Thread NSTA light intensity experiment Question

Sun 5/22/2011 11:53 AM

I tried using a flashilight shined onto a pasco light sensor in hopes of obtaining an inverse-square graph of intensity vs. distance away. My data turned out to be a really nice exponential curve instead. Is there something I'm missing? Thanks!

Bonner,David [dbonner@hinsdale86.org]

I wouldn't expect an inverse square relationship from a flashlight because it is collimated to some extent. Have you tried using a bare light bulb instead?

Bill

Hi David,

Both functions are asymptotic. How are you determining which model is best? Are you finding a much higher correlation for exponential models than a power model?

I have had students do this within a box so that ambient light is removed from the data. If there is ambient light it would translate your data upward and will ruin the match with a power model unless you first massage the data by subtracting the base reading.

I have had students get exponential decay with a light (at a fixed distance) shining through successively increased layers of wax paper. The wax paper attenuates the light dramatically and you get an exponential relationship since each layer removes a percentage of the remaining light filtering through.

Let us know your data and how you are analyzing it and we may have more thoughts.

Regards,

Josh

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P.S. If you are varying distance, the experiment *should* work. One problem that I have experienced is that flashlights are far from uniform in intensity across the cross section of the beam. You may want some way to diffuse the light to make it more consistent. Otherwise, as you back it up, it really messes with the data because the very center and a broader area including the center will not have the same value even at the same distance.

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I have a couple of questions. Do you mean an exponential decay, or an exponential increase? I wouldn't be surprised if, for a certain range of distances, the inverse-square relationship might look like an exponential decay.

Did you take the lens off the flashlight? You will only see an inverse-square relationship for a point-source, not for a focused beam.

Is the light sensor on the right range? I think the light sensors have three different range, and you'll want to make sure you choose the one that matches the intensity of your source.

Have you removed all ambient light sources?

Is there any surface (such as the table top or wall) from which your source may be scattering toward the sensor?

Jon Rockman
Castilleja School, Palo Alto CA
"Women Learning, Women Leading"

Hi all,

I sent the following directly to David, but I'm curious as to what others think of the following. Trying to figure out why there should be exponential decay of light from a flashlight beam.

In your case, though, you might have a great example of exponential decay. You have a flashlight that is attempting to take all of the light from the bulb and send it in one direction. It's failing at that, and a certain percentage is being lost to the sides. If that percentage lost is constant as you move away from the detector (and I would think it is to a first approximation), then you are removing a constant percentage from the beam in equal intervals (equal distances moved away). Sounds a lot like exponential decay to me (think radioactive decay).

Bill

Hi,

As others have pointed out, I am certain that you intended to say "exponential decay," because if the light is getting greater as you move further away, we are all going to be doomed!

So that means that you are losing too much energy density as you move away from the source.

Whether it is a collimated beam or not, there should be an inverse-square relationship. No level of collimation is 100% perfect. If you look at a point source, it emits energy in every direction, so the energy density at any spherical 3D distance, R, from the central source would be the energy emitted divided by the surface area of a sphere, or 4*pi*R^2. That is the normal inverse square relation. However, if the beam is truly collimated, its energy will spread out as a directed cone, intercepting a circle, so its energy density goes like the total emitted divided by pi*R^2...four times as much, but still an inverse-square rule. If anything, having a collimated beam should have made you misinterpret your beam as seeming too bright at long ranges (although the relationship should have been correct).

I do not have much experience with the light sensors, but I would check to make sure I am in the correct range. Also, other than the source, I would attempt to be in a completely dark room...a flashlight bulb does not have a high intensity and "dim" sunlight through a shaded window may overwhelm it at a remarkably small distance.

However, I suspect it has to do the with lensing of the flashlight. Rather than collimating the beam, the lenses have a tendency to have a loose focus (like a circular pattern) of brighter and dimmer regions. I believe that is your problem. If you were able to be in the "focused" beam nearby, but slipped into the "unfocused" part of the beam when it was dimmer (and you couldn't really tell), that would get you to lose a disproportionate amount of energy.

I hope this helped.

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Thank you to everyone who replied. I knew there was likely a quick fix. I didn't realize that the inverse square relationship would not work for a colimated beam. Hopefully using a simple light bulb should fix the issue. Thanks again!

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I have used a mini Maglite for this experiment. The reflector, when unscrewed, can be used as a base to hold the Maglite so that the light is about 7 inches above the table height. The Maglite is a good approximation to a point source.

Dale Freeland

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Hi Bill,

What I am about to write could be really flawed but I am thinking about it as I catch up on feedback to students on projects, so I am skimping on rigor here. Anyone should feel free to jump in and modify this.

I don't see the mechanism for what you are describing. If the flashlight does have light that is spread out over a region, even if unevenly, why would it lose a fixed percentage for each step backward (which are of a diminishing percentage in distance increased)? We know that the area of the initial beam at, say, 1 cm in front of the bulb that ultimately illuminates the sensor will decay proportional to 1/d^2. This would not be true if the beams were not radiating along linear paths, but the light is not being redirected much by air in the lab.

What would make this diminishing area exponentially decay in terms of light falling on the sensor? Well, the intensity of the light would have to vary in some interesting ways as we move radially out from the center of the beam.

Let f(r) = the intensity of the light (per cm^2) a distance r from center (I have noticed that many flashlights have concentric circular regions of varying intensity). If the sensor captures all of the beam's light at 1 cm and d is the distance in cms for other positions, then the light received at a greater distance would be the integral from 0 to 1/d of 2pi*r*f(r)dr. If we want this integral to yield an exponentially decaying rule with respect to d then what would f(r) have to be? Maybe, f(r) = e^(kr)/r? This yields the integral from 0 to 1/d of 2pi*e^(kr) which evaluates to 2pi/k*e^(kr) evaluated from 0 to 1/d or 2*pi/k*e^(k/d) - 2pi/k. This does not look good because we have inverse behavior int he exponent. That won't yield regular exponential decay.

So, I try f(r) = e^(k/r)/(r^3). Substituting yields the integral from 0 to 1/d of 2pi*e^(k/r)/(r^2)dr. Reversing the chain rule gives us -2pi/k*e^(k/r) evaluated from 0 to 1/d which, if k < 0 and I am fast and loose with my bounds, comes out to -2pi/k*e^(kd). Since k is negative, this integral is positive and will decay (since e's exponent is negative). So, my calculations suggest that we will only get exponential decay from a receding light if the pattern of intensity is given by the tortured function: f(r) = e^(k/r)/(r^3)!

That was fun to tinker with,

Josh

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Yeah, I think you're right. It's a cone that's changing, and the intensity is still spread out over an area. I'll have to draw more diagrams, but right now it appears my thoughts about it being a constant percentage reduction don't hold up. Well, that's why I posted it--to get feedback.

Bill

From: physics-request@list.nsta.org [mailto:physics-request@list.nsta.org] **On Behalf Of** Bob Gannon
Sent: Sunday, May 22, 2011 6:52 PM
To: Joshua Abrams; Bonner,David
Cc: Physics NSTA
Subject: Re: light intensity experiment

Try with the newer "flat" LEDs (not ones with glass bulbs.

Bob

SEHS

I use the older incandescent Maglite bulbs. I do not use light sensor from Vernier or PASCO. I do use a 1 cm x 1 cm window cut out of cardstock and placed one unit (10 cm if using meter stick or 1 envelope if using non standard unit). This window is placed at height of bulb. All light energy travels through 1 cm x 1 cm window which stays 10 cm from Maglite through out the observations.

I place a whiteboard for a screen with transparency 10 cm x 10 cm grid held up to it. Students count the squares illuminated at 20 cm (or 2 envelopes) from Maglite and find that 4 squares are illuminated. Students move the whiteboard-grid combination to 30 cm from Maglite. They find that 9 squares are illuminated but, notice that each of the squares appears dimmer with the whiteboard-grid at the 30 cm mark. I have students proceed to count illuminated squares as they move whiteboard-grid combination out to 100 cm from Maglite. They see a noticeable difference in illumination in a darkened room as the whiteboard-grid moves away from Maglite and the number of squares illuminated increases.

Students have graphed squares illuminated as distance increases. I have also provided an amount of light energy that passes through the window so that they may compute the light reaching each illuminated grid square. I have presented this method at conferences and received very positive feedback. Let me know if you are interested learning more details about this type of student work.

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