MITOCW | Investigation 2, Part 7

MARK HARTMAN: I'm going to introduce the particle model of light, or what we're going to call the particle model of light. So our CAI particle-- and again, you want to write down today's date. Write down the time. We're going to introduce this idea, CAI particle model of light.

It's going to be based off of all of our observations. I'm going to say that-- and again, this is a model, so it's going to explain why things happen. What do I say here? Light is composed of particles of energy that move away from a source-- and each one of these words is going to have a specific meaning. So source, meaning something that gives off light-- in straight lines in all directions-- and I'm also going to add this other thing-- at the same speed.

So this is what we think, or a way to think about what light is-- particles of energy. So we're just going to think-- because we saw that, when you turned a light on and pointed it towards a glass of water, that it would heat up the water. So it has something to do with energy. We're going to say particles of energy because we also saw that those particles move away from a source in straight lines, just like when we had the laser pointers. We also saw that they went in all directions. When we were looking at those shadows, light goes out not just in one direction from a source. I mean, a laser does because it's focused down, but in this case, for our light bulbs, it goes out in all directions.

We're also going to think it's particles of energy because we said that light can bounce or reflect. If you think about taking a tennis ball and throwing it against a wall, that tennis ball is going to bounce off in a different direction, or if you take one of those super bouncy balls and you throw it down on the ground, it bounces up and down.

So we're going to think that these particles are bouncy. Now, particles of energy-- what does that really mean? Well, we're not going to get into the philosophical deep understandings of light just because, like I said before, even this model doesn't explain everything. It's going to explain as much as we need it to.

So here is a drawing. I want you to put this drawing in, as well. So if we had a source of light-- here's a light bulb-- we are going to draw-- I'm just going to say from this light bulb, from the source we are going to get particles of light that we're going to call photons. Each one of these particles of energy-- we're going to say called photons. You can put that in, or you could say down below particles of energy are called photons.

We're going to say from this source these photons-- we're going to represent the speed of these photons with an arrow, and it's going to be pointing outward. And you can see that all my arrows have the same length, which means that these particles are going outward at the same speed. Now, it's not that there's only one set of particles that gets thrown out. When you turn a light on, more particles of energy come out. As we saw with the light bulb, if you leave the bulb on all day, more, and more, and more energy gets transferred to the water, and it heats up.

So it's not just one round of particles. There's also particles out here, and they're going outward, too, still in straight lines, still all at the same speed. Now, this is obviously only a two dimensional drawing, so there's particles that are coming out this direction, as well, as well as back into the board.

So here we can kind of see, well, if we have our detector, and we put it up close we're going to collect-- those particles haven't spread out. It's not that the particles themselves get bigger, but if these particles are going in straight lines, they start out close together, and then they get further out as you go away from the source. So if you're far away, you're not going to collect as many particles with the same area as if you were up close. We're going to see that in just a minute.

AUDIENCE: So you can make a box that is completely just solar panels and then put the light bulb in the box and then turn it on so it captures all the light that it hits, and then connect it to one of those [INAUDIBLE].

MARK HARTMAN: Somebody else want to explain that idea in their own words. That makes sense. Juan, why don't you try?

AUDIENCE: So they can [INAUDIBLE] solar panels [INAUDIBLE] and they calculate how much light you get out of that-- I mean, how much energy.

MARK HARTMAN: So if we could put solar panels everywhere around this bulb, we could collect all of the light.

AUDIENCE: When I was [INAUDIBLE] have a spot where there's all curved mirrors all around it and focus in [INAUDIBLE].

MARK HARTMAN: So like this. So why do people use these reflectors? Why does everybody's car have one of these-- two of these in the front?

AUDIENCE: Focus [INAUDIBLE].

AUDIENCE: To concentrate the light.

MARK HARTMAN: Right. If you just had a light bulb out at the front of your car, the light going this way-- there's going to be some light going this way, some going this way, some going backwards. You're losing that light. If Azeith, like you say, if we took our light bulb and we put it in here, the light that goes backwards gets reflected back out. So if we put this right here and we had a detector over here, we could get maybe half the light, and if we knew that there was half-- go ahead and put it. Is it on? What are you bringing this up here for?

AUDIENCE: So for example, this is a light bulb. [INAUDIBLE].

MARK HARTMAN: Turn.

AUDIENCE: Where did he come from? He was over there.

MARK HARTMAN: I think the battery has died.

AUDIENCE: My bad.

MARK HARTMAN: Do you have another one of these? What are we going to do with it?

AUDIENCE: So my explanation was going to be this is the light bulb, and--

MARK HARTMAN: Sorry.

AUDIENCE: It's all right. So how you guys see inside this [INAUDIBLE] is a curve, and it's shiny like a mirror. So you can collect those photons to focus the light and to reflect the light.

MARK HARTMAN: There we go. So show us with that one.

AUDIENCE: Watch [INAUDIBLE].

AUDIENCE: Anyways, see it's like-- can you see all this light is coming straight. And if you put this thing, it's going to be focusing in one spot.

MARK HARTMAN: So if we have some kind of reflector, if we knew what fraction of the total we collected-- if we put this here and we collected half the light over here, then we could just take the amount of light that we collected and multiply by 2, and we'd know the total. So what I want to do is let's assume-- let's try and recreate Bianca and Juan's idea.

Here is our star right here. I want everybody to stand up, and each of you is going to get a detector. Remember, we said detectors are these pieces of silicone or some other material that have a bunch of squares, pixels on them. And if I were standing right here, I could detect all the light that came into my detector, because back here there's a shadow. I'm stopping all the light. The light gets absorbed there.

So what I want to do is I want everybody to have detector, and let's collect all the light from this object. And can we turn the lights back down again? But let's collect all the light about this far away. So let's collect all the light.

So I'm going to stand here next to you, Azeith. So we're missing some light out the top.

AUDIENCE: [INAUDIBLE].

MARK HARTMAN: Here's another couple. Everybody has two hands. You don't want to stick it in to the middle. You want to-- let's all kind of-- here we go. No, you don't-- so where are we missing light?

AUDIENCE: Here.

[INTERPOSING VOICES]

MARK HARTMAN: At the bottom. So I'll add another one. Azeith, here, why don't you take that one. Put it down there. So I want you to look at how intense your detector is lit up. And Jaylen, you're not getting anything, so why don't you come down here on the bottom. There we go. Now we've covered it up.

AUDIENCE: I'm covering most of the bottom.

MARK HARTMAN: Except-- so Juan, you compare how bright-- well, OK, fine. So everybody sees that. There we go. We've collected all of them. Close enough. Now I want everybody to take a step backwards.

AUDIENCE: Wow.

MARK HARTMAN: What just happened to the intensity of light that you collected with your detector?

AUDIENCE: It decreased.

MARK HARTMAN: Right. If you put it close--

AUDIENCE: Increase.

MARK HARTMAN: --that's a lot that you're collecting. If you put it back--

AUDIENCE: Decrease.

MARK HARTMAN: --you're collecting fewer-- there's fewer of those particles, because they spread out as they get out here. Now let's try and collect all the light. What do we need to do?

AUDIENCE: We need more detectors.

MARK HARTMAN: We need more detectors.

AUDIENCE: Or just go closer.

AUDIENCE: [INAUDIBLE].

MARK HARTMAN: Or go closer. Do you think you could go fly to a star and get really close? As close as you want to?

AUDIENCE: It's possible.

AUDIENCE: No.

AUDIENCE: It'd be fun.

MARK HARTMAN: Probably not.

AUDIENCE: Well, we don't have as many detectors.

MARK HARTMAN: We don't have as many detectors. So if we're further away, we're going to need more detectors to collect all the light, and each detector is going to collect less, because if you look at this, it's illuminated less. If you put it close, it's illuminated more. The intensity is higher.

So what I want you to do with a group-- well, yeah. We're running out of time here. So if we are-- say we are all on different planets, and we are all this far from another star. What is the only thing that I can measure here? Can I measure what's in Peter's detector?

AUDIENCE: No.

AUDIENCE: No.

MARK HARTMAN: No. I can measure what's in my detector. How could I take what I measure here and predict how much light that source is putting off altogether? What would I need to do?

AUDIENCE: Collect [INAUDIBLE].

MARK HARTMAN: Say that again.

AUDIENCE: Multiply it by the number of detectors.

MARK HARTMAN: So if I know that this detector is this big, and if I knew how many other detectors I would need to cover the whole star, I could take my amount and just multiply by that number. In other words-- and this is what we're going to go back and write down-- when you collect from your detector, you only collect a fraction of the total amount of light. That fraction is the area of your detector divided by the area of what? What do we need to make here with detectors?

AUDIENCE: Sphere.

MARK HARTMAN: We need to make a?

AUDIENCE: Sphere.

MARK HARTMAN: We need to make a sphere, because if we went up close-- everybody go up close and make a sphere with your detectors.

AUDIENCE: I'm going to have to [INAUDIBLE].

MARK HARTMAN: Everybody should be about the same distance away. So Azeith, you're too close. So if we bent this around, this shape that we're omitting here is kind of a sphere shape. So if I knew the area of my detector and I knew the area of this sphere, I could figure out how much light this object put out. So I want you to keep that in mind. We're going to come back to that a little bit. So what do I need to know to figure the area of that sphere?

AUDIENCE: Area?

MARK HARTMAN: Yeah, the area of this sphere. Does anybody remember the formula for the area of a sphere from geometry class?

AUDIENCE: 4 pi r squared.

MARK HARTMAN: So the area of a sphere is 4 times pi times the radius of the sphere squared. What is the radius of our sphere in this case? Let's all make the sphere again. What's the radius of the sphere? Somebody point out the radius of our sphere.

AUDIENCE: 5.5.

AUDIENCE: The light bulb to the--

MARK HARTMAN: The light bulb to the detector. So if I'm here by myself, I would just say, well, that's the distance from my detector to the source.

AUDIENCE: But in actuality--

MARK HARTMAN: But in actuality, it's the radius of this circle if I were to collect all of the light. So let's turn this off so we don't get too blind. Let's turn the lights back on, and I just want to write that down, and I want you guys to write that down in your notes.

We're going to say, how can we collect all the light from an object? That's what we're wondering. There are two ways. We could either surround the source with detectors, or we could collect light with one detector. If we collect the light with one detector, then we want to say the fraction of the total light emitted is equal to-- actually let me put this on two lines. Fraction of the total light emitted is equal to the area of my collector-- well, actually I said collect light with one detector. Let's say-- yeah.

Now and I'm going to change from detector to collector because it's not that we just have that one little chip, but we actually have the whole telescope, the aperture of the telescope that then collects the light, and it focuses the light. Remember, when we looked at making an image with a mirror, we were collecting the total amount of light that hit the mirror, not just the light on the detector. So we could collect the light with one collector. The fraction of the total light emitted is the area of the collector over the area of a sphere.

We're just going to say the area of a sphere with radius equal to your distance from the object, because whenever we're working with something in astronomy, we can never collect all the light. We can't go out in space, and we can't do this. We can't surround every star with a bunch of detectors. What we can do is we can collect light with one collector or one telescope, and so long as we know that-- so long as we can figure out what fraction of the total light, then we can figure out how much light the overall thing is putting out.

So I'm going to draw a little diagram to go along with this. If you have a light bulb here, if you are this far away, this is your collector, and normally we say that's a telescope. This is your distance to the object. So you need to know your area of a collector compared to the area of a sphere that is centered at that object that has the same radius as the distance between you and the object. So we're never going to get all the light. We're just going to get a fraction of the light.