BOUND STATES II

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Supplementary Material for
PHY 3305 (Modern Physics)
Harris, Ch. 5.6-5.9
• Review of last class

• SWEs

• Particle in a box
  • The finite well
  • The harmonic oscillator
• We reviewed stationary states
• We discussed the time-independent SWE
• We solved our first problem involving forces
  • the infinite square well
\[ -\frac{\hbar^2}{2m} \frac{\partial^2 \Psi(x,t)}{\partial x^2} + U(x)\Psi(x,t) = i\hbar \frac{\partial \Psi(x,t)}{\partial t} \]
TIME-INDEPENDENT SWE

Assume:

\[ \Psi(x, t) = \psi(x) \phi(t) \]

\[ -\hbar^2 \frac{d^2\psi(x)}{2m dx^2} + U(x)\psi(x) = E\psi(x) \]

you get...
SOLVING PROBLEMS

* Identify the player(s) in the problem
  - what particles?

* Identify constraints
  - what forces (potentials)?

* Solve for the wave function
  - solve differential equation, use smoothness and normalization (physicality constraints)
  - smoothness = “continuity of wave function and first derivative of the wave function”

* Predict outcomes based on the wave function
  - We’ll begin to attack this later today
PARTICLE IN A BOX - “FINITE SQUARE WELL”

Region II

\[ U = U_0 \]

Region I

\[ U = 0 \]

Region III

\[ U = U_0 \]

Spatial Location

Total Energy

\[ E = KE \]

\[ x = 0 \]

\[ x = L \]
ALLOWED ENERGIES
Solutions

Density

Amplitude

Amplitude

Density

$|\psi(x)|^2$  Finite well  $\psi(x)$  $\psi(x)$  Infinite well  $|\psi(x)|^2$
**MASS ON A SPRING**

Spring constant $\kappa$

At turning points, kinetic energy is 0. Outside them it would have to be negative.

The area outside the potential energy curve is the classically forbidden region.

Total energy (kinetic plus potential) is constant. Its plot is therefore a horizontal line.

$E = KE + U$

$U = \frac{1}{2} \kappa x^2$

Position

- $-A$
- $0$
- $x$
- $+A$
Figure 5.3 Energy versus position for the interatomic force between a large atom fixed at the origin and a small one free to move.
HARMONIC OSCILLATOR: SOLUTIONS

At each energy given by $E = (n + \frac{1}{2})\hbar\omega$...

As $n$ increases toward the classical limit, the probability becomes higher near the turning points (extremes).

... a unique wave function exists.

The probability is highest at the center in the ground state, contrary to the classical case.
SPECIFIC HEAT - H₂

Specific Heat Capacity (kJ/(kg*K))

Temperature (K)
Next time

- Mid-term

- Coming up:
  - unbound states - barriers, tunneling, applications
  - why does nuclear decay take time? ("Alpha Radiation")
  - atomic spectra and "fine structure"