

## Experiment 7

### The Microwave experiment

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#### Aim:

This experiment uses microwaves in order to demonstrate the formation of standing waves, verifying the wavelength  $\lambda$  of the microwaves as well as diffraction from double slit and investigate the phenomenon of polarization.

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### Part 1: Standing Waves - Measuring Wavelengths

#### Apparatus:

Transmitter – Goniometer– Receiver

#### Introduction

When two electromagnetic waves meet in space, they superpose. therefore, the total electric field at any point is the sum of the electric fields created by both waves at that point. If the two waves travel at the same frequency but in opposite direction they form a standing wave. Nodes appear where the fields of the two waves cancel and antinodes where the superposed field oscillates between a maximum and a minimum. The distance between nodes in the standing wave pattern is just  $1/2$  the wavelength ( $\lambda$ ) of the two waves.

#### Method

1. Set up the equipment as shown in Figure 7.1. Adjust the Receiver controls to get a full-scale meter reading with the Transmitter and Receiver as close together as possible. Slowly move the Receiver along the Goniometer arm, away from the Transmitter. *How does this motion effect the meter reading?* The microwave horns are not perfect collectors of microwave radiation. Instead, they act as partial reflectors, so that the radiation from the Transmitter reflects back and forth between the Transmitter and Reflector horns, diminishing in amplitude at each pass. However, if the distance between the Transmitter and Receiver diodes is equal to  $n\lambda/2$ , (where  $n$  is an integer and  $\lambda$  is the wavelength of the radiation) then all the multiply-reflected waves entering the Receiver horn will be

in phase with the primary transmitted wave. When this occurs, the meter reading will be a maximum. (The distance between adjacent positions in order to see a maximum is therefore  $\lambda/2$ .)

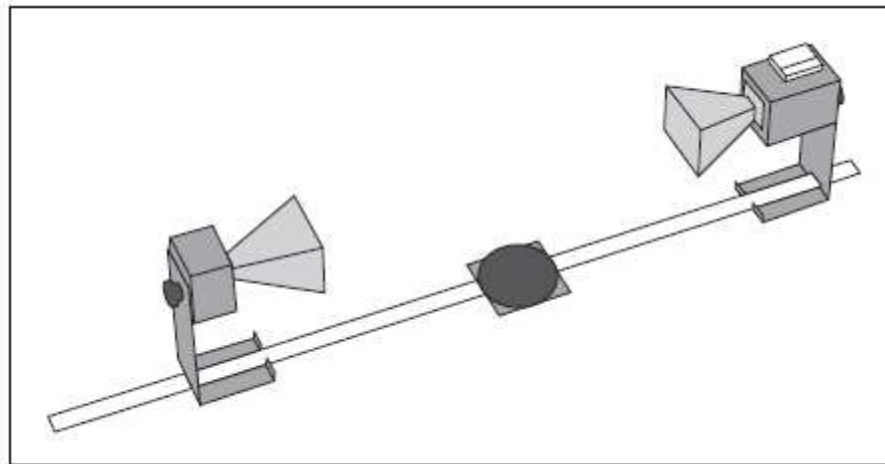


Figure 7.1: Equipment Setup

2. Slide the Receiver one or two centimeters along the Goniometer arm to obtain a minimum meter reading. Record the Receiver position along the metric scale of the Goniometer arm.  
Initial Receiver Position = .....
3. Slide the Receiver to obtain a second minimum.  
Final Receiver Position = .....
4. Repeat your measurements for 3 successive minima and find the average.

You can use table 7.1.

Initial Receiver Position ( $R_1$ )	Final Receiver Position ( $R_2$ )	$L = R_2 - R_1$
		$L_{avg.} =$

Table 7.1

5. Use the data you have collected to calculate the wavelength of the microwave radiation.
  6. Calculate the frequency of the microwave signal.
  7. Compare your result with the theoretical value.
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## Part 2: Polarization

### Apparatus:

Transmitter – Receiver – Goniometer.

## Introduction

The microwave radiation from the Transmitter is linearly polarized along the Transmitter diode axis (i.e., as the radiation propagates through space, its electric field remains aligned with the axis of the diode). If the Transmitter diode were aligned vertically, the electric field of the transmitted wave would be vertically polarized, as shown in Figure 7.3. If the detector diode were at an angle  $\theta$  to the Transmitter diode, as shown in Figure 7.4, it would only detect the component of the incident electric field that was aligned along its axis. In this experiment you will investigate the phenomenon of polarization.

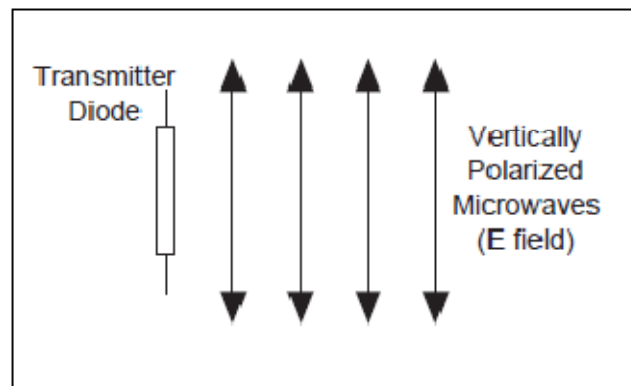


Figure 7.3: Vertical Polarization

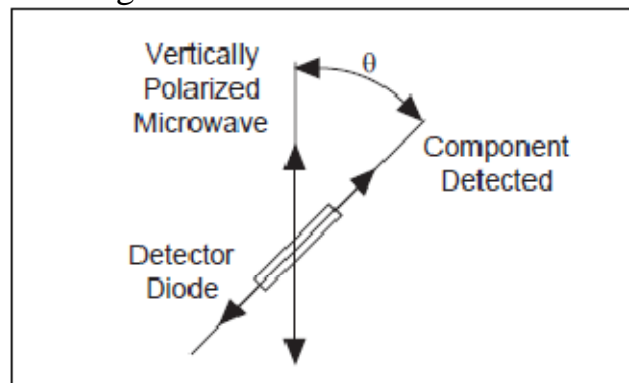


Figure 7.4: Detecting Polarized Radiation

## Method

- 1- Arrange the equipment as shown in Figure 7.1 and adjust the Receiver controls for nearly full-scale meter deflection.
- 2- Loosen the hand screw on the back of the Receiver and rotate the Receiver in increments of ten degrees. At each rotational position, record the meter reading in table 7.2.
- 3- Note what happens to the meter readings if you continue to rotate the Receiver beyond 180-degrees?

- 4- Calculate  $M$  using  $M=M_0\cos\theta$  where  $\theta$  is the angle between the detector and Transmitter diodes and  $M_0$  is the meter reading when  $\theta = 0$ .
- 5- Graph your data from step 2 of the experiment. On the same graph, plot the relationship  $M_0\cos\theta$ . Compare the two graphs.

Angle of receiver	Meter reading M	$M=M_0\cos\theta$	Angle of receiver	Meter reading M	$M=M_0\cos\theta$
0			100		
10			110		
20			120		
30			130		
40			140		
50			150		
60			160		
70			170		
80			180		
90					

Table 7.2

### Part 3: Double-Slit Interference

#### Apparatus:

Transmitter, Receiver - Goniometer, Rotating - Component Holder- Metal Reflectors (2) - Slit Extender Arm -Slit Spacer.

#### Introduction

When an electromagnetic wave passes through a two-slit aperture. The wave diffracts into two waves which superpose in the space beyond the apertures. Similar to the standing wave pattern, there are points in space where maxima are formed and others where minima are formed. With a double slit aperture, the intensity of the wave beyond the aperture will vary depending on the angle of detection. For two thin slits separated by a distance  $d$ , maxima will be found at angles such that  $d \sin\theta = n\lambda$ . (Where  $\theta$ = the angle of detection,  $\lambda$  = the wavelength of the incident radiation, and  $n$  is any integer) (See Figure 7.5).

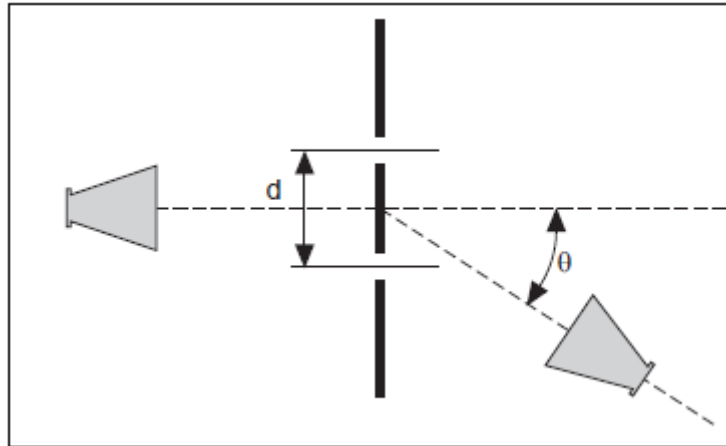


Figure 7.5 Double-Slit Interference

## Method

- 1- Arrange the equipment as shown in Figure 7.6 Use the Slit Extender Arm, two Reflectors, and Slit Spacer to construct the double slit. (We recommend a slit width of about 1.5 cm.) Be precise with the alignment of the slit and make the setup as symmetrical as possible.
- 2- Adjust the Transmitter and Receiver for vertical polarization ( $0^\circ$ ) and adjust the Receiver controls to give a full-scale reading at the lowest possible amplification.
- 3- Set the Goniometer arm so the Receiver directly faces the Transmitter. Adjust the Receiver controls to obtain a meter reading of 1.0. Now set the angle  $\theta$  to each of the values shown in table 7.3. At each setting record the meter reading in the table.
- 4- Plot your data.

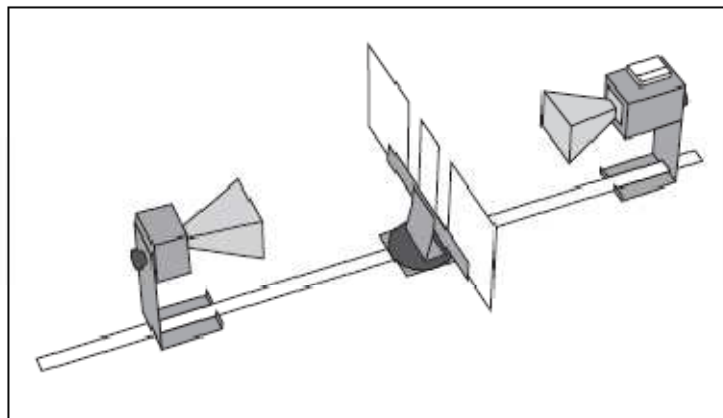


Figure 7.6 Equipment Setup

Angle	Meter Reading	Angle	Meter Reading
0°		45°	
5°		50°	
10°		55°	
15°		60°	
20°		65°	
25°		70°	
30°		75°	
35°		80°	
40°		85°	

Table 7.3

# Equipment

## Introduction

There are many advantages to studying optical phenomena at microwave frequencies. Using a 2.85 centimeter microwave wavelength transforms the scale of the experiment. Microns become centimeters and variables obscured by the small scale of traditional optics experiments are easily seen and manipulated. The PASCO scientific Model WA-9314B Basic Microwave Optics System is designed to take full advantage of these educational benefits. The Basic Microwave Optics System comes with a 2.85 centimeter wavelength microwave transmitter and a receiver with variable amplification (from 1X to 30X). All the accessory equipment needed to investigate a variety of wave phenomena is also included.

This manual describes the operation and maintenance of the microwave equipment and also gives detailed instructions for many experiments. These experiments range from quantitative investigations of reflection and refraction to microwave models of the Michelson and Fabry-Perot interferometers. For those who have either the Complete Microwave Optics System (WA-9316) or the Microwave Accessory Package (WA-9315), the manual describes experiments for investigating Bragg diffraction and Brewster's angle.

## Equipment

### Gunn Diode Transmitter

The Gunn Diode Microwave Transmitter provides 15 mW of coherent, linearly polarized microwave output at a wavelength of 2.85 cm. The unit consists of a Gunn diode in a 10.525 GHz resonant cavity, a microwave horn to direct the output, and an 18 cm stand to help reduce table top reflections. The Transmitter may be powered directly from a standard 115 or 220/240 VAC, 50/60 Hz outlet by using the provided power supply. Other features include an LED power-indicator light and a rotational scale that allows easy measurement of the angle of polarization.

The Gunn diode acts as a non-linear resistor that oscillates in the microwave band. The output is linearly polarized along the axis of the diode and the attached horn radiates a strong beam of microwave radiation centered along the axis of the horn.

### To Operate the Microwave Transmitter

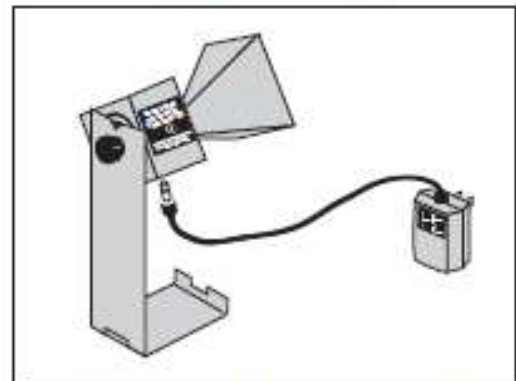
Simply plug the power supply into the jack on the Transmitter's bottom panel and plug the power supply into a standard 115 or 220/240 VAC, 50/60 Hz outlet. The LED will light indicating the unit is on.

► **CAUTION:** The output power of the Microwave Transmitter is well within standard safety levels. Nevertheless, one should never look directly into the microwave horn at close range when the Transmitter is on.

### Power Supply Specifications:

9 Volt DC, 500 mA.

Miniature Phone Jack Connector (the tip is positive)



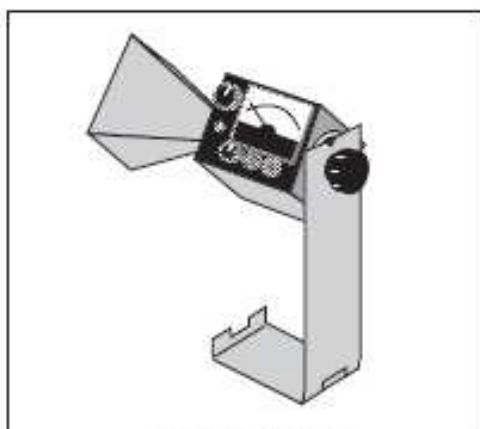
Microwave Transmitter with Power Supply



### Microwave Receiver

The Microwave Receiver provides a meter reading that, for low amplitude signals, is approximately proportional to the intensity of the incident microwave signal. A microwave horn identical to that of the Transmitter's collects the microwave signal and channels it to a Schottky diode in a 10.525 GHz resonant cavity. The diode responds only to the component of a microwave signal that is polarized along the diode axis, producing a DC voltage that varies with the magnitude of the microwave signal.

Special features of the Receiver include four amplification ranges—from one to thirty—with a variable sensitivity knob that allows fine tuning of the amplification in each range. For convenience in class demonstrations, banana plug connectors provide for an output signal via hookup to a projection meter (such as PASCO Model ES-9065 Projection Meter or SE-9617 DC Voltmeter). This output can also be used for close examination of the signal using an oscilloscope. The receiver is battery powered and has an LED battery indicator; if the LED lights when you turn on the Receiver, the battery is working. As with the Transmitter, an 18 cm high mount minimizes table top reflections, and a rotational scale allows convenient measurements of polarization angle.



Microwave Receiver

The female audio connector on the side of the Receiver is for an optional Microwave Detector Probe (PASCO Model WA-9319). The probe works the same as the Receiver except it has no horn or resonant cavity. The Probe is particularly convenient for examining wave patterns in which the horn could get in the way, such as the standing wave pattern described in Experiment 3 of this manual.

►NOTE: The detector diodes in the Receiver (and the Probe) are non-linear devices. This non-linearity will provide no problem in most experiments. It is important however, to realize that the meter reading is not directly proportional to either the electric field ( $E$ ) or the intensity ( $I$ ) of the incident microwave. Instead, it generally reflects some intermediate value.

### To Operate The Microwave Receiver:

►NOTE: Before using the Receiver, you will need to install the two 9-volt transistor batteries—they are included with the system. See the instructions in the Maintenance section at the end of this manual.

- ① Turn the INTENSITY selection switch from OFF to 30X, the lowest amplification level. The battery indicator LED should light, indicating that the battery is okay. If it does not, replace the battery following the procedures in the Maintenance section of this manual.

►NOTE: The INTENSITY selection settings (30X, 10X, 3X, 1X) are the values you must multiply the meter reading by to normalize your measurements. 30X, for example, means that you must multiply the meter reading by 30 to get the same value you would measure for the same signal with the INTENSITY selection set to 1X. Of course, this is true only if you do not change the position of the VARIABLE SENSITIVITY knob between measurements.

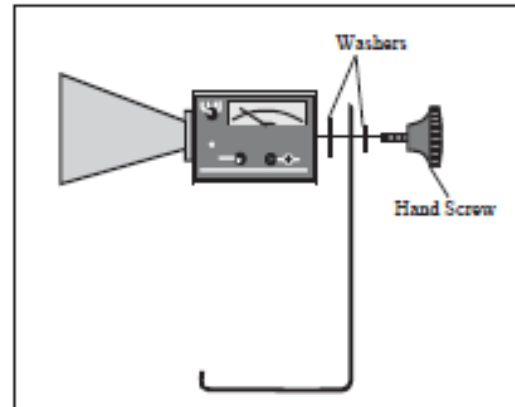
- ② Point the microwave horn toward the incident microwave signal. Unless polarization effects are under investigation, adjust the polarization angles of the Transmitter and Receiver to the same orientation (e.g., both horns vertically, or both horns horizontally).
- ③ Adjust the VARIABLE SENSITIVITY knob to attain a meter reading near midscale. If no deflection of the meter occurs, increase the amplification by turning the INTENSITY selection switch clockwise. Remember, always multiply your meter reading by the appropriate INTENSITY selection (30X, 10X, 3X, or 1X) if you want to make a quantitative comparison of measurements taken at different INTENSITY settings.



## Initial Setup

To attach the microwave Transmitter and Receiver to their respective stands prior to performing experiments, proceed as follows:

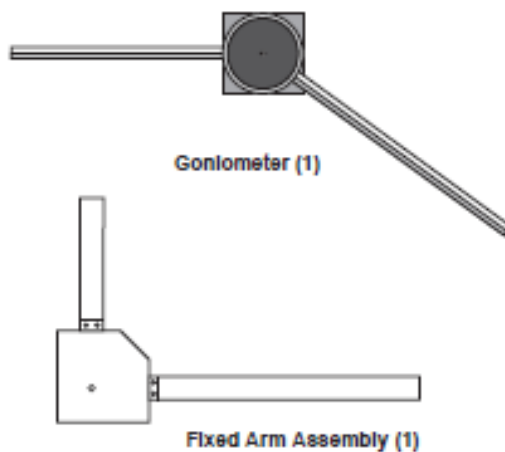
- ① Remove the black hand screw from the back panel of both the Transmitter and the Receiver.
- ② Attach both units to the stands as shown below. Observe the location of the washers.
- ③ To adjust the polarization angle of the Transmitter or Receiver, loosen the hand screw, rotate the unit, and tighten the hand screw at the desired orientation. Notice the rotational scale on the back of each unit for measuring the angle of polarization. Be aware, however, that since the Transmitter and Receiver face each other in most experiments it is important to match their polarization angle. If you rotate one unit to an angle of 10-degrees, you must rotate the other to -10-degrees (350-degrees) to achieve the proper polar alignment.



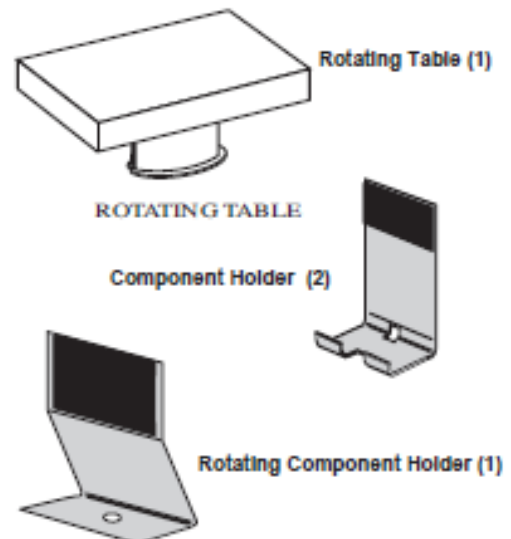
Attaching the Transmitter and Receiver Stands

## Accessory Equipment

Accessory equipment for the Basic Microwave Optics System includes:



**PASCO**  
SCIENTIFIC

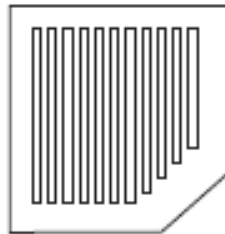




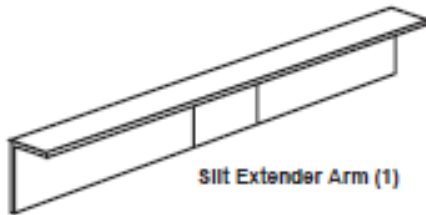
**Metal Reflector (2)**



**Partial Reflector (2)**



**Polarizers (2)**



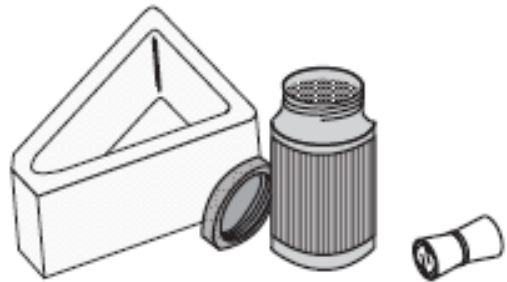
**Slit Extender Arm (1)**



**Narrow Slit Spacer (1)**



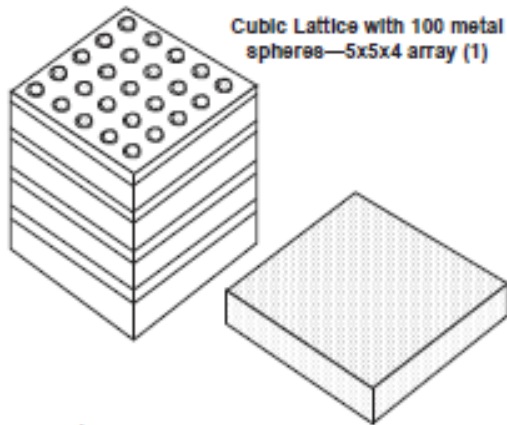
**Wide Slit Spacer (1)**



**Ethafoam Prism Mold w/  
Styrene Pellets (1)**

**Tubular  
Plastic Bags (4)**

The WA-9315 Microwave Accessory Package (which is part of the Complete Microwave Optics System Model WA-9316) includes the following:



**Cubic Lattice with 100 metal  
spheres—5x5x4 array (1)**

**Polyethylene Panel (1)**

The following components, compatible with the WA-9314B Basic Microwave Optics System, are available from PASCO scientific:

**Model WA-9319 Microwave Detector Probe** plugs directly into the Microwave Receiver. The probe is essential for experiments in which the horn of the Receiver might otherwise interfere with the wave pattern being measured.

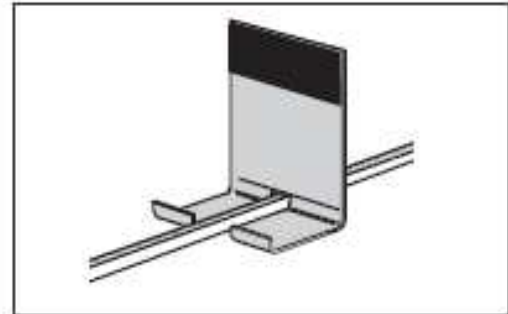
**Model WA-9318 Microwave Modulation Kit** includes a modulator and microphone. With this kit, you can use your Transmitter and Receiver as a microwave communications system.

## Assembling Equipment for Experiments

The arms of the Goniometer slide through the holes in the Component Holders as shown. Make sure the magnetic strip on the bottom of the arm grips the base of the carriage. To adjust the position of the holders, just slide them along the Goniometer arms. Attach the mounting stands of the microwave Transmitter and Receiver to the arms of the Goniometer in the same manner.

For most experiments it is advantageous to attach the Transmitter to the long arm of the Goniometer and the Receiver to the shorter, rotatable arm. This maintains a fixed relationship between the microwave beam and components mounted on the long arm (or on the degree plate) of the Goniometer. In turn the Receiver moves easily to sample the output.

Reflectors, Partial Reflectors, Polarizers, Slit Spacers, and the Slit Extender Arm all attach magnetically to the Component Holders. The metric scale along the Goniometer arms and the degree plate at the junction of the arms allow easy measurement of component placement. When rotating the rotatable arm, hold the degree plate firmly to the table so that it does not move.



**Mounting the Component Holder**

### ► IMPORTANT NOTES:

1. **CAUTION**—Under some circumstances, microwaves can interfere with electronic medical devices. *If you use a pacemaker, or other electronic medical device, check with your doctor or the manufacturer to be certain that low power microwaves at a frequency of 10.525 GHz will not interfere with its operation.*
2. Always mount the apparatus on a **CLEAN, SMOOTH** table. Before setting up the equipment, brush off any material—*particularly metal chips*—that might have adhered to the magnetic strips on the bottom of the Goniometer arms.

