NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 283 – Modern Physics Fall 2025

Problem Set #7

Problem Set Due: Thurs., Oct. 30, 2025
Read Krane: Chapter 7.1-7.8

1. **OpenStax University Physics Vol. 3: Section 1.7:** Problem 64
2. **OpenStax University Physics Vol. 3: Section 1.7:** Problem 65
3. **OpenStax University Physics Vol. 3: Section 2.1:** Problem 26 (see solution to #27)

4. **Krane: Problem 20** **page 234** (just show calculation)
5. **Krane: Problem 21** **page 234** (just show calculation)
6. **Krane: Problem 24** **page 234** (sketch energy level diagram)
7. **Krane: Problem 26** **page 234** (sketch energy level diagram)
8. **Krane: Problem 27** **page 234** (sketch energy level diagram)

Take home Quiz #2 extension
worth 25 points on Quiz #2
(open book/open internet problem)

See next page:

For the integrals, use only the trigonometric identities below (*do not use integral tables*):

(i) $\tan A = \dfrac{\sin A}{\cos A}$

(ii) $\sin^2 A + \cos^2 A = 1$

(iii) $\sin 2A = 2\sin A \cos A$

(iv) $\cos(2A) = \cos^2 A - \sin^2 A = 1 - 2\sin^2 A = 2\cos^2 A - 1$

(v) $\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$

(vi) $\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$

9. *Heisenberg Uncertainty Relation:* An electron is trapped in an infinitely deep one-dimensional well of width L.

(a) Using a symmetry argument, what is the average momentum, p_{ave}, of the electron? Carefully explain your answer.

(b) Using the operator form for momentum, $\hat{p} = -i\hbar \dfrac{d}{dx}$, find p_{ave} using the definition:

$$p_{ave} = \left\langle \hat{p} \right\rangle = \left\langle \psi \left| \hat{p} \right| \psi \right\rangle = \int_{-\infty}^{\infty} \psi(x) \hat{p} \psi^*(x)\, dx\,.$$

(c) What is $\left(p^2\right)_{ave}$ using your knowledge of what $\left(p^2 / 2m\right)_{ave}$ is?

(d) Show that your result for part (c) agrees with the calculation using the momentum operator:

$$(p^2)_{ave} = \left\langle \hat{p}^2 \right\rangle = \left\langle \psi \left| \hat{p}^2 \right| \psi \right\rangle = \int_{-\infty}^{\infty} \psi(x) \hat{p}^2 \psi^*(x)\, dx\,.$$

(e) Do **Krane: Problem 39(c) page 176**.

(f) Using **Krane: Problem 38 page 176**, what is the product $\Delta x \Delta p$? Does it obey the Heisenberg uncertainty relation? (that is, is it greater than or equal to $\hbar/2$?)