1.4.3 Quiz: The formula for an x-ray projection

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Question 1

1/1 point (graded)

Recall that $p = -\ln\left(\frac{I}{I_0}\right) = \int_0^L \mu(x)\,dx.$. If $I = I_0$, what can you say about the value of p? Does this make sense with the idea that p is a measure of how much the x-ray is attenuated?

Choose the best answer.

- $p = 0$, since if $I = I_0, p = -\ln(I/I_0) = -\ln(0) = 0$. This makes sense since the output intensity is equal to the input intensity, so this means the x-ray is not attenuated at all.
- (selected) $p = 0$, since if $I = I_0, p = -\ln(I/I_0) = -\ln(1) = 0$. This makes sense since the output intensity is equal to the input intensity, so this means the x-ray is not attenuated at all. ✔
- p is not defined, since if $I = I_0, p = -\ln(I/I_0) = -\ln(1)$ which is undefined. This makes sense since the output intensity is equal to the input intensity, so this means that the x-ray didn't pass through anything so attenuation amount is undefined.
- $p = 1$, since if $I = I_0, p = -\ln(I/I_0) = -\ln(1) = 1$. This makes sense since the output intensity is equal to the input intensity, so this means their ratio is 1, so the attenuation is 1.

Explanation

If $I = I_0, p = \ln(I/I_0) = \ln(1) = 0$. Since the output intensity is equal to the input intensity, this means the x-ray is not attenuated at all, so it makes sense that p equals zero.

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Answers are displayed within the problem

Question 2

1/1 point (graded)

At first glance, the quantity $p = -\ln(I/I_0)$ might appear to be negative because of the negative sign.

But it doesn't make sense to talk about negative attenuation! Why not? The projection p is measuring how much the x-ray is attenuated through an object. We know x-rays are attenuated as they pass through objects, depending on the thickness and attenuation coefficient of the material. So we expect the value of p to be positive, or zero if there is no attenuation like an x-ray passing through air.

Which of the following reasons explain mathematically why the formula $p = -\ln\left(\frac{I}{I_0}\right)$ produces a non-negative value? Choose all that apply.

- [ ] A. Since $\frac{I}{I_0} < 0$, $\ln\left(\frac{I}{I_0}\right) < 0$, so $-\ln\left(\frac{I}{I_0}\right) > 0$.
- [x] B. Since $\frac{I}{I_0} < 1$, $\ln\left(\frac{I}{I_0}\right) < 0$, so $-\ln\left(\frac{I}{I_0}\right) > 0$. ✔
- [ ] C. Since $I_0 < I$, $\ln\left(\frac{I}{I_0}\right) < 0$, so $-\ln\left(\frac{I}{I_0}\right) > 0$.
- [x] D. Since $I_0 > I$, $\ln\left(\frac{I}{I_0}\right) < 0$, so $-\ln\left(\frac{I}{I_0}\right) > 0$. ✔
- [x] E. Since $I < I_0$, $\ln(I) - \ln(I_0) < 0$, so $-\ln\left(\frac{I}{I_0}\right) > 0$. ✔
- [ ] F. Since $I < I_0$, $\ln(I) - \ln(I_0) > 0$, so $-\ln\left(\frac{I}{I_0}\right) > 0$.

✔

Explanation

Choice (B) and (D) and (E). At first glance, the quantity $-ln(I/I_0)$ might appear to be negative, because of the negative sign. However, I, the output intensity is less than I_0, the input intensity, so I/I_0 is a number less than 1. We know that $\ln(x) < 0$ for x <1, so in fact $\ln(I/I_0)$ will be negative, which means $-\ln(I/I_0)$ will be positive. This matches with our understanding of p as a positive (or zero) value, since it measures attenuation.

Choice (E) is also valid since $\ln(I) - \ln(I_0) = \ln\left(\frac{I}{I_0}\right)$ by rules of logarithms: $\ln(A/B) = \ln(A) - \ln(B)$.

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Question 3

3/3 points (graded)

The following is a graph of the projection values of x-rays traveling through a 2D object at from different positions on the x-ray source. All x-rays have the same initial intensity.

Rank these three points from lowest to highest output x-ray intensity.

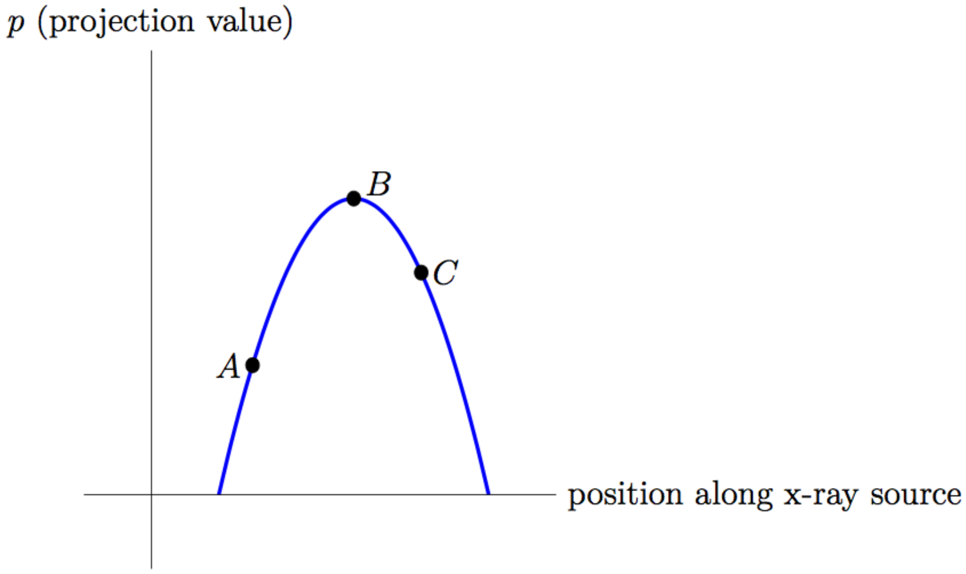

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Image Description

Lowest:

B ▼ **Answer:** B

Middle:

C ▼ **Answer:** C

Highest

A ▼ **Answer:** A

Explanation

Intuitively, we think of p as a measure of attenuation of the x-ray. Thus a larger p-value means more of initial intensity of the x-ray has been attenuated as it travels through the object, which results in a smaller output intensity.
Thus the largest p-value corresponds to the smallest output intensity, and vice-versa, resulting in the ranking B, C, A.

We can also see this from the relationship: $p = -\ln\left(\frac{I}{I_0}\right)$, which can be rewritten as $I = I_0 e^{-p}$.

A larger p-value results in a smaller value of e^{-p} since e^{-x} is a decreasing function, and thus a smaller value of I.

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