SI Physics - Full Discipline Demo

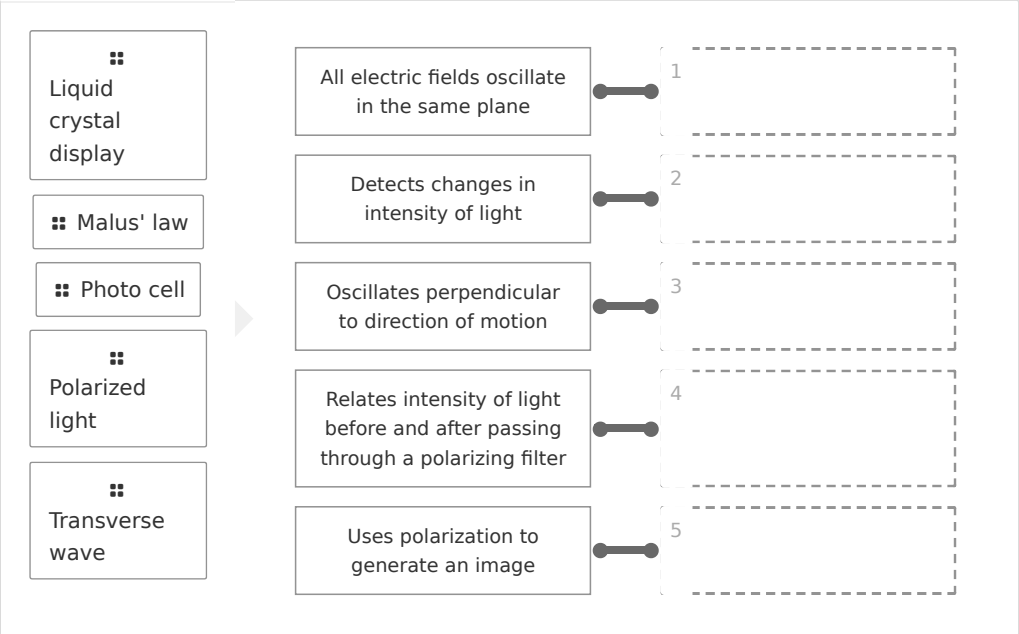
Polarimetry

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term with the best description.

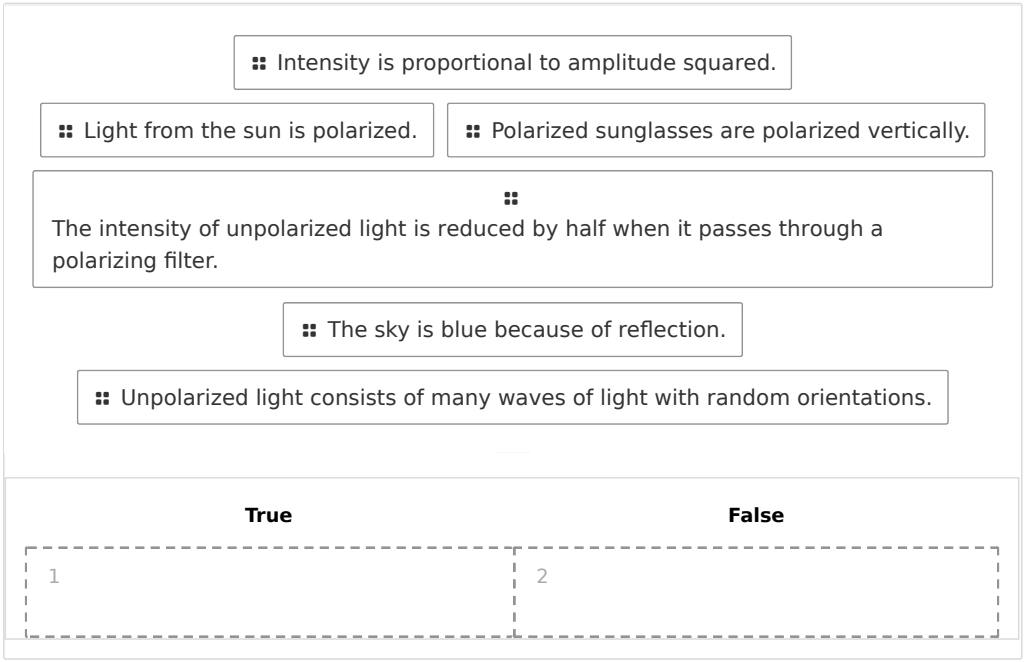


Correct answers:

1 Polarized light 2 Photo cell 3 Transverse wave 4 Malus' law

5 Liquid crystal display

Categorize each statement as true or false.



Correct answers:

1 Intensity is proportional to amplitude squared.

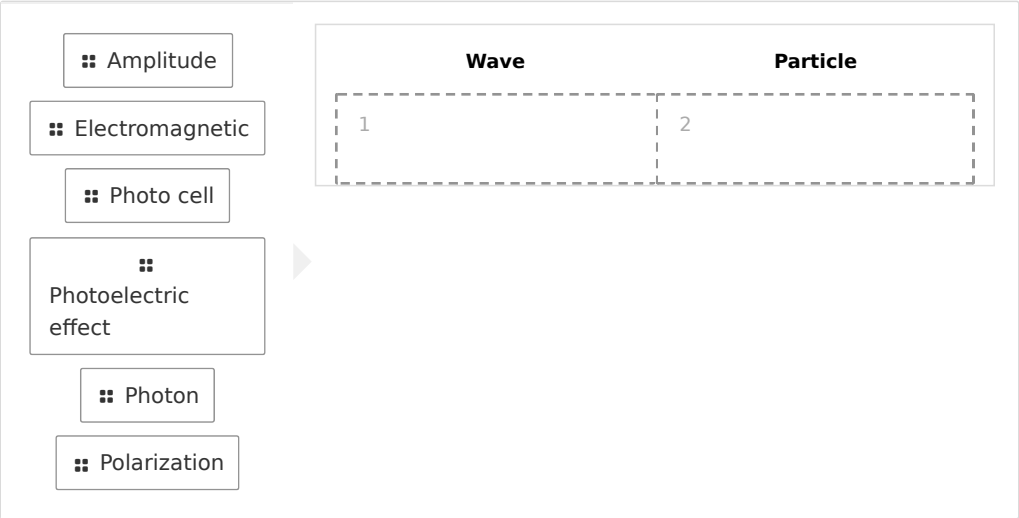
Unpolarized light consists of many waves of light with random orientations.

Polarized sunglasses are polarized vertically.

The intensity of unpolarized light is reduced by half when it passes through a polarizing filter.

2 Light from the sun is polarized. The sky is blue because of reflection.

Categorize each term as relating to the wave or particle nature of light.



Correct answers:

1 Amplitude Electromagnetic Polarization

2 Photo cell Photoelectric effect Photon

Exploration

Light is a(n) _____, meaning it oscillates perpendicular to the direction of propagation.

- longitudinal wave
- transverse wave ✔
- oscillating electric field
- None of the above

Linearly polarized light all oscillates in the same plane, called the _____.

- plane of polarization ✔
- parallel plane
- plane of alignment
- None of the above

When unpolarized light encounters two polarizing filters aligned perpendicular to each other, no light is transmitted through the second filter.

- True ✔
- False

Only the component of light parallel to the _____ of a polarizing filter is transmitted through the filter.

- plane of polarization ✔
- intensity
- polarization axis
- None of the above

The intensity of a light wave is proportional to the amplitude of the wave.

- True
- False ✔

When a small potential difference is applied across an LCD pixel, the pixel is _____.

- bright
- dark ✔
- unaffected
- None of the above

The _____ effect occurs when photons of light encounter a metallic surface and eject electrons.

- solar cell
- photon
- photoelectric ✔
- None of the above

For a photodiode, intensity is proportional to _____.

- resistance
- 1/resistance ✔
- resistance squared
- None of the above

Exercise 1

Why would an LCD display on calculators or electronic wristwatches appear completely black when viewed through polarized sunglasses? How could one read the display without removing the sunglasses?

If an LCD display appears black when wearing polarized sunglasses, this means the light from the display is polarized perpendicularly to the polarization of the sunglasses. One could read the display without removing the glasses by tilting their head or tilting the calculator or wristwatch.

Why might it be beneficial for a photographer to have a polarizing filter for their camera when taking pictures outdoors?

There may be a strong glare on the object or scenery being photographed and using a polarizing filter would reduce the glare, increasing the clarity of the picture.

What does the vertical polarization axis of polarized sunglasses indicate about the direction of polarization of light bouncing off a horizontal surface, such as a wet road or lake surface? Hint: The purpose of polarized sunglasses is to reduce glare without blocking out all light.

Polarized sunglasses being vertically-polarized means they will let vertically-polarized light through while blocking all horizontally-polarized light. Since these sunglasses reduce glare, this implies that the majority of the light bouncing off the object, which causes the glare, is horizontally polarized.

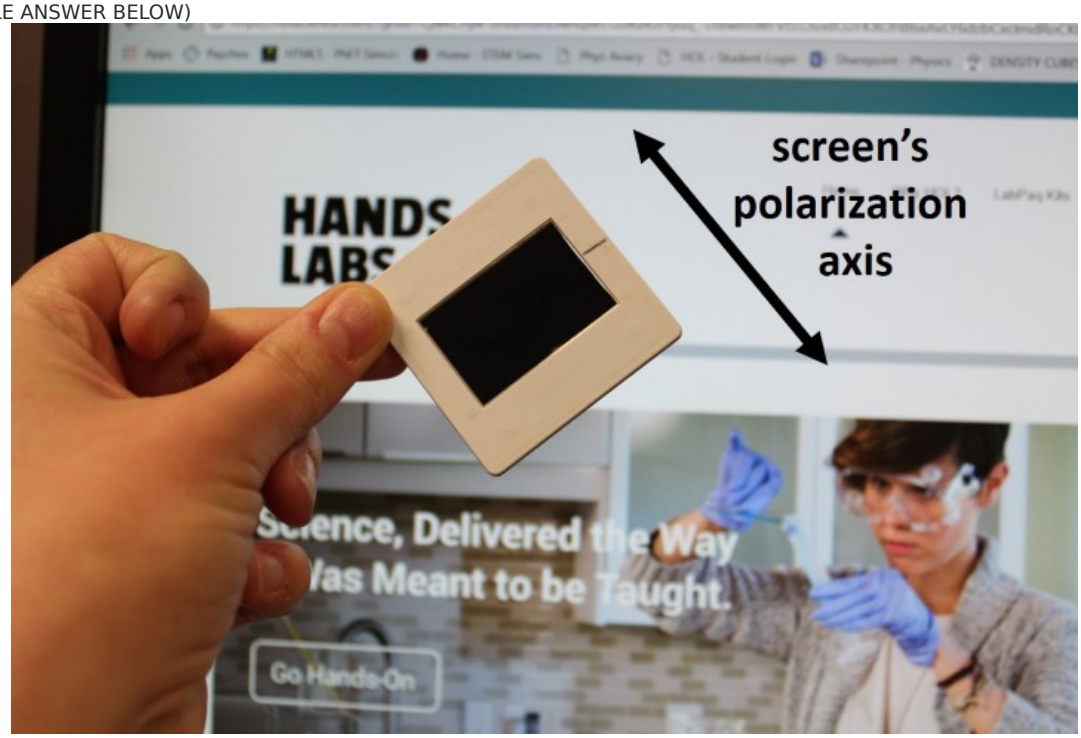
Panel 1: Blue Sky Polarization Observations

(SAMPLE ANSWER BELOW)

As the filter rotates, the clouds in the sky become more or less clear and crisp. When the filter's polarization axis is at an angle from the vertical, the clouds appear to be the most crisp and easiest to see.

Photo 1: Computer Screen Polarization

(SAMPLE ANSWER BELOW)



Panel 2: Crossed Polarizers

(SAMPLE ANSWER BELOW)

As the card rotated relative to the stationary one, the light dimmed until it was completely dark, then brightened again as the card continued to rotate. When the polarization axes of the two cards were perpendicular, it was the dimmest, and when they were parallel it was the brightest.

Exercise 2

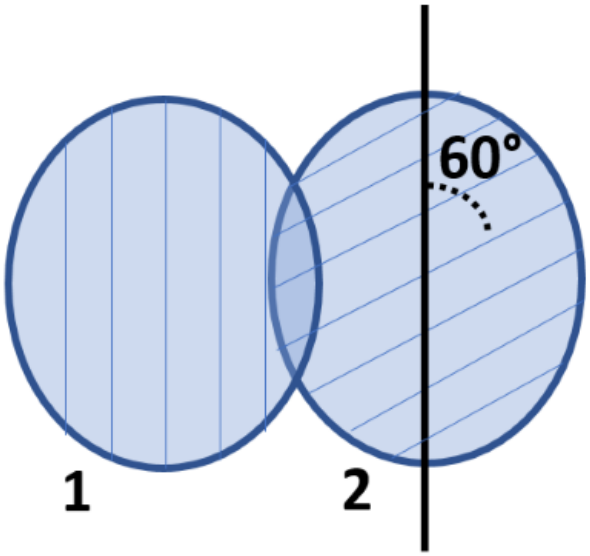
Why was this exercise performed in a dimly-lit room? What was the purpose of measuring the background intensity?

This exercise is done in a dimly-lit room because ambient light in the room will be detected by the photocell. The background intensity was determined so it could be subtracted from the flashlight intensity incident on the photocell. This gives a more accurate depiction of what happens to light intensity with the addition and rotation of polarizing filters.

What is the transmitted intensity of light if unpolarized light passes through a single polarizing filter and the initial intensity is 80 W/m^2?

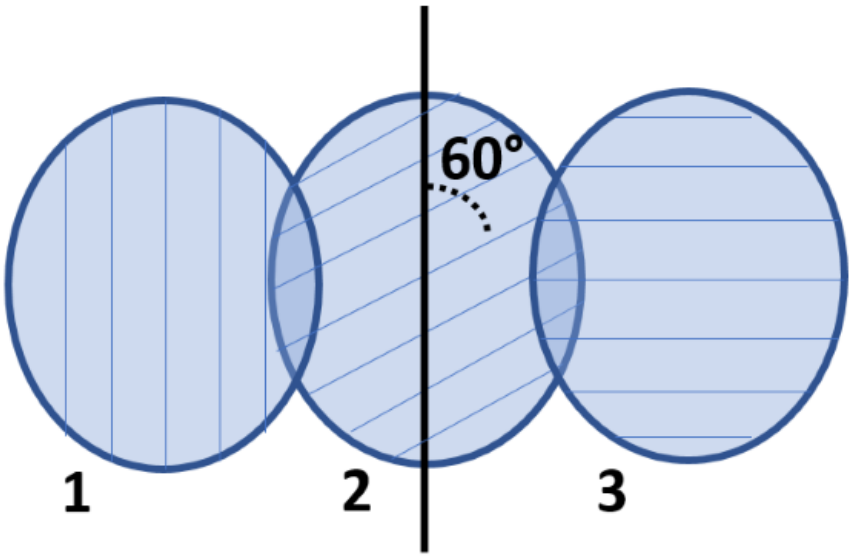
A polarizing filter blocks out all components of light perpendicular to the polarization axis and allows light parallel to the axis to be transmitted. So, half of the incident light is transmitted through a single filter. Thus, the transmitted light intensity is 40 W/m^2.

What is the transmitted intensity of light if an additional polarizer is added at a 60° angle to the setup described in Question 2? Show all work in your answer.



For two polarizers at a relative angle Θ, the new intensity I is given by $I=I_0\cos^2\Theta$. After the light that passes through the first filter, it has an intensity of 40 W/m^2. The second filter is at a 60° angle relative to the polarization axis of the first filter. So, the intensity of light after passing through the second filter is: $I=40\ W/m^2*(\cos(60°))^2=40\ W/m^2*(1/2)^2=40\ W/m^2*(1/4)=10\ W/m^2$.

What is the transmitted intensity of light if an additional polarizer is added perpendicular to the first polarizer in the setup described in Question 3? Show all work in your answer.



After the light that passes through the second filter, it has an intensity of 10 W/m^2. The third filter is at a 30° angle relative to the polarization axis of the second filter. the intensity of light after passing through the third filter is: I=10 W/m^2*$(\cos(30°))^2$=10 W/m^2*$(0.866)^2$=7.5 W/m^2.

How do Graphs 1 and 2 illustrate the behavior of light transmission through two and three polarizing cards?

For two filters, one would expect that at a relative angle of 90° no light would pass through. The behavior would look like a $\cos^2\Theta$ function, which begins at 1, when axes are parallel and is 0 at 90° and 270°; Graph 1 matches this. For three filters, one would expect to see no light transmitted when the center filter makes a 90° angle with either card (at 5 cm or 15 cm). This would resemble the function: $\cos^2\Theta*\cos^2(90°- \Theta)\sim \cos^2\Theta*\sin^2\Theta$, which is 0 at every 90° interval; Graph 2 matches this.

Data Table 1: Background Intensity
(SAMPLE ANSWER BELOW)

Background Resistance R_0 (kΩ)	Background Intensity $1/R_0$
990	0.00101

Data Table 2: Resistance and Light Intensity for Single Polarizer
(SAMPLE ANSWER BELOW)

Number of Polarizing Cards	Resistance R (kΩ)	Relative Light Intensity 1/R (a.u.)	Adjusted Light Intensity 1/R - $1/R_0$ (a.u.)	Ratio
0	0.840	1.19	1.19	0.560
1	1.50	0.667	0.666	

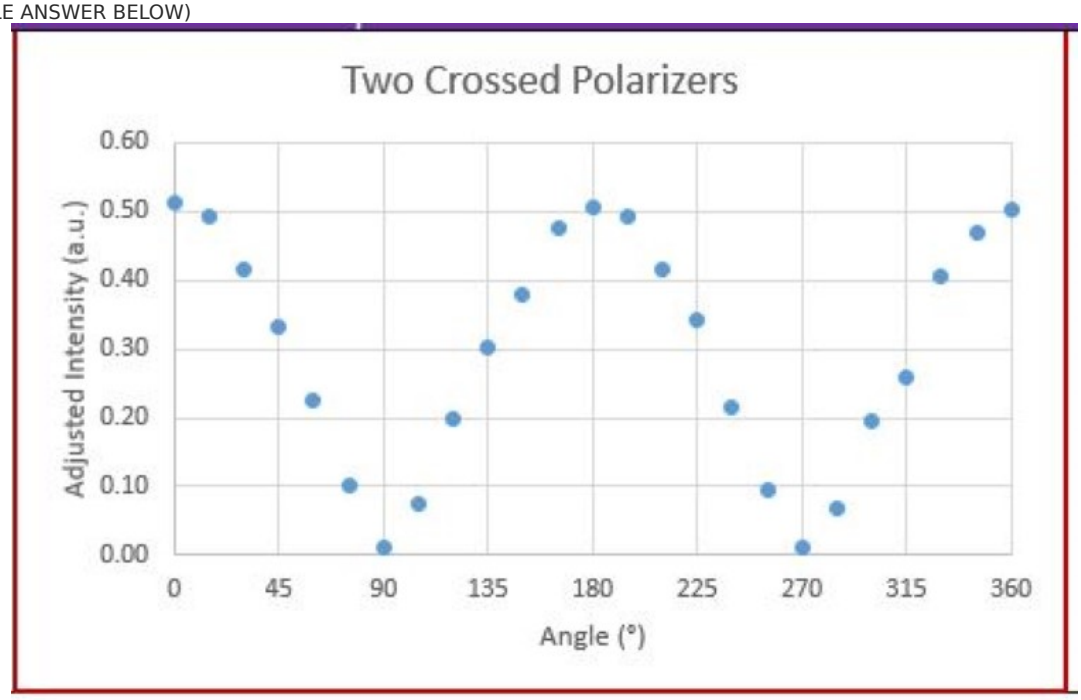
Data Table 3: Resistance and Light Intensity for Two Crossed Polarizers
(SAMPLE ANSWER BELOW)

Angle (°)	Resistance R (kΩ)	Relative Light Intensity 1/R (a.u.)	Adjusted Light Intensity 1/R - $1/R_0$ (a.u.)
0	1.94	0.515	0.514
15	2.03	0.493	0.492
30	2.39	0.418	0.417
45	2.99	0.334	0.333
60	4.41	0.227	0.226
75	9.87	0.101	0.100
90	82.00	0.01220	0.01119
105	13.20	0.07576	0.07475
120	5.01	0.200	0.199
135	3.29	0.304	0.303
150	2.62	0.382	0.381
165	2.10	0.476	0.475
180	1.97	0.508	0.507
195	2.03	0.493	0.492
210	2.40	0.417	0.416
225	2.92	0.342	0.341
240	4.65	0.215	0.214
255	10.53	0.09497	0.09396
270	80.00	0.01250	0.01149
285	14.60	0.06849	0.06748
300	5.13	0.195	0.194
315	3.86	0.259	0.258
330	2.45	0.408	0.407
345	2.13	0.469	0.468

360	1.99	0.503	0.502

Graph 1: Two Crossed Polarizers

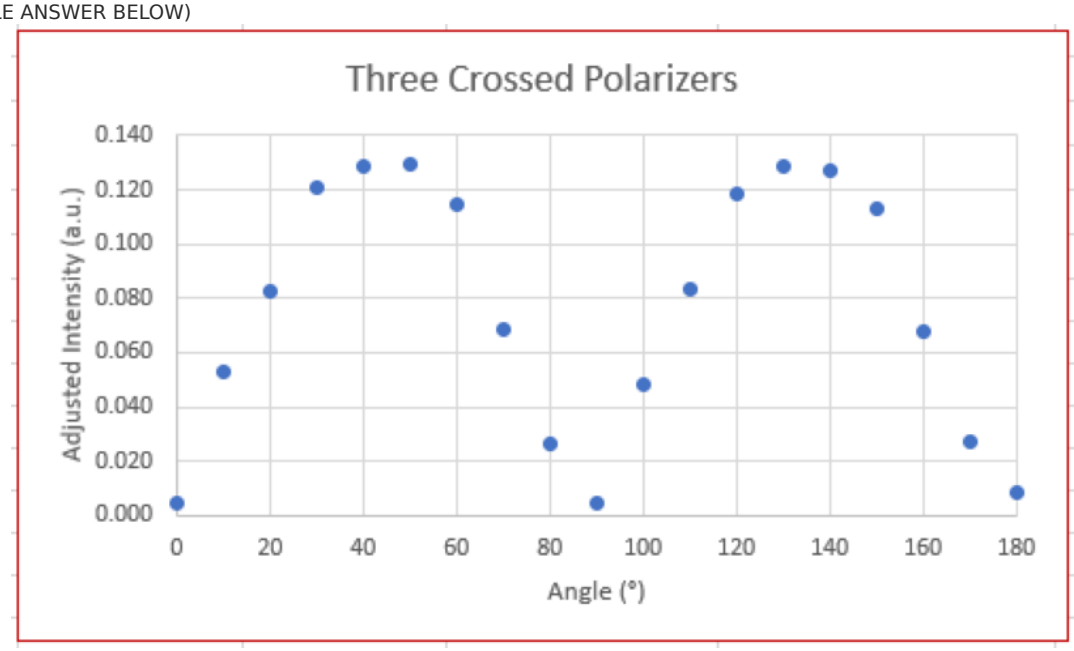
(SAMPLE ANSWER BELOW)



Data Table 4: Resistance and Light Intensity for Three Crossed Polarizers
(SAMPLE ANSWER BELOW)

Angle (°)	Resistance R (kΩ)	Relative Light Intensity 1/R (a.u.)	Adjusted Light Intensity 1/R - $1/R_0$ (a.u.)
0	192.20	0.0052029	0.0041929
10	18.54	0.05394	0.05293
20	11.91	0.08396	0.08295
30	8.20	0.122	0.121
40	7.72	0.130	0.129
50	7.66	0.131	0.130
60	8.64	0.116	0.115
70	14.33	0.06978	0.06877
80	36.50	0.02740	0.02639
90	172.50	0.0057971	0.0047871
100	20.25	0.04938	0.04837
110	11.85	0.08439	0.08338
120	8.35	0.120	0.119
130	7.72	0.130	0.129
140	7.81	0.128	0.127
150	8.78	0.114	0.113
160	14.57	0.06863	0.06762
170	35.50	0.02817	0.02716
180	104.30	0.0095877	0.0085777

Graph 2: Three Crossed Polarizers
(SAMPLE ANSWER BELOW)



Competency Review

Light can be polarized by _____.

- transmission
- reflection
- scattering
- All of the above ✔

Light waves that oscillate perpendicular to the polarization axis of a polarizing filter are _____ by the filter.

- transmitted
- stopped ✔
- reflected
- None of the above

Polarization by reflection most often produces horizontally-polarized light.

- [x] True
- [ ] False

_____ produces partially-polarized skylight.

- [ ] Transmission
- [ ] Reflection
- [x] Scattering
- [ ] All of the above

The plane of oscillation of a light wave can be decomposed into _____ components.

- [ ] two parallel
- [x] two perpendicular
- [ ] three perpendicular
- [ ] None of the above

The intensity of polarized light passing through a polarizing filter is proportional to _____ of the polarization axis relative to the plane of polarization.

- [ ] angle
- [ ] cosine of the angle
- [x] cosine squared of the angle
- [ ] None of the above

When initially-unpolarized light passes through three polarizing filters, each oriented at 45 degree angles from the preceding filter, _____ of the initial light passes through the last filter.

- less than half ✔
- none
- half
- None of the above

A photo cell detects light intensity using the _____.

- wave nature of light
- polarization of light
- photoelectric effect ✔
- None of the above

In the photoelectric effect the number of electrons ejected is _____ to the intensity of the light.

- proportional ✔
- inversely proportional
- unrelated
- None of the above

The background intensity measured by a photodiode must be _____ the measured intensity to accurately determine the true intensity.

- added to
- subtracted from ✔
- divided by
- None of the above

Light emitted from an LCD is polarized.

- [x] True ✔
- [ ] False

The polarization of skylight is the greatest at an angle of _____ degrees from the Sun.

- [ ] 0
- [x] 90 ✔
- [ ] 180
- [ ] All of the above

When polarized light is viewed through a polarizing filter, the transmitted intensity _____ as the filter is rotated through 180 degrees.

- [x] changes slowly ✔
- [ ] changes instantaneously
- [ ] remains constant
- [ ] None of the above

The polarization axis of a polarizing filter is determined by finding the direction at which glare is _____.

- [ ] maximized
- [x] minimized ✔
- [ ] slightly reduced
- [ ] None of the above

When the polarization axes of two polarizing filters are aligned, the intensity of light that passes through the filters is _____.

- zero
- the same as the initial intensity
- half the initial intensity ✔
- None of the above

When the polarization axes of two polarizing filters are offset by 25 degrees, the intensity of light that passes through the filters is _____.

- zero
- less than half the initial intensity ✔
- half the initial intensity
- None of the above

When the polarization axes of three polarizing filters are offset by 90 degrees, the intensity of light that passes through the filters is _____.

- zero ✔
- the same as the initial intensity
- half the initial intensity
- None of the above

Extension Questions

Damon purchased a pair of sunglasses that were advertised as being polarized. Describe how Damon could test the sunglasses to verify they are polarized. (SAMPLE ANSWER BELOW)

While looking through the sunglasses, view an object with glare, such as a pond or car windshield, and tilt your head sideways to see if the glare is stronger at this angle. If the amount of glare changes with the angle of the glasses, the sunglasses are polarized. Or look at an LCD screen such as a cell phone or digital watch screen through the glasses, rotating the screen while keeping the sunglasses stationary. If the screen appears dark at some point during the rotation, the sunglasses are polarized.