Light : Polarization, Interference, Thin film Interference, Single slit and Double slit Interference

Setting:
Introductory physics class for majors where the concepts of polarization and interference are introduced.

Purpose/Rationale:
The purpose of the lesson is for the students to engage with the different phenomena of the wave nature of light. In this lesson, simple demonstrations in conjunction with PhET are used so that the students can explore the underlying concepts of polarization and the different interference phenomena. The polarization and the thin film interference can be related to some daily world examples like the principle behind sunglasses and the colored soap films. The wave nature of light can be demonstrated using the single and double slit interference experiments. The double slit interference act as an introduction to the dual nature of light and can be extended into studying the behaviour of the electrons and hence into the introductory quantum physics.

Virginia Standards of Learning:
http://www.doe.virginia.gov/testing/sol/standards_docs/science/courses/stds_physics.pdf

PH.3: The student will investigate and understand how to demonstrate scientific reasoning and logic.

PH.4: The student will investigate and understand how applications of physics affect the world. Key concepts will include the basics behind sunglasses and the blue color of the sky in the case of polarization. The colored surfaces on a soap film can be explained by the theory of thin film interference. The single and double slit interference patterns will demonstrate the wave nature of light.

PH.9: The student will investigate and understand how to use models of transverse and longitudinal waves to interpret wave phenomena. Key concepts include
a) fundamental wave processes (reflection, refraction, diffraction, interference, polarization) and
b) light in terms of wave models.

Engage:
With the help of demonstrations, PhET and YouTube videos, the teachers will exhibit the different processes like polarization, interference and diffraction of light. The open ended questions along with the predictions and reasoning will engage the students to learn more about the underlying concepts of such phenomena. The sunglasses, the color of the sky and the colored soap films are the real world application of these processes. These examples will help students link their observations in their daily life to the theory that they learn in the class. The teacher can ask the students to predict the results of the single slit and the double slit interference experiments visualized using PhET.

Explore:
Using the knowledge of the transverse nature of light, the students will explore the idea of linear polarization with the help of the polaroid demonstration. This can be an introduction into the circular and elliptical polarization. The wave nature of light can be explored by studying the interference patterns. The refraction and reflection of light from surfaces will lead into the interference from thin films. The single and double slit experiments further explore the wave nature of light and will be useful in studying the behavior of electrons in a quantum physics class.

Explain:
The students will explain their hypotheses for all the different demonstrations. Peer to peer discussion and the discussion led by the teacher from the topics that have are known will help build up to the conceptual understanding of these various phenomena.

Elaborate:
Once the idea of the wave nature of light is introduced by these processes, it is used to explain more about the dual nature of light. Further, this could be extended to the behavior of electrons and basics of quantum physics.

Evaluate:
The worksheet of practice problems serves as a means for evaluating the understandings of the students. Small group work centered around solving the problems together on white boards allows for the instructor to work with each group individually to check understandings and right misconceptions.

1. Polarization:
Materials and Resources:
Two polaroids (If possible, slinky and a wooden/plastic structure containing few horizontal/ vertical bars that can act as the polaroid) and some YouTube videos (if required).

Safety:
This experiment does not have any safety measures.

Procedure:
Case 1: If the slinky and the polaroid structure is available - Use the slinky to generate a transverse wave and make it pass through the polaroid (both the horizontal and vertical way). This will give the students an idea to explore the idea of polarization.
Next the two polaroids can be used to exhibit the same concept with light as the source of the transverse wave, hence showing that light is a transverse wave and is unpolarized in general.
Case 2: If the slinky is unavailable, use the YouTube videos to show the above experiment and then proceed with the experiments with the polaroid.

Engage:
The teacher will engage the students in learning about the concept of polarization of light during the experiments using the polaroids. Students will work to develop key intuitions about linear polarization from the fact that light is a transverse wave. Students will have the opportunity to make predictions of the outcome of the experiment before the demonstration is conducted.

Following the experiments, the teacher will lead a group discussion in which students will diagram their observations and seek an answer to why light behaves in the particular manner. Once the simple linear polarization concepts are discussed, the teacher can move into the complicated examples of circular and elliptical polarization. The open ended questions for the linear polarization can help build up for the circular and the elliptical cases. There will be simple examples of all the cases on the activity sheet that will help the students understand the concept better. Lastly, the examples of sunglasses can be used as a real world application of the polaroids. The blue color of the sky can be thought of another example of polarization.

Explore:
The students will explore the facts about the different kinds of polarizations of light, starting with simple experiments for linearly polarization. The experiments with the polaroids will help in exploring the linear polarization. Since the circular and the elliptical polarization are not so easy to visualize, YouTube videos can be used and the examples on the activity sheet will further help. The students will be encouraged to work in groups and explore the different hypotheses. The working principle behind the sunglasses and the color of the sky will help the students relate what they learn to real world examples.

Explain:
The students will explain their predictions and hypotheses about the experiments using the polaroids. The circular and elliptical polarization can be worked out and discussed once the linear polarization is understood, building on the prior knowledge. The concept of the color of the sky due to scattering can be explained as another example of polarized light.

Elaborate:
Polarized light has a lot of application, the common ones being used in sunglasses or in photography lenses. The demonstrations will give a simple overview of the idea. The selection of colors of the sky during the different times of the day can be thought of as polarization of light.

2. Thin Film Interference

Materials and Resources:
Soap solution and pipes (to make the soap film), PhET

Safety:
This experiment involves soap solution. Thus the students need to be careful not to have any contact with the eyes.

Procedure:
The students can use the pipes to make soap films from the soap solution. A very thin soap film is required to observe the desired effect.

Engage:
The experiment will be performed by the groups of students so that they can see the colors themselves. The teacher will ask the students to reason what happens on a daily basis if a soap film comes in contact with air. Using the concepts of the refraction and reflection of light form the surfaces, the students will develop an idea about the concept of the thin film interference.

Explore:
The refraction and reflection of light from the surfaces is the introduction to the theory of the interference. Firstly, the concept of interference of two light waves is explored using a PhET. This revises the prior knowledge of the wave nature of light. Next the reasoning of the colored films are explored by making simple ray diagrams. Using the knowledge of constructive and destructive interference, an instructor led discussion can help to derive the formula for the thin film interference.

Explain:
The colored films can be analyzed by discussions and open ended questions. The diagrams will help in explaining the process in a simple manner as well as in deriving the mathematical formula. The prior knowledge of constructive and destructive interference, refraction and reflection will aid in explaining the process at hand.

Elaborate:
Since this is a daily phenomenon, it will be easier for students to make predictions about it. Also, using the ray diagrams and the previous ideas about interference will help in developing a better understanding of the thin film interference, which can be later extended to some other examples.

3. Single Slit and Double Slit Experiments

Materials/Resources:
PhET (and YouTube videos)

Engage:
Building up on the previous knowledge of interference, the class can start with the double slit experiment. One can start by predicting what would happen to particles with one or both slits open and then lead into the wave nature. The PhET is used to demonstrate the phenomenon. Once the double slit is done, the students can predict what would happen with a single slit. Different widths of the slit can be used to see the effects.

Explore:
The interference and the wave nature of the light is an introduction to this class. The students get to explore the fact that waves interfere in a different way and this will lead into concepts used later in quantum mechanics. Using the PhET, one can change the width of the slit(s) and the distance from the source. Again, simple diagrams can be used to go through the mathematical details of the processes. The students also explore the difference between a normal interference and a diffraction pattern.

Explain:
Similar to the previous topic, the prior knowledge of constructive and destructive interference will aid in explaining the process at hand. Also, the resulting pattern obtained will explain the differences between an interference and a diffraction process. The change in the widths of the slit and the number of slit will explain on what parameters affect the result. The discussion led by the teacher with the help of diagrams can help in coming up with a mathematical formula for these processes.

Elaborate:
It is an important experiment which exhibits the wave nature of light. It leads into the dual nature of light and hence, extends into the basics of quantum mechanics. This similar experiment can be used to understand the nature of electrons, leading into the dual nature of electrons.