# Quantum I (PHYS 3220)

concept questions

# Clicker Intro

Do you have an iClicker? (Set your frequency to CB and vote.)

A) Yes

B) No

# Have you looked at the web lecture notes for this class, before now?

A) Yes

B) No

# Intro to Quantum Mechanics

# In Classical Mechanics, can this equation be derived?

$$\vec{F}_{net} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}t}$$

A) Yes

B) No

# Can this equation be derived?

$$\vec{\tau}_{net} = \frac{\mathrm{d}\vec{L}}{\mathrm{d}t}$$

A) Yes

B) No

(ICLICKER frequency is CB)

Have you done the assigned reading for today?

A) Yes – Griffiths only
B) Yes – Web notes only
C) Yes – both text and notes
D) Not really – but I will soon!
E) Nope

Postulate #3 says $|\psi(x)|^2 dx$ =
Prob(particle is between x and x+dx)
What conclusion can you draw?

A) $\int_{-\infty}^{\infty} |\psi(x)|^2 dx$ must be exactly =1

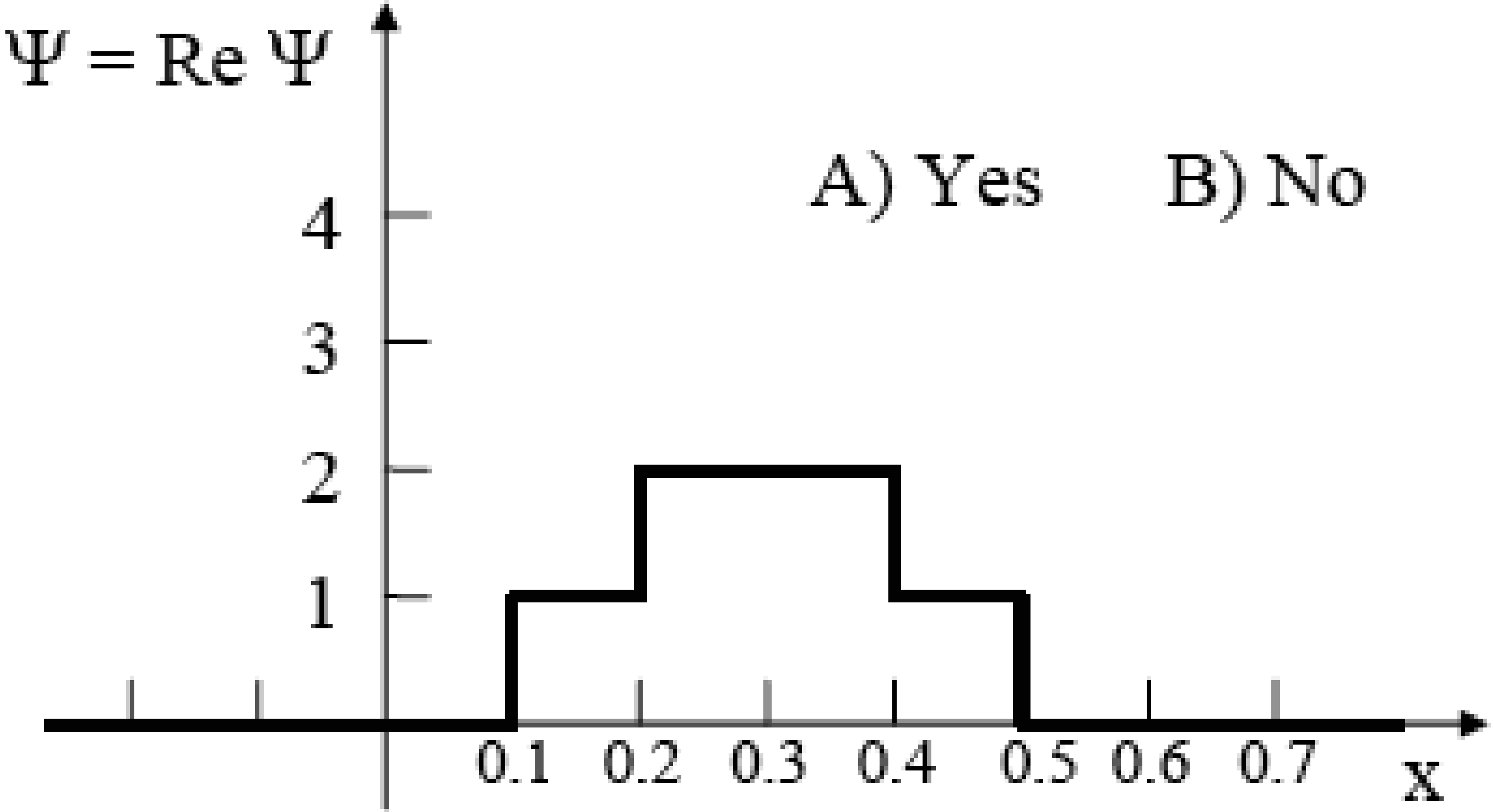
B) $\int_{-\infty}^{\infty} |\psi(x)|^2 dx$ is finite, but needn't =1

C) $|\psi(x)|^2$ must be *finite* at all x.

D) More than one of these

E) One/more are *true,* but do not *follow*

# Is this wave function normalized? (This wave function is pure real)

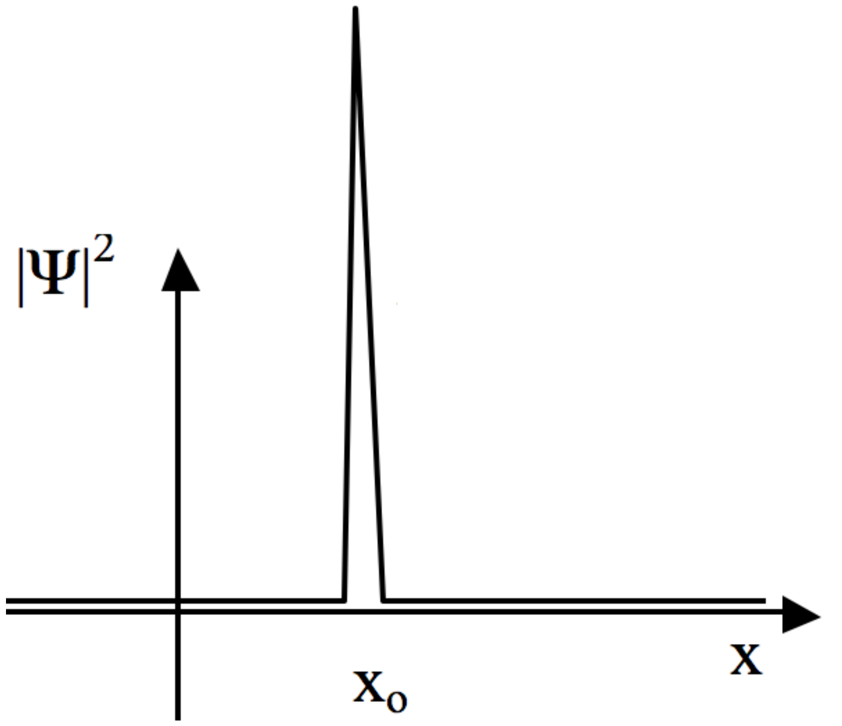


# How would you physically interpret the wave function in the sketch?

A) This doesn't look very physical…

B) QM doesn't let you "interpret" wave functions like this

C) It's a large particle




D) a small particle

E) a particle located at a definite spot ($x_0$)

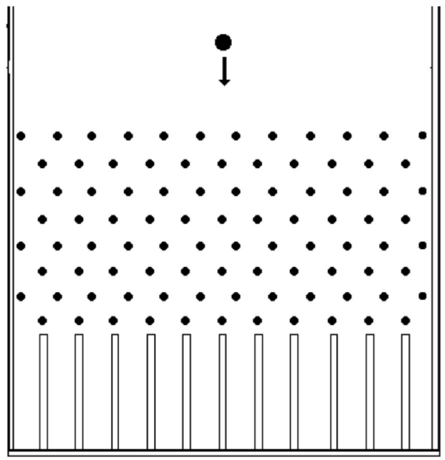
# Statistics and Probability

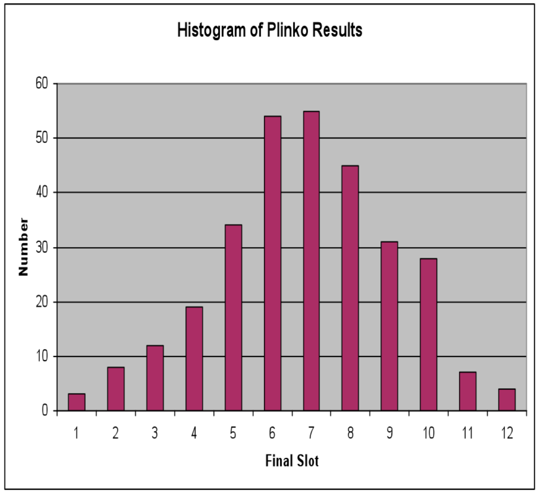
You flip an ordinary coin in the air and get 3 heads in 3 tosses. On the 4th toss, the probability of heads is …

A) greater than 50%

B) less than 50%

C) equal to 50%



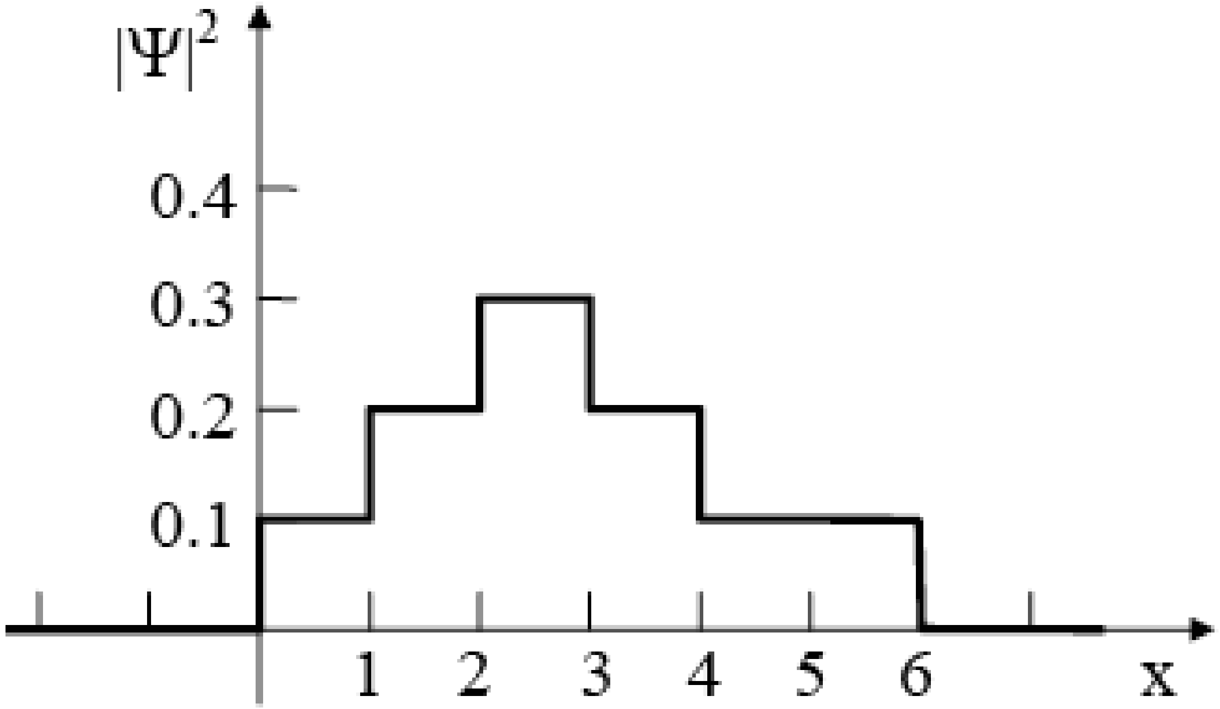



Plinko! A marble is released from the same starting point each time. *Classical physics says identical systems with exactly the same initial conditions always lead to the same final result, in a deterministic and repeatable way.*

Is the distribution of final outcomes for the Plinko game (played 300 times) in this example in conflict with our theories of classical systems?

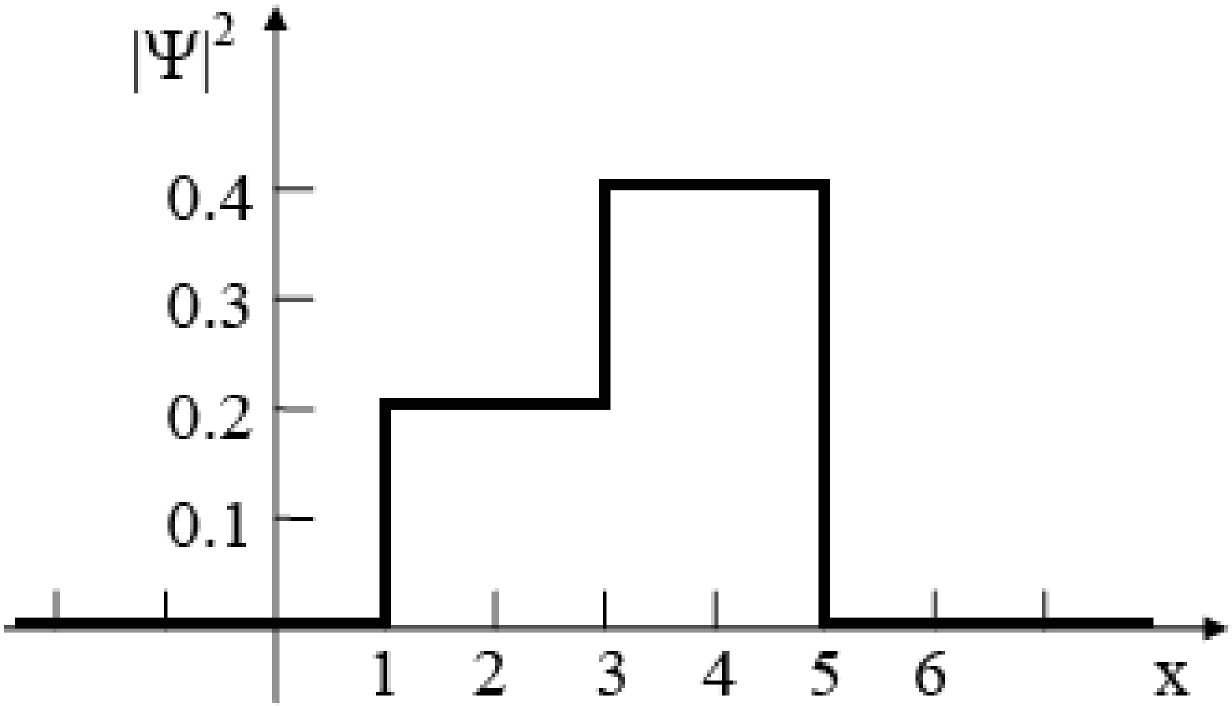
A) Yes B) No

The probability density $|\Psi|^2$ is plotted for a **normalized** wave function $\Psi(x)$. What is the probability that a position measurement will result in a measured value between 2 and 5?




A) 2/3
B) 0.3
C) 0.4
D) 0.5
E) 0.6

The probability density $|\Psi|^2$ is plotted for a **non-normalized** wavefunction $\Psi(x)$. What is the probability that a position measurement will result in a measured value between 3 and 5?




A) 2/3

B) 4/9

C) 1/2

D) 0.6

E) 0.4

# Do you plan on attending Tutorial today? (4 PM, basement Tutorial bay)

A) Yes, I’ll be there!

B) Maybe

C) No/can’t come

N independent trials are made of a quantity x. The possible results form a *discrete spectrum* $x_1$ , $x_2$ , ... $x_i$ , ... $x_M$ (M possible distinct results). Out of N trials, $n_i$ of the trials produce result $x_i$.

If you add up all the results of all N trials, what is the sum of the results?

| $x_i$ | $n_i$ |
|---|---|
| $x_1 = 17$ | $n_1 = 5$ |
| $x_2 = 18$ | $n_2 = 50$ |
| $x_3 = 19$ | $n_3 = 150$ |
| $x_4 = 20$ | $n_4 = 25$ |
| $x_5 = 21$ | $n_5 = 50$ |
| $x_6 = 22$ | $n_6 = 20$ |

A) $\sum_i x_i$

B) $\sum_i n_i x_i$

C) $\sum_i N$

D) $N$

E) $N \cdot \sum_i x_i$

N = 342 trials, (6 different possible results in each trial)

What is the best estimate of the probability that a token picked from the bag will be an 8?

| $x_i$ | $n_i$ |
|---|---|
| $x_1 = 4$ | $n_1 = 21$ |
| $x_2 = 5$ | $n_2 = 1$ |
| $x_3 = 6$ | $n_3 = 80$ |
| $x_4 = 7$ | $n_4 = 70$ |
| $x_5 = 8$ | $n_5 = 110$ |
| $x_6 = 9$ | $n_6 = 60$ |

A) zero

B) $\frac{6}{342}$

C) $\frac{1}{6}$

D) $\frac{80}{342}$

E) $\frac{110}{342}$

# For a large number N of independent measurements of a random variable x, which statement is true?

A) $\left\langle \mathrm{x}^2 \right\rangle \geq \langle x \rangle^2$ always

B) $\left\langle x^2 \right\rangle \geq \langle x \rangle^2 \quad or \quad \left\langle x^2 \right\rangle < \langle x \rangle^2$

depending on the probability distribution.

A ball is released from rest.

You take *many* pictures as it falls to x=H (pictures are equally spaced in time).

What is <x>, the average distance from the origin in randomly selected pictures

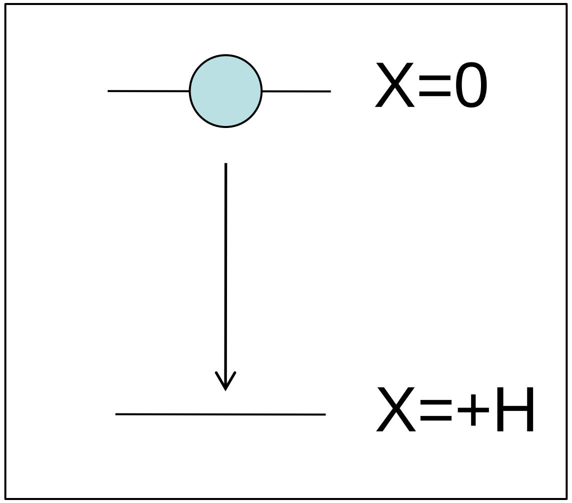
A) H/2

B) larger than H/2 but less than H

C) larger than H

D) smaller than H/2

E) ???



# Waves

A traveling wave is described by

$Y_1(x,t) = 4 \sin(2x - t)$

All the numbers are in the appropriate SI (mks) units.

To 1 digit accuracy, the wavelength, λ, is *most nearly*…?

A)1m B) 2m

C) 3m D) 4m

E) Considerably more than 4m.

Two traveling waves 1 and 2 are described by the equations.

$Y_1(x,t) = 8 \sin(4x - 2t)$

$Y_2(x,t) = 2 \sin(x - 2t)$

All the numbers are in the appropriate SI (mks) units.

Which wave has the higher speed?

A) Wave 1

B) Wave 2

C) Both waves have the same speed

# Have you ever studied the (classical) Wave Equation?

A) Yes

B) No

C) Not sure

Let $y_1(x,t)$ and $y_2(x,t)$ both be solutions of the same wave equation; that is,

$$\frac{\partial^2 y_i}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y_i}{\partial t^2}$$

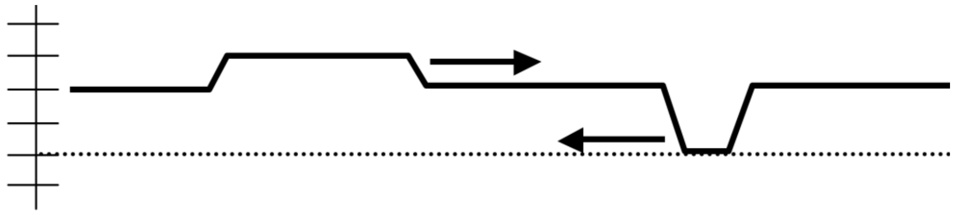
where *i* can be 1 or 2, and v is a constant.

Is the function $y_{sum}(x,t) = ay_1(x,t) + by_2(x,t)$ still a solution of the wave equation? (with a, b constants)

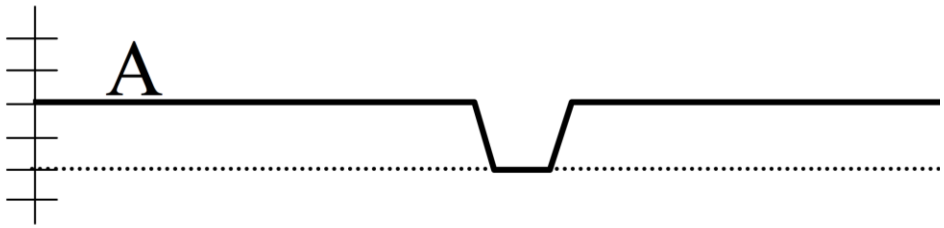
A) Yes, always B) No, never

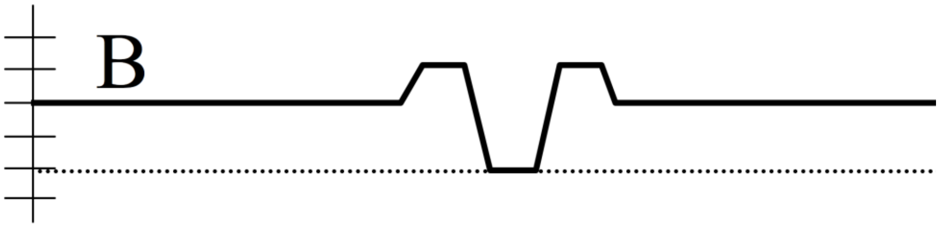
C) Sometimes, depending on $y_1$ and $y_2$.

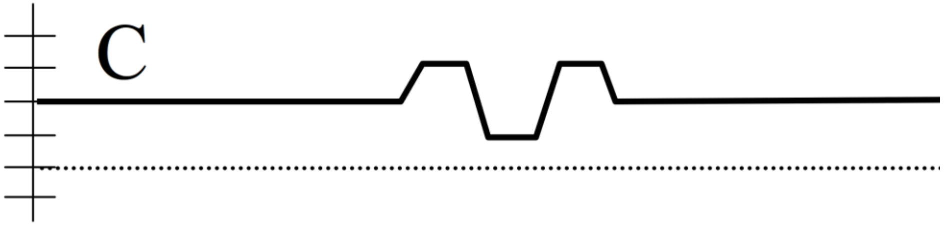
Two impulse waves are approaching each other, as shown.

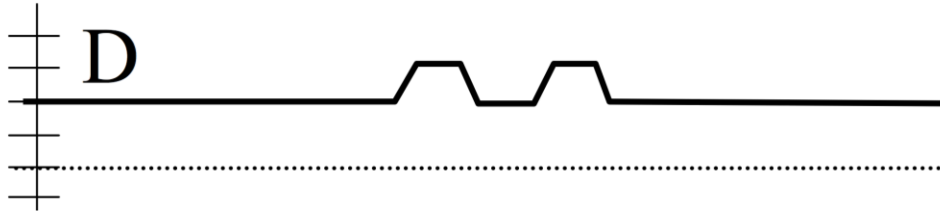


Which picture correctly shows the total wave when the two waves are passing through each other?



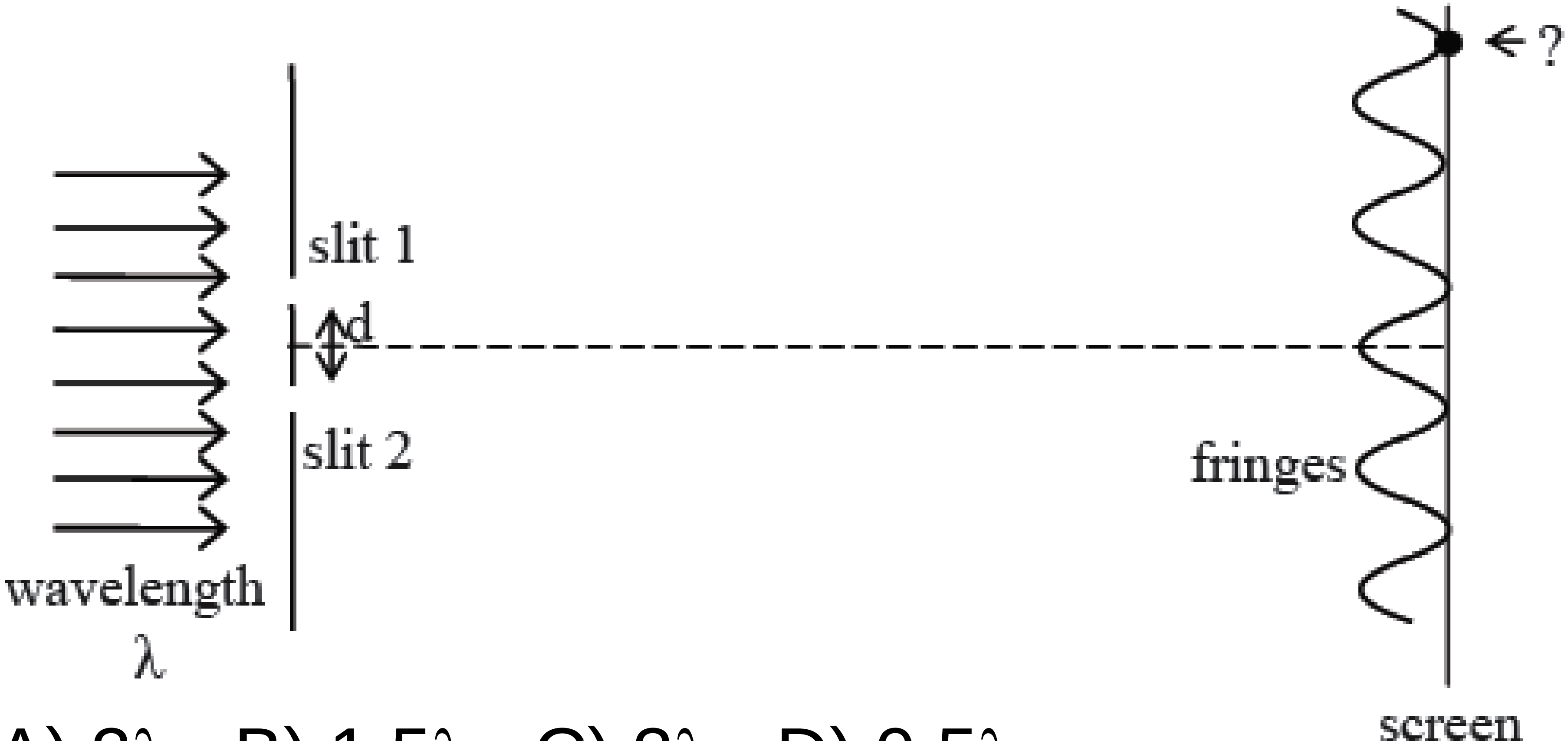




or E) None of these is remotely correct

A two-slit interference pattern is viewed on a screen. The position of a particular minimum is marked. This spot on the screen is further from the lower slit than from the top slit. How much further?




A) 2λ   B) 1.5λ   C) 3λ   D) 0.5λ

E) None of these

Two radio antennae are emitting isotropic radio signals at the same frequency f in phase. The two antennae are located a distance 10.5λ apart (λ = c / f). A technician with a radio tuned to that frequency f walks away from the antennae along a line through the antennae positions, as shown:


As the technician walks, she notes the tone from the radio is:

A) very loud, all the time.

B) alternates loud and quiet as she walks.

C) very quiet, all the time.

D) quiet at first, and then loud all the time

Do you plan to attend today's Tutorial (on interpretation of wave functions, the Schrodinger Eqn, and time dependence)

A) Yes, at the 3 pm "sitting…"

B) Yes, at the 4 pm sitting…

C) Perhaps, more likely at 3

D) Perhaps, more likely at 4

E) No, can't come/not planning on it.

A linear operator L[f(x)] has the property $L(a \bullet f_1 + b \bullet f_2) = a \bullet L(f_1) + b \bullet L(f_2)$, a and b any constants. How many of these operators are linear operators? (A and B are constants).

I. $\mathrm{L}\left[\mathrm{f}\left(x\right)\right] = \left(\mathrm{f}\left(x\right)\right)^2$

II. $\mathrm{L}\left[\mathrm{f}\left(x\right)\right] = A \cdot \mathrm{d}^2\mathrm{f}\left(x\right) \big/ \mathrm{d}x^2$

III. $\mathrm{L}\left[\mathrm{f}\left(x\right)\right] = \sin\left(\mathrm{f}\left(x\right)\right)$

IV. $\mathrm{L}\left[\mathrm{f}\left(x\right)\right] = A \cdot \mathrm{f}\left(x\right) + \mathrm{B}$

V. $\mathrm{L}\left[\mathrm{f}\left(x\right)\right] = \exp\left(\mathrm{f}\left(x\right)\right) = e^{\mathrm{f}\left(x\right)}$

A) None of these

B) 1 of these

C) 2

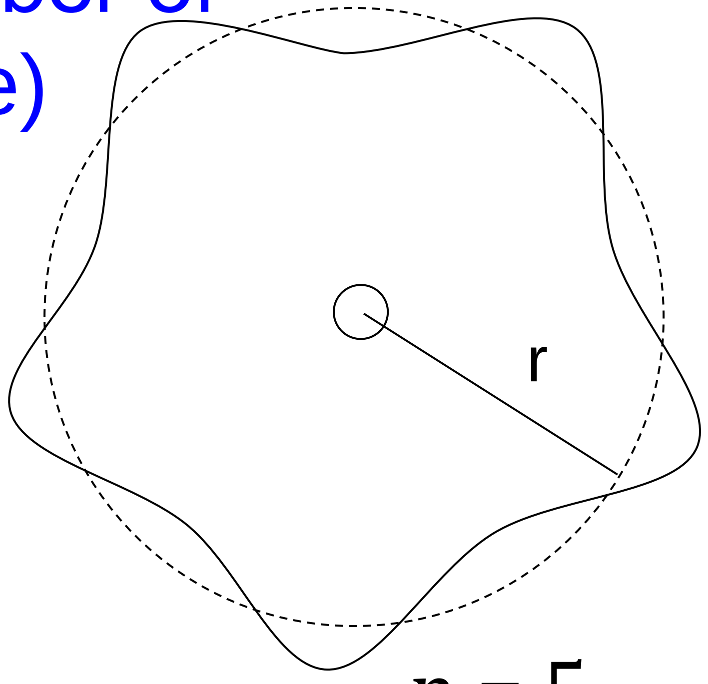
D) 3

E) 4 or more of these

Take deBroglie seriously, electrons are waves! Assume an integer # of wavelengths of the orbiting electron must "fit" on the circumference of the orbit (why?)

First: derive a formula relating λ, r (radius), and "n" (the number of wavelengths around the circle)

Then: solve for L = r p (angular momentum) using deBroglie's relation for momentum.




n = 5

Starting with the assumed solution
$\Psi(x,t) = A \exp[i(kx - \omega t)]$ ,
how can one obtain a factor of $\omega$
(perhaps with other factors)?
Use the *operator…*

A) $\dfrac{\partial}{\partial x}$ B) $\dfrac{\partial}{\partial t}$ C) $\dfrac{\partial^2}{\partial x^2}$

D) $\dfrac{\partial^2}{\partial t^2}$ E) $\dfrac{\partial}{\partial x} + \dfrac{\partial}{\partial t}$

Starting with the assumed solution $\Psi(x,t) = A \exp[i(kx - \omega t)]$ , how can one obtain a factor of $k^2$ (perhaps with other factors)? Use the *operator…*

A) $\dfrac{\partial}{\partial x}$ B) $\dfrac{\partial}{\partial t}$ C) $\dfrac{\partial^2}{\partial x^2}$

D) $\dfrac{\partial^2}{\partial t^2}$ E) $\dfrac{\partial}{\partial x} + \dfrac{\partial}{\partial t}$

Two particles, 1 and 2, are described by plane wave of the form $\exp[i(kx - \omega t)]$. Particle 1 has a smaller wavelength than particle 2: $\lambda_1 < \lambda_2$

Which particle has larger momentum?

A) particle 1

B) particle 2

C) They have the same momentum

D) It is impossible to answer based on the info given.