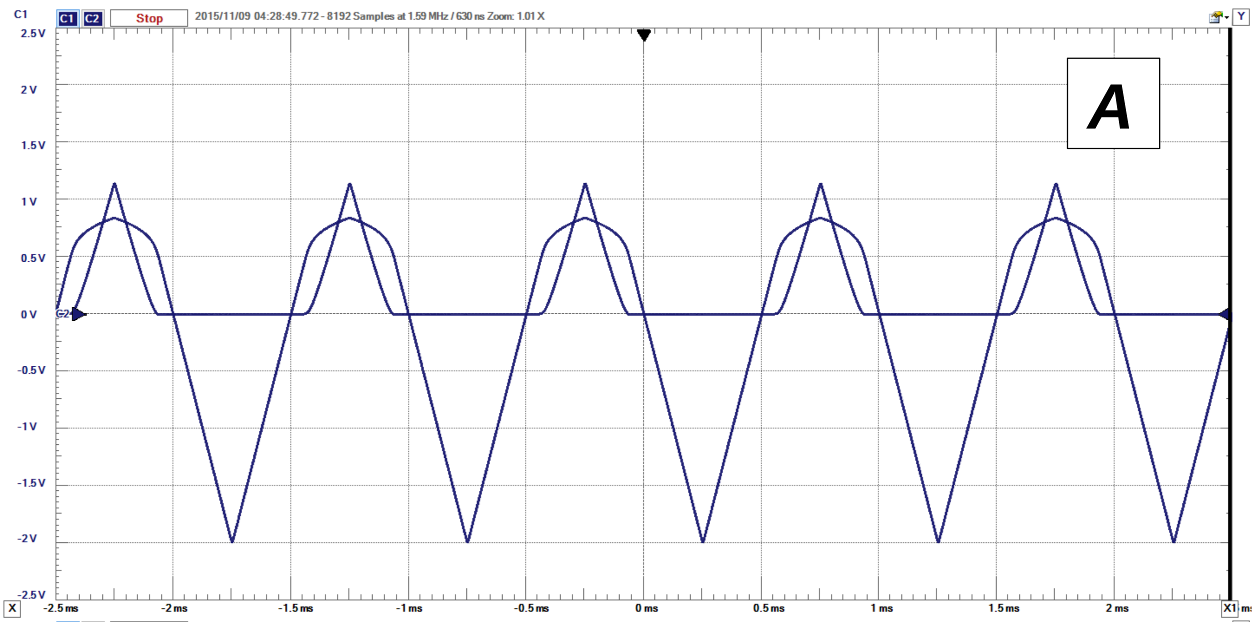
a. (2.5 Pts) What is the name and the color of the wire used for Vsource? *Only the signal, not the ground.*

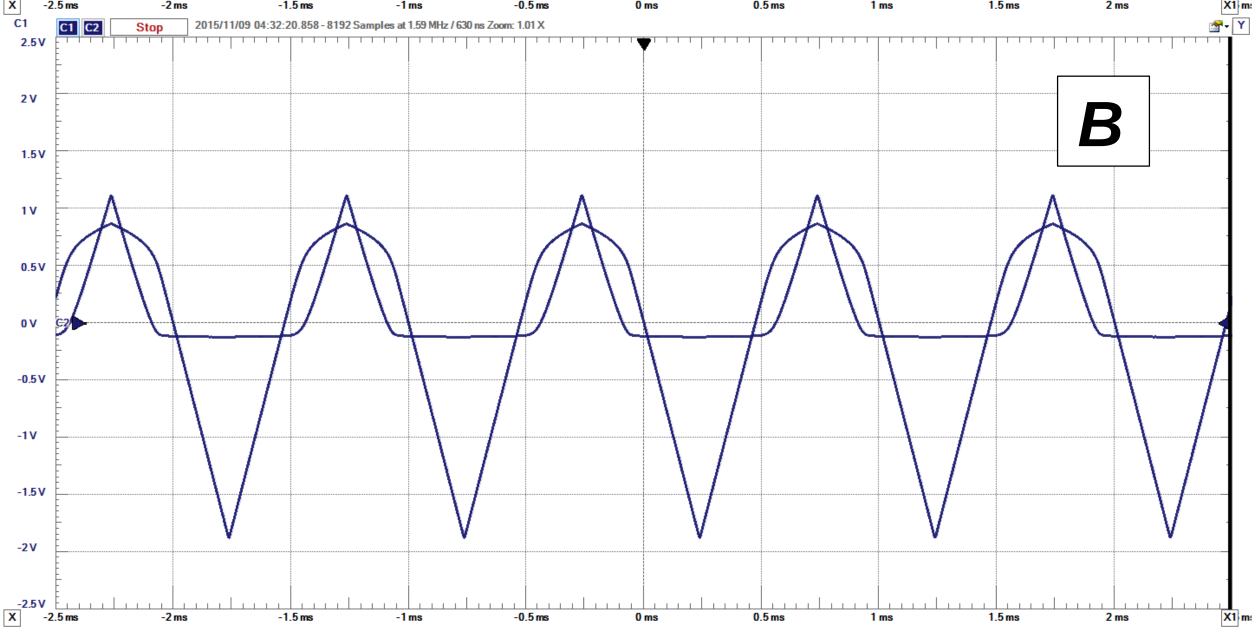
b. (2.5 Pts) What is the name and the color of the wire used for VDC? *Only the signal, not the ground.*

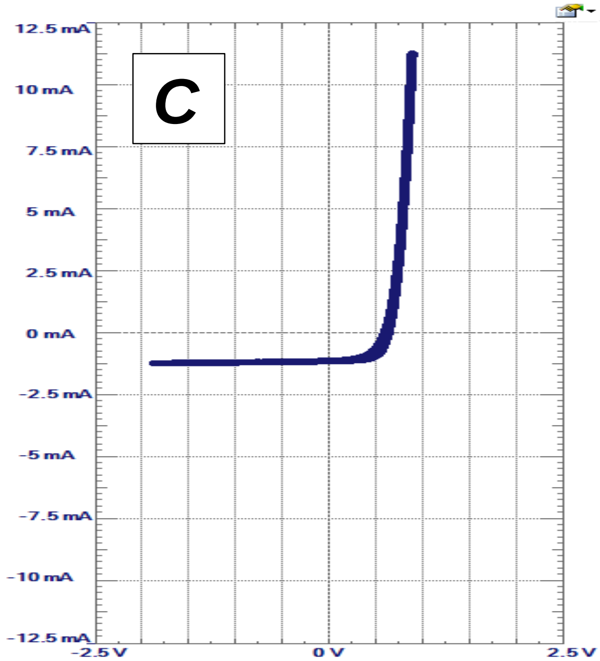
Problem 3 (10 Points) – Photodiode Experiment

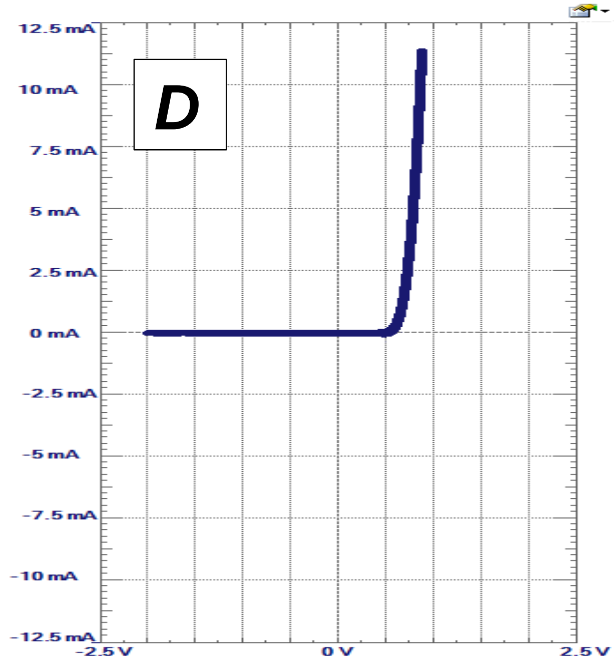
In the diode experiments, you measured voltages and plotted the I-V curves for regular signal diodes (1N914) and a Light Emitting Diode (LED). The same steps can be used to plot similar characteristics for photodiodes and solar cells. Assume that this has been done for an infrared (IR) photodiode, once when it is in the dark and once when it is illuminated by an IR LED. The following sets of raw data are obtained for the voltage across the resistor and the voltage across the diode, as a function of time. The function generator is set to produce a triangle wave with an amplitude of 2V. The vertical scale is 0.5V/Div and the horizontal scale is 0.5mS/Div.











A math channel is also added to display the current through the diode which is then displayed as an I-V curve using the ‘AddXY’ option. For the XY plot, the vertical scale is 2.5mA/Div and the horizontal scale is 0.5V/Div. All four plots are shown but they are not identified, so you must identify them. *Hint: Which plots look like what you have seen before and which are different?*

a. (3 Pts) Which two plots correspond to the case of no IR illumination on the photodiode? *Circle the correct letters.*

A B C D

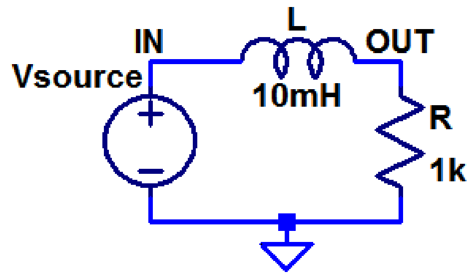
b. (3 Pts) Which two plots correspond to the case of where the IR LED is illuminating the photodiode? *Circle the letters.*

A B C D

c. (4 Pts) For the non-illuminated case, add the loadline to the I-V plot for the source voltage maximum (2V). Note that the resistor R = 100Ω. For the illuminated case, add the loadline for the source voltage minimum (-2V).

Problem 4 (15 Points) – Phasor Analysis of Filters

A simple filter is configured with an inductor and a resistor, as shown. Note that in this case, an ideal inductor is assumed, so there is no separate resistance shown for the inductor.



a. (3 Pts) Is this a high pass or a low pass filter?

b. (3 Pts) Find the general form of the filter transfer function $H(j\omega)=\frac{\tilde{V}_{OUT}}{\tilde{V}_{IN}}=?$ *Hint: Model as a voltage divider using the impedances of the inductor and resistor.*

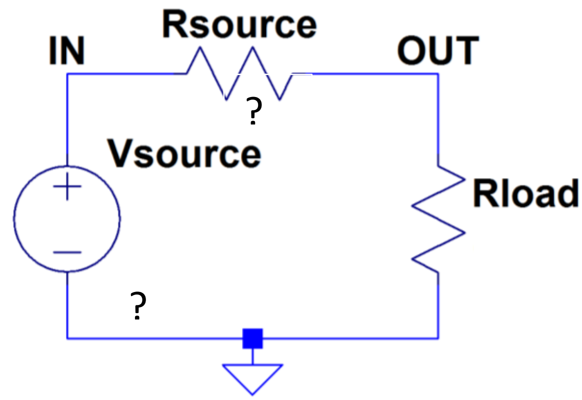
c. (3 Pts) Find the corner frequency in radians. $\omega_C=?$

d. (3 Pts) The input voltage is given as $V_{IN}(t)=\cos\omega_C t$. That is, it has a magnitude of 1V, no phase and is at the corner frequency. Write the input voltage <u>in phasor form</u> $\tilde{V}_{IN}=?$ and then solve for the output voltage in phasor form $\tilde{V}_{OUT}=?$. *Hint: Simplify the transfer function at the corner frequency, then solve for* $\tilde{V}_{IN}$.

e. (3 Pts) Convert the output voltage back to time varying form $V_{OUT}(t)=?$

Problem 5 (10 Points) – Source Characterization Using a Voltage Divider

Batteries and other voltage sources can generally be modeled by combining an ideal voltage source and a resistor. The circuit at the right is set up to study some kind of a black box DC voltage source. Six different load resistors are connected and the voltage V(OUT) is measured. The results of the six trials are listed in the table below. *Note that there is more information than you need to find the source voltage and resistance.*



Trial	Rload	V(OUT)
1	1MΩ	12V
2	100kΩ	11.99V
3	10kΩ	11.94V
4	1kΩ	11.43V
5	100Ω	8V
6	10Ω	2V

a. (5 Pts) Determine the source voltage Vsource.

b. (5 Pts) Determine the source resistance Rsource.

Problem 6 (10 Points) – Phase

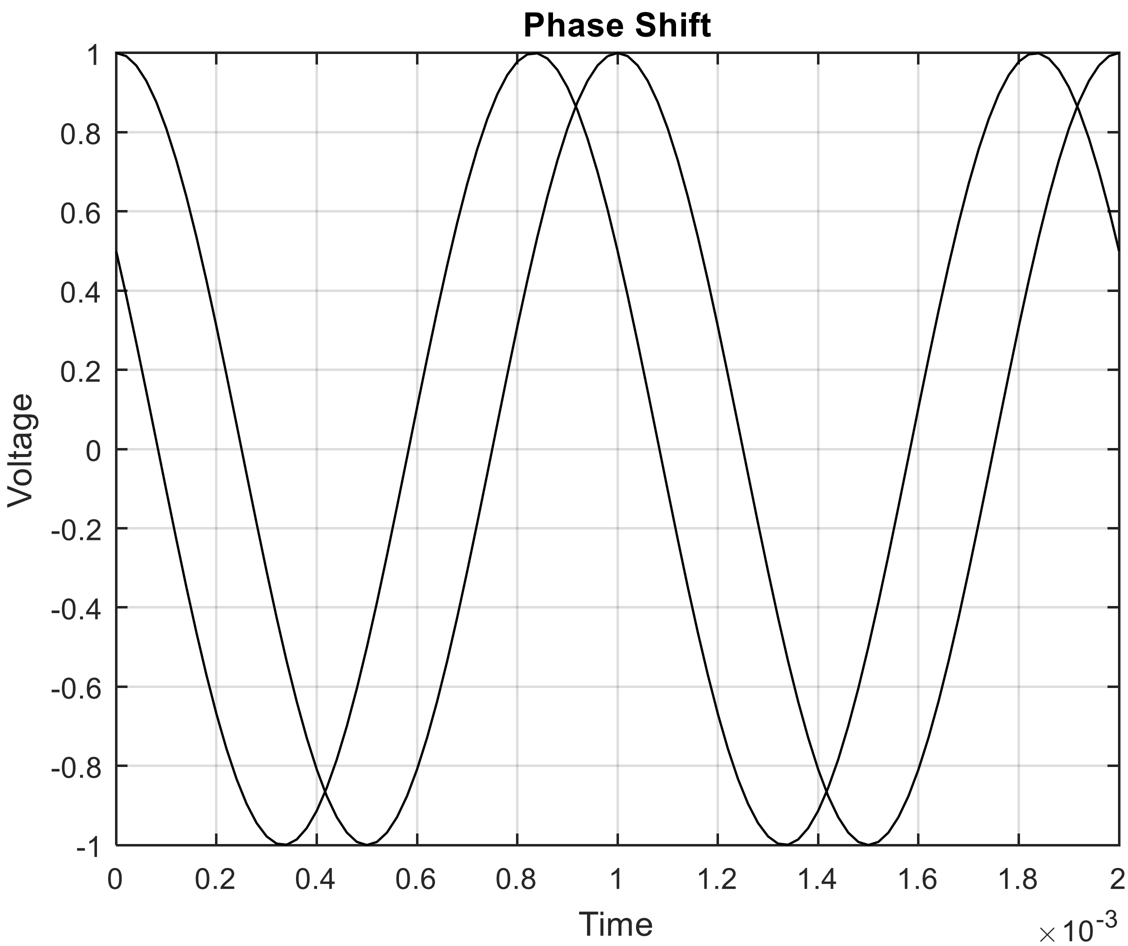
In the Matlab generated plot below, two cosinusoidal voltages are shown vs time. $V(t) = \cos(\omega t)$ and $U(t) = \cos(\omega t + \varphi)$. The magnitude of both voltages is 1V. The vertical scale is 0.2V/Div and the horizontal scale is 0.2ms/Div

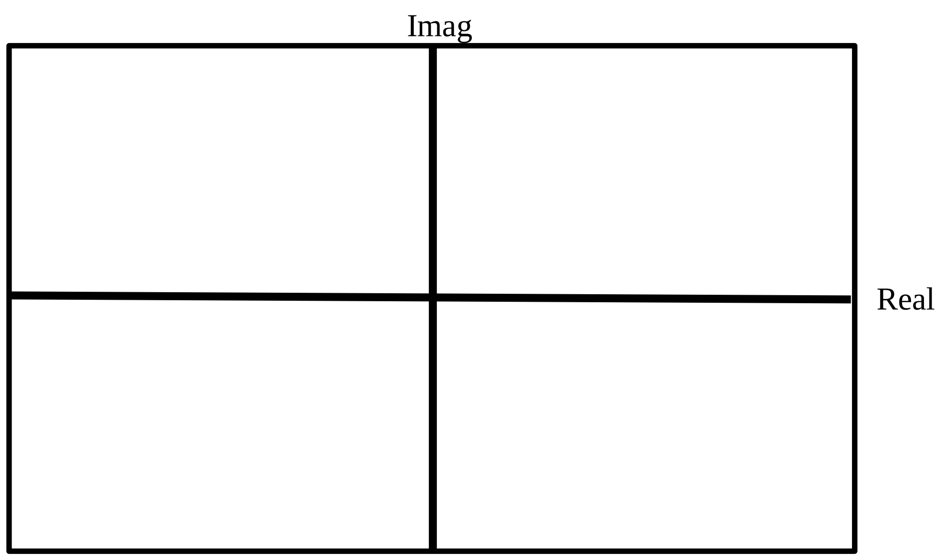
a. (4 Pts) Determine the frequency *f Hz* and ω *Radians.*

b. (2 Pts) Determine the phase of *U. Be sure to specify its sign.*

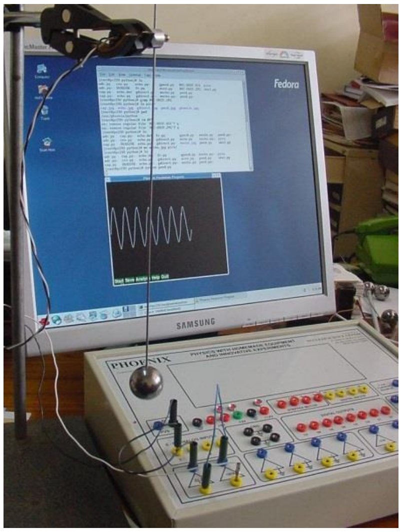
c. (2 Pts) What is the phasor form of $\tilde{U} = ?$

d. (2 Pts) Plot the point for the phasor voltage on the complex plane. *Plot the point that represents its value as a complex number. Be sure to fully label the plot.*

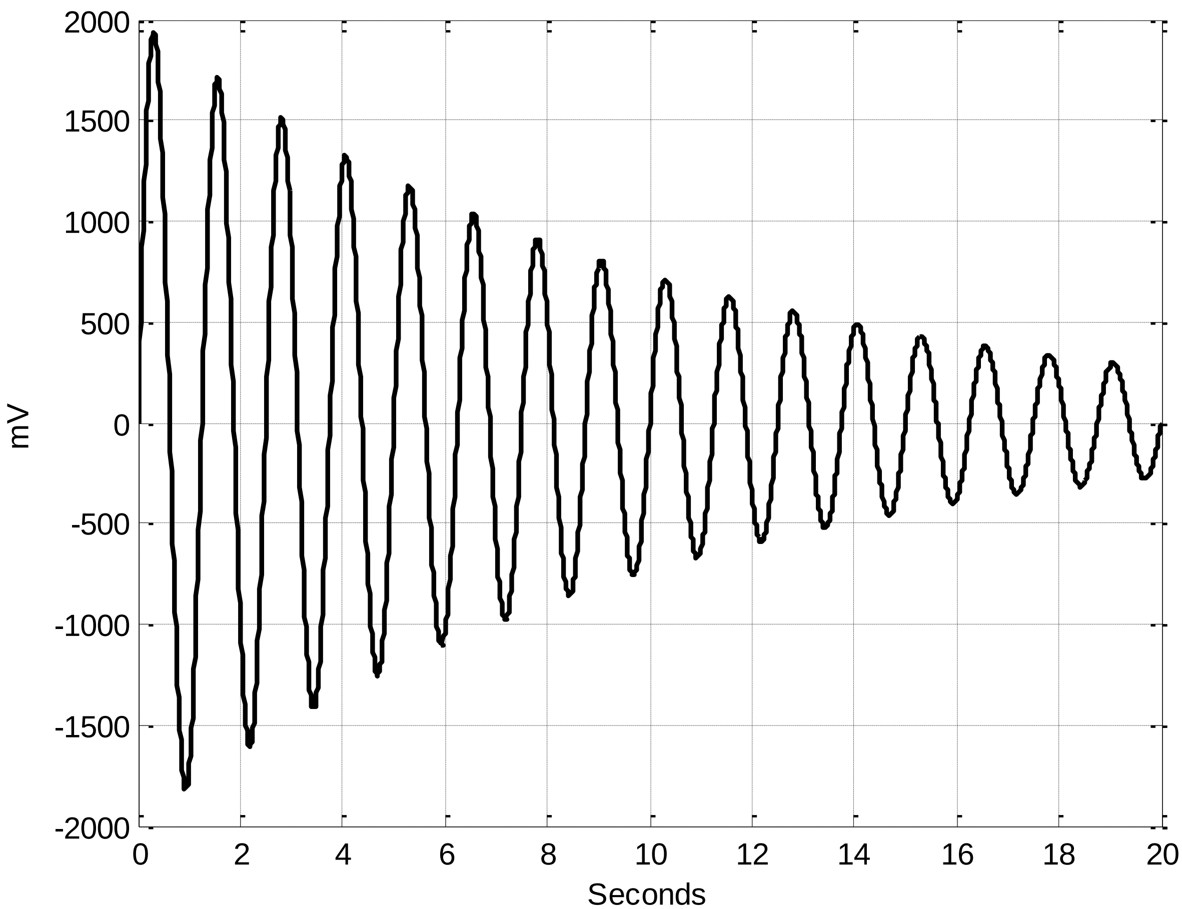




Problem 7 (15 Points) – Harmonic Oscillators and Math



We encounter the harmonic oscillator in an unlimited number of circumstances in engineering and science. For example, you have likely done some kind of a pendulum experiment in Physics. A pendulum experiment from the Inter-University Accelerator Center in New Delhi uses a clever measurement setup to monitor the motion of a simple ball and rod pendulum. They did not have an elaborate sensor, so they used a DC motor as a generator, which they clamped in place and attached the rod to the motor axle. The Phoenix (Physics with Home-made Equipment & Innovative Experiments) system they developed is used to record the data. For clarity, their data are plotted below using Matlab, rather than showing their raw data. Simple motors are also generators, so if something mechanically drives the axle, the wires that usually go to the power supply will see a voltage induced.

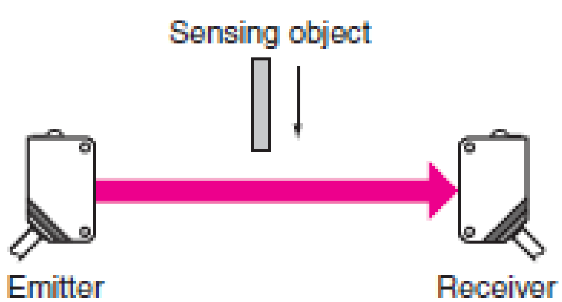


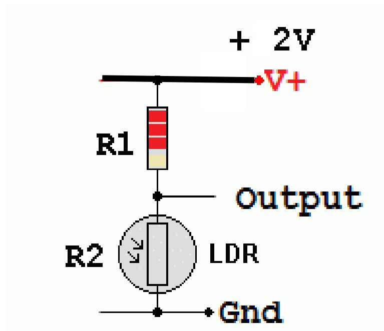
The horizontal scale is time (2 sec per division) and the vertical scale is mV (500mV per division). The horizontal scale is from 0s to 20s. The vertical scale is from -2000mV to 2000mV.

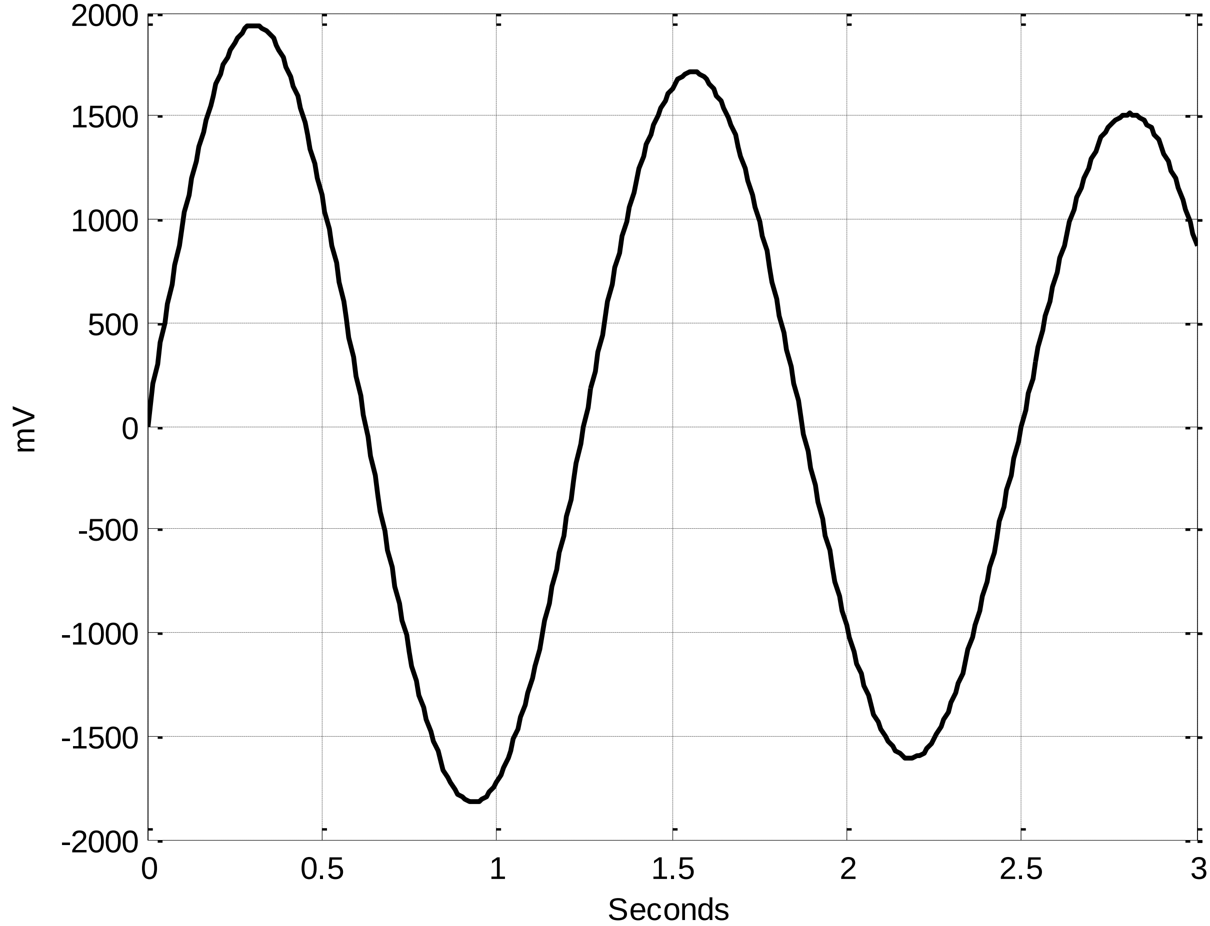
a. (6 Pts) Find the decay constant α and the angular frequency ω for this data. *See part b for how α and ω are used to mathematically represent the decaying voltage. Also,* $\alpha = \frac{1}{\tau}$ *since we have been using the constant τ to represent decay.*

b. (6 Pts) Write the mathematical expression for the voltage in one of the forms $V(t) = Ae^{-\alpha t}\cos\omega t$ or $V(t) = Ae^{-\alpha t}\sin\omega t$, depending on which form fits the data better. Use real values for the constants and provide units where appropriate.

c. (3 Pts) The students doing this experiment also used a clever position measurement to validate their velocity data. They directed a beam of light perpendicular to the motion of the pendulum ball so the ball would block the beam when passing by. The beam is detected by a photocell (Light Dependent Resistor), whose resistance is 1kΩ when illuminated and 100kΩ when the light is blocked. The photocell is connected to a +2V DC supply through resistor R1, forming a voltage divider. The stripes on R1 are Red-Red-Red. Sketch the voltage measured across the photocell vs t on the plot below (an expanded version of the plot above). Assume the full displacement of the ball is 20cm and the ball diameter is about 2cm. *Be neat and label your plot, but perfect accuracy is not necessary.*






2000
1500
1000
500
0
-500
-1000
-1500
-2000
mV
0
0.5
1
1.5
2
2.5
3
Seconds

Problem 8 (5 Points) – IR LED, Reading Spec Sheets

The infrared LED in the Digilent parts kit is a QED-123 from Fairchild Semiconductor. Excerpts from the spec sheet are found at the beginning of this quiz. Read the following from Warwick University about IR health issues, and then answer the two questions below.

- "Infra-red radiation, also known as IR, is named because the wavelength is slightly longer than red light in the visible light spectrum. Infra-red is usually divided into near (IR-A), mid (IR-B) and far-infrared (IR-C) regions;
  Near IR-A: 700 nm–1400 nm and the region closest in wavelength to the red light visible to the human eye
- Mid IR-B: 1400 nm–3000 nm
- Far IR-C: 3000 nm–1 mm

Mid and far-IR are progressively further from the visible spectrum and nearer to microwave radiation.
There are two potentially significant hazards associated with IR radiation:
Thermal effects.
Infrared waves are given off by all warm objects and produce heat in all objects they strike. The waves cause heat by exciting molecules (increasing their movement) in the substances they strike. The earth is warmed by infrared radiation from the sun.
Eye effects.
The main biological effects of IR-A radiation are infrared cataracts and flash burns to the cornea due to temperature rise in the tissue. But IR-A radiation wavelengths are close to the visible light wavelengths and are transmitted to a small extent to the retina; permanent retinal damage can occur if exposure is prolonged. As wavelengths increase into the IR-B and IR-C regions the radiation is no longer transmitted to the retina but corneal flash burn injuries can still be caused.

a. (3 Pts) In which IR wavelength range does the QED-123 IR LED operate? *Circle the correct answer.*

IR-A IR-B IR-C

b. (2 Pts) What is the value of the voltage necessary for the LED to emit light?