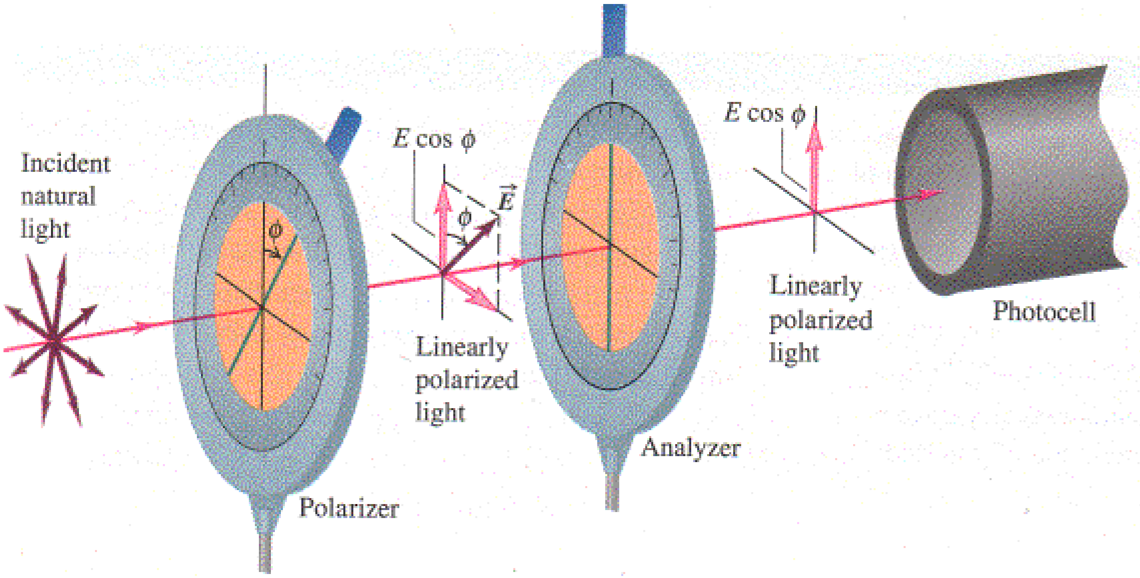
Malus' Law

Purpose: To measure the variation of the transmission of radio waves through 2 polarizers as the orientation angle between them is changed. This is a quantitative continuation of the "Polarized or Unpolarized" activity and should be done in this order.



http://en.wikipedia.org/wiki/Malus%27s_law#Malus.27_law_and_other_properties

Student Info:

1) Designed for Physics (Grades 11/12)
2) Prior Knowledge: "Polarized or Unpolarized" Activity, Graphing of Trig. Functions
3) Suggested Website:
   http://scholar.hw.ac.uk/site/physics/topic6.html

Teacher Info:

1) Prior Knowledge: Polarization Activity and Graphing of Cosine Function
2) Vocabulary: Malus' Law, intensity, electric field and crossed polarizers
3) Suggested Website:
   http://en.wikipedia.org/wiki/Malus's_law

Time Required:

1) Setup ≈ 20 min
2) Activity / Lab ≈ 20 min
3) Data Analysis ≈ 30 min
4) Discussion / Wrap Up ≈ 20 min

Materials Needed:

1) VSRT System (See Appendix I)
2) Single CFL set 2 feet from detectors next to each other (~2.5 inches center to center)
3) Polarizers (~2mm wide / ~2mm spacing) made from metallic tape (Cu or Al) and Polarizer Holder marked at 10° Increments (or mounted to a protractor)

Procedure:

1) Start VSRT System and verify operation without polarizers.
2) Place both polarizers in the same orientation and verify signal level above 100K.
   * Note: If the CFL/LNBF distance is changed, the signal level can be adjusted near 100K, so the output is roughly the % transmission.
3) Rotate one polarizer relative to the other (in front of separate detectors) in 10° increments and record the Power in column #2 in the table below.

4) Repeat until the polarizers are oriented at 90° (crossed) to each other.

Data Table:

Angle [°]	*** Power [K]**	**% Transmission**	**Theoretical Transmission [%])**	**% Difference**
0				
10				
20				
30				
40				
50				
60				
70				
80				
90				
			Average % Diff. =	

*** - See <u>Basic VSRT Operation</u> for discussion of Power [K]**

Calculations:

1) Calculate the % Transmission by dividing the Power at a certain angle by the Power at 0°. { Note: The results should be less than 100% }

2) Compute the theoretical transmission by taking the cosine of the angle, then squaring it and multiplying by 100 for a percentage;

$$\text{i.e. – Trans(theo)} = \cos^2 \theta * 100\%$$

3) Calculate the % Difference = $\dfrac{\text{(\% Transmission – Theoretical Transmission)}}{\text{Theoretical Transmission}}$

4) Average the % Difference and place result in the shaded box on lower right.

Graphing:

1) Setup the graph for the % Transmission (0% to 100%) vs. Angle (0° to 90°) adjusting the scale of the axes to maximize the size of the graph.

2) Graph the measured transmission (2^{nd} column) vs. angle and label it.

3) Graph the theoretical transmission (3^{rd} column) vs. angle and label it.

Questions:

1) Is the graph of % Transmission vs. Angle linear? Why or Why Not?

2) For which angles is there good agreement (<5% difference) between the measured transmission and the theoretical transmissions?

3) Where is the % Transmission most sensitive to small changes in angle (few °)?

4) Where is the % Transmission least sensitive to small changes in angle (few°)?

5) Explain the answers for questions #3 & #4 based on the shape of the curves.

Additional Activities:

1) Vary the polarizer slit widths and spacings to check these effects.
   Note: The slit/spacing width needs to be ~ $1/10^{th}$ the wavelength (~2.5mm).
2) Try both polarizers in front of either LNBF. Does this also work? Why?

Sample Results:

Malus' Law using 12GHz radio waves

Right Polarizer - Horizontal

I(max) = 160

Angle [°]	Signal	Fit=I(max)*cos²θ
0	162	160
10	159	155
20	126	141
30	109	120
40	86	94
50	60	66
60	55	40
70	31	19
80	18	5
90	7	0