ILLINOIS

Center for Academic Resources in Engineering (CARE) Peer Exam Review Session

PHYS 214 – University Physics: Quantum Physics

Midterm 2 Worksheet

The problems in this review are designed to help prepare you for your upcoming exam. Questions pertain to material covered in the course and are intended to reflect the topics likely to appear in the exam. Keep in mind that this worksheet was created by CARE tutors, and while it is thorough, it is not comprehensive. In addition to exam review sessions, CARE also hosts regularly scheduled tutoring hours.

Tutors are available to answer questions, review problems, and help you feel prepared for your exam during these times:

Session 1: 2/18, 6-8 pm in 4035 CIF, led by Aparna, Sarah, and Zaahi

Can't make it to a session? Here's our schedule by course:

https://care.grainger.illinois.edu/tutoring/schedule-by-subject

Solutions will be available on our website after the last review session that we host.

Step-by-step login for exam review session:

1. Log into Queue @ Illinois: https://queue.illinois.edu/q/queue/844
2. Click "New Question"
3. Add your NetID and Name
4. Press "Add to Queue"

Please be sure to follow the above steps to add yourself to the Queue.

Good luck with your exam!

1. Consider the wavefunction $\Psi(\text{x}) = \text{N}e^{ikx}$, $0 \leq x \leq L$

a) What is the momentum of a particle given by $\Psi(\text{x})$?

b) Find the probability density and show that it is constant in position over the given interval.

c) Knowing that this wavefunction has definite momentum (momentum eigenstate), what can be said of its position?

2. In a photoelectric effect demonstration, the intensity of the incident light is gradually increased, but no photocurrent is detected. Provide an explanation for this result.

3. A laser with time-varying frequency is directed at a barrier with a narrow slit followed by a screen. Assuming the laser intensity is constant, as the frequency increases, how does the number of photons per second arriving at the screen change?

4. A spacecraft is being pushed by a laser of wavelength 400 nm emitting photons at a rate of 10^{22} photons per second. Calculate the acceleration of the spacecraft given its mass is 4000 kg. Values are given in meters per second.

a) 3.25×10^{-6}

b) 1.53×10^{-3}

c) 4.14×10^{-9}

d) 1.7×10^{-5}

e) 5.5×10^{-4}

5. Verify the following identity: $\sin(kx) = \dfrac{(e^{ikx} - e^{-ikx})}{2i}$. Hint:

$$e^{i\theta} = \cos(\theta) + i\sin(\theta)$$

6. Light with wavelength 100 nm is incident on a metal. The speed of the ejected photoelectrons is measured to be 10^6 meters per second. Find the work function of this metal.

a) 1.99×10^{-18}

b) 1.53×10^{-18}

c) 4.55×10^{-18}

7. A particle's wave function is given by

$$\Psi(x) = \begin{cases} Ax & \text{if } 0 \leq x < L/4 \\ AL/4 & \text{if } L/4 < x < 3L/4 \\ -A(x-L) & 3L/4 \leq x \leq L \\ 0 & \text{elsewhere} \end{cases}$$

a) Sketch this wave function.

b) Without integrating, find the probability of finding the particle between $x = 0$ and $x = L/2$.

c) Find the normalization constant A in terms of L.

8. A material with work function $\Phi = 3.4$ eV has a laser beam with $\lambda = 200$ nm and power $P = 2.3 \times 10^{-4}$ W.

a) Calculate N_γ, the number of photons hitting the material per second.

b) Calculate the energy E_{e^-}, the maximum energy of each ejected electron.

c) Say we have a device that detects the power of the ejected electrons. Calculate the maximum power P this device could measure (assuming every photon ejects an electron, and each electron has maximum energy).

9. Confirm that the wave function

$$\Psi(x) = \frac{1}{5}\left(e^{i\pi/2} + 4i\right)$$

is normalized over the range $0 < x < 1$.

10. We have an electron double slit experiment. Describe what will happen to the spacing of the fringes if we:

a) decrease the slit separation

b) decrease the screen distance

c) send fewer electrons per second

d) replace the electrons with neutrons of the same momentum

e) send the electrons with greater momentum

11. A baseball pitcher throws a standard baseball (m = 0.145 kg) at a speed of 35 m/s. Determine the baseball's De Broglie wavelength, and use this to explain why we don't see interference patterns in day-to-day life (unless you're a physicist).

12. Suppose we have a simple wave function (a momentum eigenstate), $\Psi(x) = Ne^{ikx}$, where N is the normalization constant and k is the wave number.

(a) What is the certainty in momentum (how many values could we possibly measure)?

(b) What is the certainty in position (what does the probability density look like)?

(c) Describe how parts (a) and (b) are consistent with Heisenberg uncertainty.

(d) Now, suppose we add another momentum eigenstate such that the wave function now reads as $\Psi(x) = N(e^{ikx} + e^{-ikx})$. Repeat parts (a) - (c) for this new wave function.

13. A particle's wave function is given by

$$\Psi(x) = A\Big(3\,e^{ik_1 x} + (1+i)\,e^{-ik_1 x} + 2\,e^{ik_2 x}\Big)$$

a) List the possible momentum eigenvalues of the particle.

b) What is the probability of measuring the momentum

$$p = +\hbar k_1\,?$$

14. A particle's wave function is given by

$$\Psi(x) = A\Big(e^{-i\theta}\, e^{-ik_1 x} + (2e^{i\phi})\, e^{ik_2 x} + (8\cos\alpha + 8i\sin\alpha)\, e^{-ik_2 x}\Big)$$

a) List the possible momentum eigenvalues of the particle.

b) Find the corresponding possible energy eigenvalues.

c) What is the probability of measuring the energy

$$E = \frac{(\hbar k_2)^2}{2m}\,?$$