Parallax

Overview:

Parallax is a phenomenon in which two stationary points change their position relative to each other, due to change in position of the person viewing them. Astronomers have been using parallax for the last few centuries to measure distances between celestial objects but all living beings have been using parallax for millions of years to estimate distances.
This unit is a formal introduction to parallax where students will do simple experiments to experience parallax. Also, in this unit the students will set up an experiment to see how human beings have been using parallax to measure the distances.

Time Required: Two Sessions of 40 minutes each

Type of Learning Unit: Laboratory

Learning Objectives:

Understanding Parallax
Verification of laws of reflection
Application of laws of reflection

Links to Curriculum:

Class 8: Chapter 16: Light
Class 10: Chapter 10: Light – Reflection and Refraction

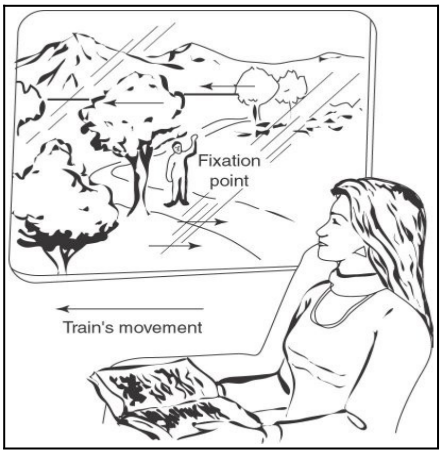

Figure 1: Source: http://www.appstate.edu/~steelekm/classes/psy3215/MonocularDepth/motionparallaxcue.htm

Introduction:

While travelling on a train and looking out of the window, you might have noticed that objects closer to you seemed to move in the backward direction while objects farther away appeared to go along with you. Of course, you would have realized that even the objects farther away slowly lag behind and disappear from your view eventually. Further, the speed at which both the near and far objects appeared to move was proportional to the speed of the train. When the train moved faster, the objects also seemed to speed up.

This optical effect of objects closer to the observer in her field of view appearing to move faster than objects farther away is called motion parallax, or simply, parallax.

The concept of parallax is used in determining which of two given objects is nearer to the observer.

Materials required:

- A foam sheet (approx 30cm x 40cm)
- A4 size sheets of paper
- 1 plane mirror
  (the mirror should not have a frame)
- At least 2 needles, taller than the mirrors
  (in case they are not available, ball pen refills will serve the purpose)
- Rubber band and allpins or Cloth clips
- Thumb tacks

Task 1a: Parallax in the classroom – 1

When some stationary object is seen from different viewing position, it feels like the stationary object has moved. Let us verify this by a simple activity.

Extend one of your hands in front with only index finger pointing up. Use your other hand to close your left eye. Now adjust the position of your finger such that, your finger appears exactly along one vertical edge of the blackboard. Next, keep your finger steady, open your left eye and close the right eye. What did you observe?

> Even though the finger was not moved and obviously the edge of the blackboard didn't move, the two are no longer in the same line.

Why did it happen?

> When you switch the left eye and the right eye, observer's viewing position changes. Here by 'observer', we don't mean the whole student (who hasn't changed his/her position). Instead, we refer to some imaginary tiny person who was first at the position of left eye of the student and then 'walks' to the right eye position.

Task 1b: Parallax in the classroom – 2

1) Gather two of your friends. Let's call them A and B. Now all three of you stand in one straight line. Here you as the observer are going to stand facing towards your friends. Let there be enough distance, at-least 2m, between any two of you. You will observe that your view of your friend B (who is standing farther from you) is blocked by your friend A(who is standing nearer to you).

2) Now, take a few steps to your **right**. A and B should not move from their position. Observe your friends again and record them as follows;

    a) A appears to have moved towards **left / right / not moved**. (select one)

    b) B appears to have moved towards **left / right / not moved**. (select one)

    c) Who appears to have moved more? **A / B / Both have moved equally** (select one)

    d) Originally A and B were along the same line of sight. Now A is to the **left / right / still aligned** of B. (select one)

3) Now come back to your original position and then move a few steps **left**. What did you observe now?

    All students should take turns to be the observer and note their own observations.

> When you move to the right, both A and B will appear to have moved to the left. But A would have appeared to moved by a larger distance than B. Similarly, if you move towards the left both A and B move towards the right again, A moving larger distance than B. So, initially for the observer A and B appeared to be in the same line as the observer, but now they are not.

4) Lastly, ask A and B to stand close to each other(almost no separation). Repeat the experiment you just performed. What do you observe?

> If both A and B are standing close to each other, again they both would move in the direction opposite to your motion but now they are moving with same speed. Thus they remain together.

Extra diagram from task 1b

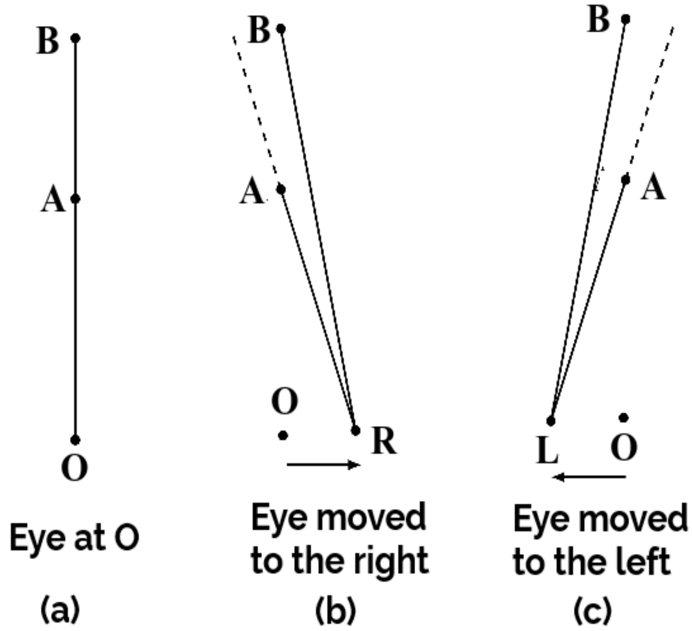

Figure (T): Concept of parallax

Notice that the object that appears to follow your motion is always farther from you.

Discussion:

1) When you are travelling in a car or a train distant objects like mountains or moon seem to be 'travelling with you' because
   a) As you move, these objects also move in the same direction.
   b) These objects actually move backward, but appear to move forwaard in comparison with nearby objects like trees or poles.
   c) They never appear to travel along. I have never observed this.

The correct answer is (b). As in the task 1b, the trees or poles on the side of road / track are like student A and distant objects such as mountains are like student B. More distant the object, lesser will be the parallax and hence the distant objects appear to travel with the observer longer then the objects which are closer.

2) While travelling in a train, I noticed two trees in a field. As the train moved, both the trees appeared to be moving backwards. But the separation between them hardly changed. This means ________________.

This means both of them were almost at the same distance from the observer. Like the situation when A and B were standing together, the separation between two objects will remain unchanged if they are at the same distance from O.

Task 2: Using parallax to locate the image position

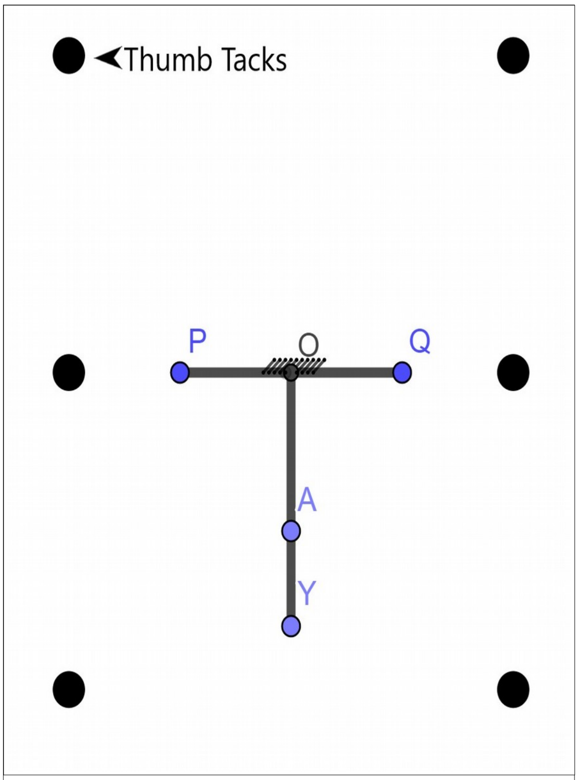

Figure 2: Setup for Task 2

When you get ready for the school, you must be checking yourself in a mirror. You would have certainly noticed that when you stand far from mirror, your image appears to be far behind the mirror and if you stand close to mirror, even your image is close to the mirror. But can we find out the exact location of your image?

> In this activity we will use the concept of parallax to determine exact position of the image.

1) For our reference, we will draw a "T" shaped figure on the paper. Attach the paper to a drawing board using 6 thumb tacks (see figure 2). Make sure the paper is completely flat and there are no creases or bumps.
2) We are going to keep our mirror on the top line of the "T" (i.e. line PQ in the figure) and the line OY, which is perpendicular to PQ will be reference line for our object, whose image we want to see.
3) Place a mirror upright along the line PQ, such that its centre is approximately at O.
4) In any good experiment, it is important to identify possible errors and minimize them. In this case, there are two important points to remember.
   a) The typical mirrors which we use are just a plain glass with reflective coating on the back surface. Make sure the reflecting surface is exactly on the line PQ.
   Question: How can we find out if our mirror is front coated or back coated?

> You can touch the mirror's front surface and see if the image of the finger actually touches your finger or there is a small gap.

   b) The mirror should be exactly upright and firmly affixed to the board This can be done in either of two ways. In the first method, you can attach binder clips or cloth clips on both sides of the mirror to give it support. The clips can then be firmly affixed to the board with allpins on the side. OAlternatively, you can attach allpins directly to the mirror using a rubber band and then mount it on the drawing board (see figure 3).

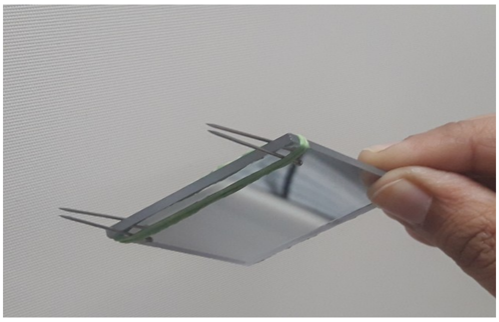
Figure 3: Allpin and rubber band arrangement

5) Let's take a needle and mount it somewhere along the line OY (recommended distance is about 5 cm). Let's call the position of the needle 'A'. You must ensure that the needle is strictly vertical.
6) Now adjust yourself such that the drawing board is at your eye-level. Look in the mirror. You will see the image of the needle at A. Move your head to make sure that you can see both the needle at A and its image.
7) Our goal is to now put a second needle behind the mirror such that, it is at the same position as the image. Take another needle (call it M) and place it behind the mirror, such that it coincides with the needle at A . You can see tip of M above the mirror.

8) Move your head so that the image of A in the mirror (call it A') is aligned with the top visible part of the needle M.

9) Now, move your head slightly to the **right**. Observe the image of A (let's call it A') and the needle M. Explain the reasons for following possible observations:

a) The two are no longer aligned. A' is now to the **left** of M.

This means A' has moved **more than / less than / same as** (select one) than M.

This means A' is **closer than / farther than / at same distance as** (select one) M.

b) The two are no longer aligned. A' is now to the right of M.

This means A' has moved **more than / less than / same as** (select one) than M.

This means A' is **closer than / farther than / at same distance as** (select one) M.

c) The two are still exactly aligned.

This means A' has moved **more than / less than / same as** (select one) B.

This means A' is **closer than / farther than / at same distance as** (select one) M.

a) A' has moved more than M and it means that A' is closer than M.
b) A' has moved less than M and it means that A' is farther than M.
c) A' has moved same as M and it means that A' is at same distance as M.

10) Check that you get the opposite behaviour when you move your head to the **left.**

11) Depending on which of the above three situations occurred, adjust the position of M to get it as close to A' as possible. Repeat steps 8 to 10. Keep repeating the process till you are satisfied that M is exactly at same distance as A'. Encircle this final position of the needle and mark it as point B.

It is important that the student arrives at the final position of needle B by following a systematic method of checking the left and right shift of the image with respect to the needle and not just by trial and error. This will ensure that they understand the concept of parallax.

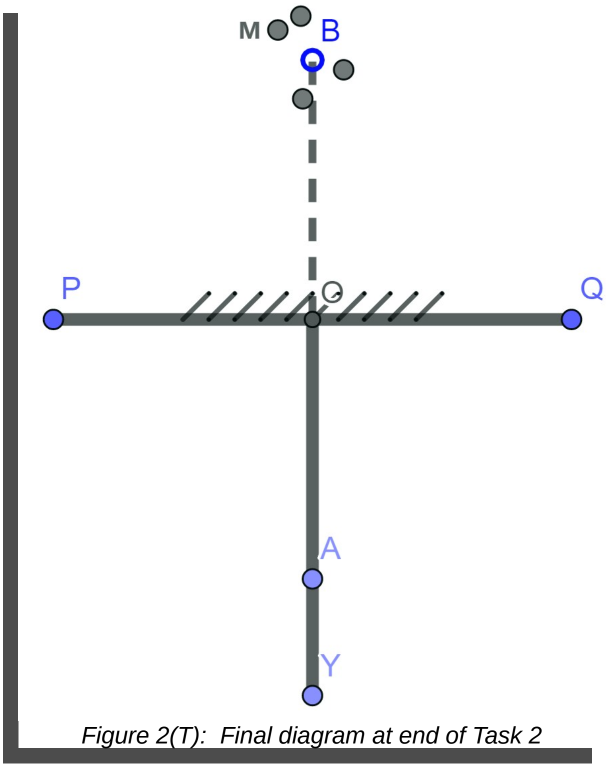

Figure 2(T): Final diagram at end of Task 2

12) Once you have obtained point B remove the mirror and the needles. Draw a line to join the

points A and B. Does the point O lie on this line (exactly or approximately)?

13) Measure distances OA and OB. What can be concluded from this?

> The final diagram should look somewhat similar to Fig. 2(T). And students will conclude that object distance (OA) is same as the image distance (OB)

Discussion:

1) Why is it important for the mirror and the needles to be strictly vertical?

> Unless the mirror as well as the needles are strictly vertical, the objects and their images will not be parallel and therefore, it will be impossible to align them perfectly. Of course, some small allowance may be made for this condition without affecting the results.

2) Did you find O, A, B to be perfectly collinear? If not, what could be the possible reason?

> If either the reflecting surface of the mirror is not placed perfectly along the line PQ, or the needle A is not placed perfectly on the line OY, the points A, its image B and O will not be collinear.

3) In case O, A and B are not perfectly collinear, can OA and OB be termed as the object distance and image distance, respectively? Would you still find OA=OB? Explain.

> Here, by construction, OA is the object distance, provided the mirror is exactly along PQ and A lies on the line OY. If these conditions are not met (when O, A and B are not perfectly collinear), neither is OA the object distance nor is OB the image distance. However, still OA=OB, provided O lies anywhere on the reflecting surface. This may be illustrated with a simple ray diagram.