DATE	COURSE/YEAR/GROUP	NAME

UNIVERSITY OF PLYMOUTH

Department of Communication & Electronic Engineering

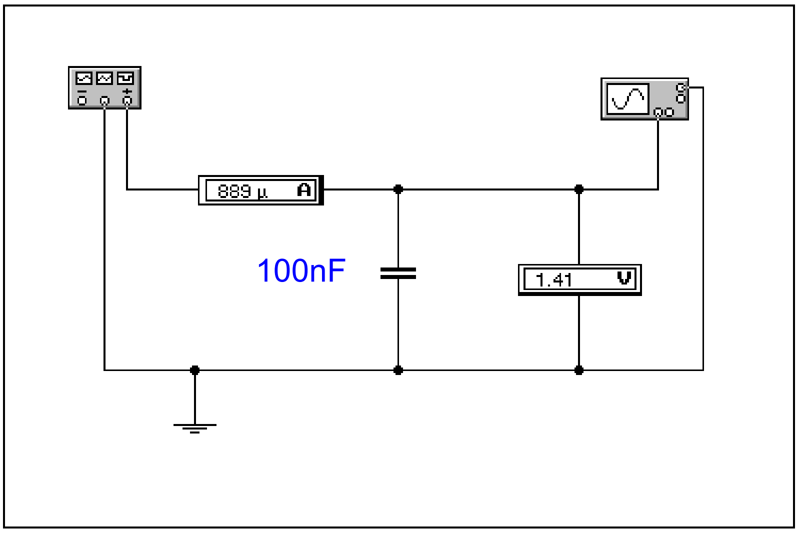
COMPUTER SIMULATION USING "ELECTRONICS WORKBENCH"

The Reactance of a Capacitor

1. Reactance

Reactance is a.c. resistance. It equals V/I and is measured in ohms.

Assemble the circuit shown below, using a capacitor (rotated), a voltmeter, an ammeter, a function generator, and oscilloscope. Don't forget to include the earth.
To get each meter to read on a.c., double click on the meter, and select the AC mode.
Highlight the capacitor by pointing at it and double clicking. Set its value to 100 nF. De-select the capacitor by clicking right with the screen arrow pointing to empty space.



Expand the function generator, and set it as follows:

Waveform	sinusoidal	Frequency	1 kHz
Duty Cycle	50	Amplitude	2 V
Offset	0		

Expand the oscilloscope, and set it as follows:

Timebase	0.20 ms/div	
Channel A	1.00 V/div	& DC

Run the simulation by clicking on the 'Run' switch.

Record the voltmeter reading. Does it agree with the function generator setting, and oscilloscope trace? (Hint: remember the voltmeter and ammeter give rms values).

2. Ohm's Law

Alter the voltage on the function generator, and take five readings for voltage and current. Calculate the ratio: Voltage/current (This is called the reactance, and is the a.c. resistance measured in ohms).

Voltage V (Volts)	0.707	1.41	2.12	2.83	3.54
Current I (mA)					
Voltage/current (kΩ)					

Does the capacitor obey Ohm's Law at this frequency?
Plot the results on a graph I against V

3. Reactance at Different Frequencies

Set the voltage back to 2 V amplitude, and leave it at this value. What is the rms voltage?

This time vary the frequency on the function generator and read off the current. Suitable frequencies are suggested below.

Frequency	10 Hz	50 Hz	100 Hz	500 Hz	1 kHz
Current I, μA					
Reactance = V/I (kΩ)					

Plot the results on a graph I against f and reactance (see section 2) against 1/f
(NB To calculate the reactance correctly in kΩ, the current must be converted from μA to mA).

What pattern do you see? Express your conclusions in two sentences using the terms 'proportional' and 'inversely proportional'. (See Appendix).

Sentence 1 The current is …………………. to the frequency

Sentence 2 The reactance is …………………. to the frequency.

4. Reactance of Different Capacitors

Set the frequency to 1 kHz, and the applied voltage to 2 V. Do no alter these values. Change the capacitor value and record the current in each case.

Capacitance, nF	100	220	470	1000
Current, mA				
Reactance, (kΩ)				

Again express these results using the terms 'proportional' and 'inversely proportional' (See Appendix).

The current is …………………. the capacitance

The reactance is …………………. the capacitance.

5. The Formula, Reactance = 1/(2πfC)

Select three of your readings and check this formula.

f /Hz	C /nF	Measured Reactance from V/I	Calculated Reactance from 1/(2πfC)

6. Resistors in AC Circuits

Does the ratio V/I for a resistor vary with the frequency?

If you are not sure, replace the capacitor with a 1 kΩ resistor, and find out.

Conclusion:

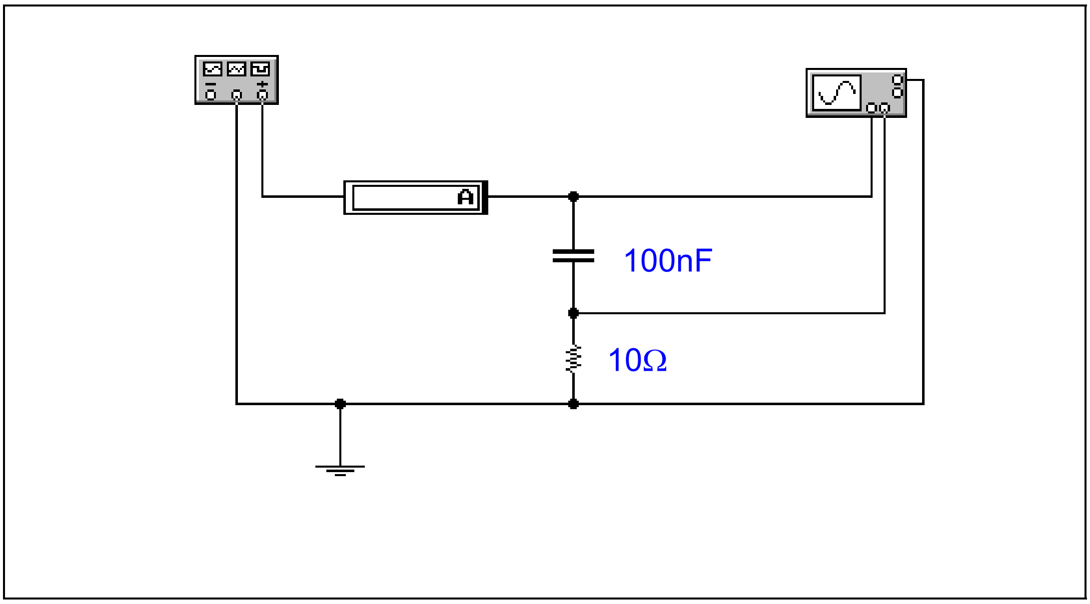
7. Phase Shift

When an alternating voltage is connected to a resistor, the current pulses to and fro in synchronism with the voltage, i.e. when the voltage is a maximum, so is the current. We say that they are in phase.

With a capacitor, things are more complicated.

Unfortunately, it is not too easy to display current waveforms, as the only instrument available is the oscilloscope, which displays voltage. What we have to do is insert a small resistor in series with the capacitor, and monitor the voltage across this. If it is small enough, say 1% of the reactance of the capacitor, it will not upset the circuit significantly.

Wire up the following circuit (R= 10Ω, C= 100nF). We will test this first at a frequency of 1 kHz. Look up the reactance of the capacitor from earlier on, and decide if the resistor value is small enough.



Channel A on the oscilloscope monitors the applied voltage, and channel B shows the voltage across the resistor. This is representative of the circuit current.
Set the oscilloscope as follows:

Timebase	0.20 ms/div
Channel A	1.00 V/div
	X Pos 0.11 (this lines the waveform up with the screen divisions).
Channel B	Select DC
	0.01 V/div (we are measuring a small voltage)
	Select DC

Run the simulation. You should certainly see some phase shift.

To help identify the traces, you can colour them as follows:

Point to the wire leading to channel A input on the CRO, and double click. A small panel of colours appears. Select the desired colour. Do the same for the channel B input. Red and blue seem to stand out best.

What is the phase shift? Measure this as a fraction of a cycle (i.e., 0.5 would be equivalent to the signal inverted).

Phase shift = ……… *360 degrees = ……. degrees

Does the current lead the voltage, or the voltage lead the current?

The ……………………………………………….

Try altering the frequency, but not too much. Try 500 Hz and 2 kHz. You should not be surprised if the height of the current waveform changes.

Why is this?

Does the phase shift change? (Again measured as a fraction of a cycle and then *360 degrees):
Phase shift = ……… *360 degrees = ……. degrees

8. Conclusions
Summarise the results from this sheet:-

1.

2.

3.

4.

5.

9. Appendix - Patterns of Proportionality

If a variable y is directly proportional ('$\propto$') to another variable x, then

when x doubles, so does y

a graph of y against x is a straight line through the origin.

This is written as **y** $\propto$ **x** or **y = kx** where k is a constant.

If y is inversely proportional to x, then

when x doubles, y halves

a graph of y against 1/x is a straight line through the origin.

This is written as **y** $\propto$ **1/x** or **y = k/x** where k is a constant.

From the readings in these investigations, you can probably pick up the patterns by inspection of the figures. However, it would be very useful to plot graphs of:

I against V	section 2
I against f	section 3
reactance against 1/f	section 3

What two graphs should you plot for section 4?

Does the formula **Reactance = 1/(2πfC)** summarise all the results of this investigation?