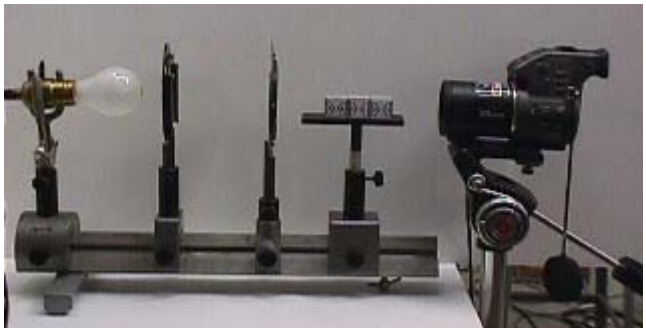
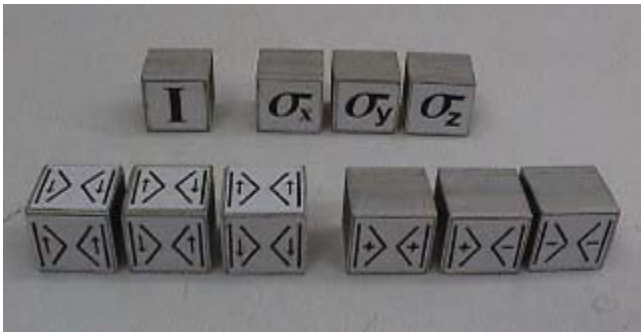
Question #290

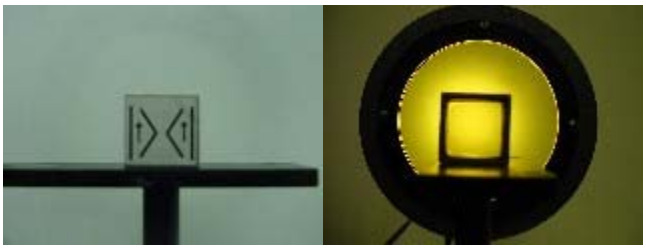
This question begins a set of three questions regarding an optical model of quantum mechanical states of the electron.

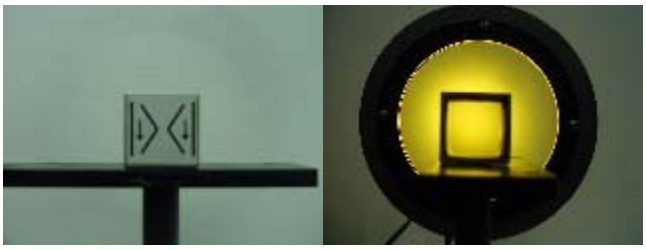
For this question we will use the optical system seen at the left below, consisting (left to right) of a (white) light, a (negative) yellow filter, an etched glass screen to diffuse the light, a variety of optical elements housed in small aluminum cubes open on two ends, such as the ones shown in the photograph at the right below, and a digital camera, looking backward (through the little cubic optical elements) along the optic axis of the system.



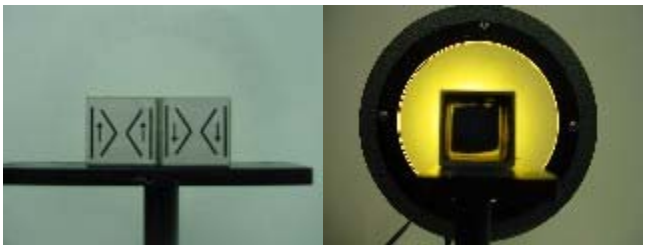


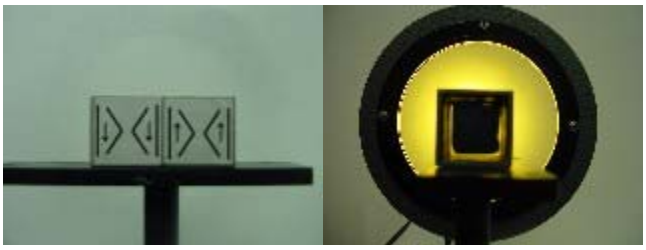
Two little aluminum cubes, seen in the pairs of photographs below, have optical elements in them. If we look through either of the two cubes (right-to-left) with our digital camera, keeping them in the same orientation as in the photograph at the left, the light from the background may be slightly attenuated, but not blocked completely, as seen in the two pairs of photographs directly below.





If we position the two cubes together and look through both of them, at the same time, we notice that the light is almost entirely blocked, as seen in the pair of photographs at the left below. If we invert the two cubes front-to-back and again look through both of them, we again notice that all of the light is blocked, as seen in the pair of photographs at the right below.



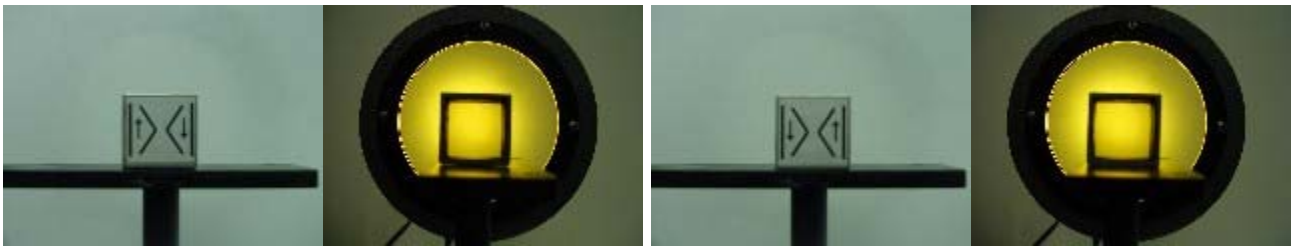


On the other hand, if we place two identical cubes together and look through them, we see light!

Part 1: What is in each of the the two cubes? One limitation: whatever is in the two cubes is symmetric in the up-down direction, as indicated by the little identification symbols on the cubes.

- (a) a polaroid (specify the alignment)
- (b) a quarter-wave plate (specify the alignment).
- (c) a half-wave plate (specify the alignment).
- (d) a combination of the above (specify).
- (e) something else (specify).

Now suppose that we introduce a third little aluminum cube, perhaps containing a different optical element or elements, between the two original elements, as seen in the photograph at the left below. If we look backward through this optical cube, we notice that it again passes most of the light, independent of its orientation. Notice that the same cube is used for both of these photographs; it is simply *rotated* to change its "definition."



Here are some combinations of two of the above optical elements. Because the color of the light passing through the system is yellow, at this point you may treat *both* the dark green and the black situations as the same: no light is passing throught the system.

1 

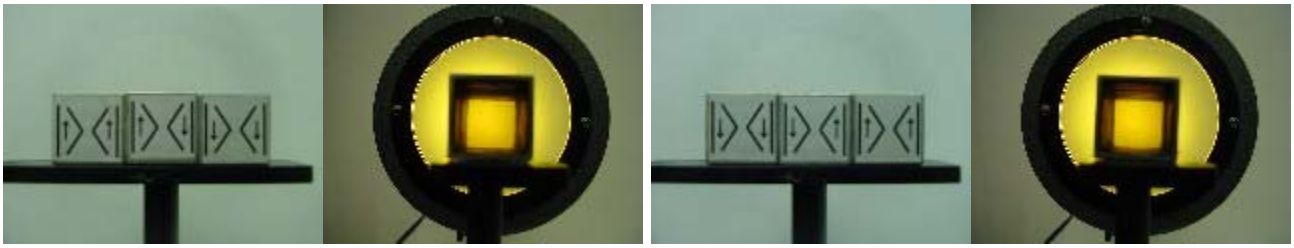
2 

3 

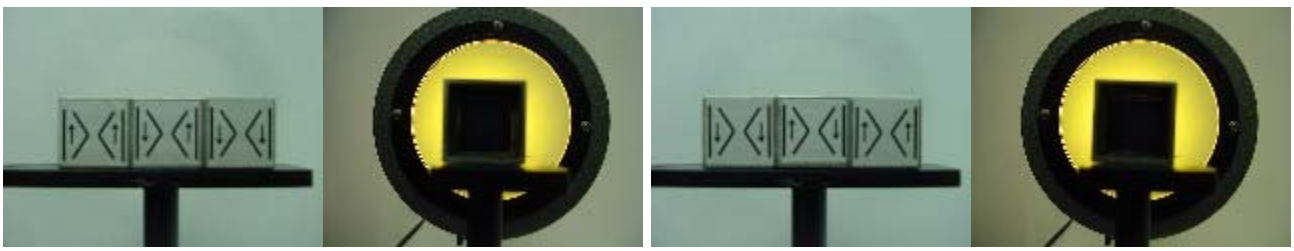
4 

The three cubes in all four pairs of photographs above are *the same*! In fact, the difference between the pairs of photographs at the left above and the pairs of photographs at the right above is that the *all three cubes* have been rotated 90^{o} to get from the situation at the left to the corresponding situation at the right. (The center cube *only* has been rotated 90^{o} between the pairs of photographs at the left and the pairs of photographs at the right above.) Well, not quite! The green color (rather than totally dark) occurs when the "up-down" cube is rotated end-for-end to produce the same up-down configuration, as seen in the identification photographs at the left of each pair. For this part of the question you may therefore assume that both the totally dark and the dark green results are equivalent: no light is passing.

If we line up the three cubes as seen in the photographs at the left below, and look through the three aligned cubes, we see that light is no longer blocked, but comes through the cubes.



If we rotate the center cube by 90^{o}, redefining it as seen in the photographs below, and again look through the three cubes into the light, we note that light is *not* seen.



Part 2: What is in the middle cube?

- (a) a polaroid (specify orientation).

- (b) a quarter-wave plate (specify orientation).
- (c) a half-wave plate (specify orientation).
- (d) a combination of the above (specify).
- (e) something else (specify).

Part 3. Finally, why is the light from the cases above, "up-up--downup" and "down-up--down-down," dark green rather than totally black? It should be pointed out here that if the "up-down" cube is rotated to end-for-end, resulting in the same up/down configuration, no light gets through, and the area is dark, like the others in the second column for two cube cases above. Conversely, if the "up-down" cube in the originally totally dark photographs above is rotated end-for-end, resulting in the same up/down configuration, the light coming through will be green.

Click here for Answer #290 after October 1, 2007.

Question of the Week

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For questions and comments regarding the *Question of the Week* contact
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given on the Lecture-Demonstration Home Page.