

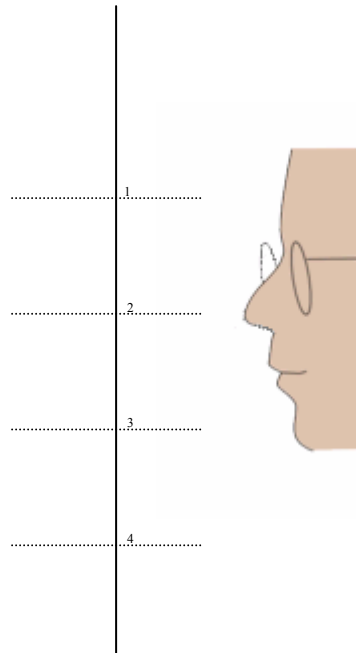
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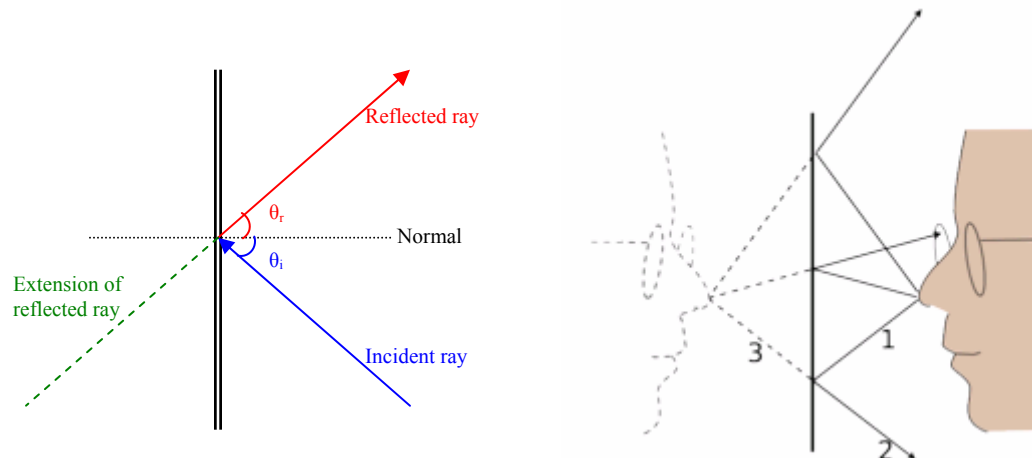
Reflection I: Flat Mirror

1. If the vertical line shown below was a mirror, and the man's face would be reflected on the left side, find the point where the image of the man's mouth should appear. Draw a ray from the man's mouth to all four points listed on the mirror (the normals have been drawn for you as dotted lines); reflect the rays, and find the image point by where the extensions of the reflected rays converge. (4 pts)



a.

- b. **Hint:** Remember that rays of light bounce off the mirror, and the reflected rays are extended into the mirror, where the image point appears. Listed below is an example of the image point of the man's nose.



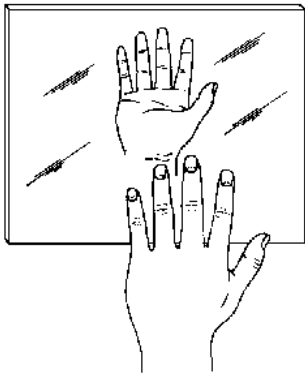
i.

2. Reflect the pencil over the mirror using ray diagrams. Draw a ray, normal, reflection, and extension of the reflected ray to find the image point of both the eraser and the tip of the pencil. (4 pts)



3. A ray of light strikes a mirror at an angle of incidence of 28° . What is the angle of reflection? (2 pts)

4. If the hand featured below is 4 inches away from the mirror shown, how far away from the actual hand is the image of the hand? (2 pts)

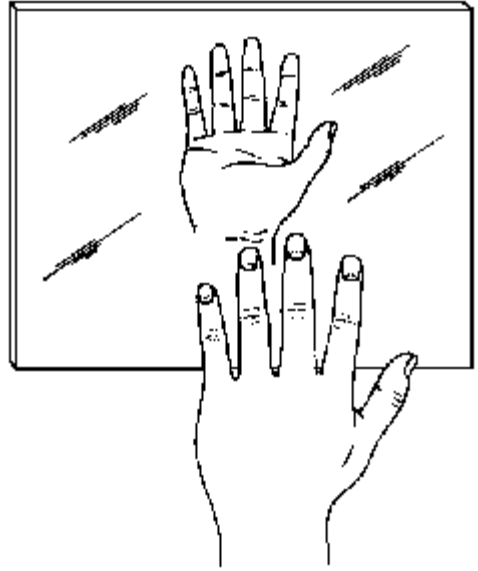


Optics - Mirror Reversal?

Taken from *Physics Problems to Challenge Understanding*, emphasizing concepts, and insight. Compiled and annotated by Donald Simanek.

<http://www.lhup.edu/~dsimanek/scenario/insight.htm>

Why does a plane (flat) mirror seem to reverse your image left/right but not up/down? This frequently asked question has value for encouraging students to think more precisely and use words carefully. Why should this question even be interesting? Where's the "problem"? The discussion shouldn't be carried out entirely in the abstract. Have a large mirror to demonstrate. Rotate the mirror around its normal as a student looks at the image. The image doesn't rotate. The mirror seems to be operating with axial symmetry. Then why should the mirror treat up/down differently than right/left? (Some students will even suggest gravity has something to do with it, so have such students look in the mirror and lean their heads sidewise.) Have one student look into the mirror while another stands behind the mirror looking at the first student. Have each touch the top of their heads. Have each touch their right ear. Perhaps have each wear something distinctive on the right ear.



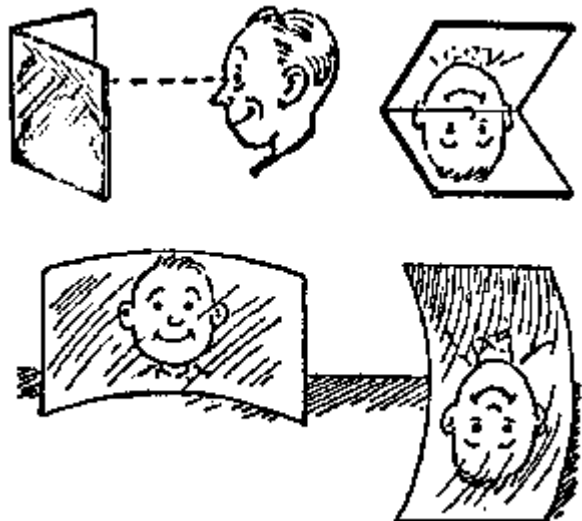
The figure below shows that a pair of plane mirrors at right angles behaves differently than does a single plane mirror. Have two mirrors hinged (for ease of storage) with a precise arrangement to hold them at perfect right angle alignment for the demo. Curved cylindrical mirrors can be made by forcing thin plastic mirrors into a slight curve. This may not seem like physics, but it is certainly a good exercise in geometric thinking.

Answer:

The plane mirror doesn't reverse up/down, all agree. It doesn't reverse left/right either. If you point a finger up, the image finger points up. If you point a finger to your right, the image points its finger to *your* right. When you keep all right/left references consistently in a *fixed* reference frame there's no problem. But there's more that's worth investigating here.

There's considerable literature on this question, some of it misses the mark. A good summary can be found in: Martin Gardner's *The New Ambidextrous Universe*, Freeman, 1990 ... 1979, pp. 3-6 and 19-22. Much of the confusion rests on three things:

1. The ambiguity of the terms up/down and left/right.
2. Other semantic difficulties.



3. Shifting reference coordinates during the discussion.
4. Failure to explain the matter and still address the fact that the plane mirror is symmetric about any of its normals.

Explanation 1. As I look in the mirror I see an image of myself. I compare it, and what it does, with a mental picture of a clone of myself facing me. Imagine that my mystical clone separates from my body to stand beside me, both of us facing the mirror. At this point we both have the same coordinates for up/down and left/right. I tell my clone to walk around and stand beside the mirror facing me and "do as I do." I observe that when I touch my right ear my mirror image touches the ear to the right of me. My clone touches its right ear, which is to the left of me. This seems opposite. Yet when I touch the top of my head, both the clone and the image touch the top of their heads, and that's **up** for all of us!

What I've forgotten is that my clone had to rotate 180 degrees about a vertical axis after leaving my body and then walking around to face me. That is a reversal of the clone's left/right coordinate reference. (It also reverses forward/backward, with respect to a line from my nose perpendicular to the mirror, a fact whose importance will be clearer in explanation 2.)

Explanation 2. The plane mirror, having symmetry about any normal, can be rotated about that axis without any change in the image. For simplicity, imagine the axis from your nose and normal to the mirror. All image transformations must be symmetric with respect to that axis. The mirror does not invert up/down or right/left. It inverts *along the mirror's axis*. If you mentally walked forward through the mirror, till your right ear was at the position of the image's right ear, and your left ear at its left ear, your nose would be at the back of its head, and the back of its head would be at your nose. The top of your head would be at the top of the image's head, and both are still "up." Your reference for right/left and up/down hasn't changed, for you walked along the symmetry axis of the mirror. The mirror inverts the image along its symmetry axis, inverting the nose to the back of the head and vice versa. It is a well-known, and easily provable fact, that any point on the image is exactly as far from the mirror as the corresponding object point. Thus your image's nose is nearer to you than the back of its head.

Further experiments.

Hold a printed page facing the mirror. The writing on the image is 'backwards' just as it would be if the printing were on a transparent sheet and you were trying to read it from the back side.

For a new slant on this problem, hold a large plane mirror at arm's length and in a horizontal plane facing up and look at the reflection of a poster on the wall that has printed text. The image is upside down and the text reads backwards. Now swing your arm to the right and rotate the mirror until it is in a vertical plane, keeping the poster's image in your view. The image rotates through 180 degrees, and is now upside down. Swing your arm up and high, rotating the mirror another 90 degrees till it is facing down. The image has rotated another 180 degrees, and is now right side up. The image rotates through twice the angle that the mirror rotates. Rotate your arm another 90 degrees until... Whoops. You'd better seek medical help for that arm.