PART I: CLASSICAL (+ a little quantum theory about phonons)

Coupled oscillators:

1. Chain of atoms coupled by springs
   (= chain of frictionless carts coupled by springs)

2. Chain of pendulums connected by springs

3. Chain of LC resonator circuits wired together.

CONCEPTS:
- Natural freqs
- Normal modes
- When coupling is harmonic and only to nearest neighbors we describe normal modes using wave vectors. ⟶ dispersion relations.
- First Brillioun Zone
- Fixed-end vs. periodic B.C.s
- Quantized energy in a normal mode ⟷ phonon.
- Phonon occupation number (Bose-Einstien Statistics)
- total energy stored in vibrational modes ⟷ heat capacity
- Dispersion relation for diatomic lattice.

EXAMPLE QUESTIONS:
- Write down and solve eqns of motion for a system of coupled oscillators.
- Use boundary conditions & dispersion relation to calculate natural freqs.

PART II : QUANTUM

Theme: LCAO states are a good approximation to the actual electron eigenstates that exist in a lattice of quantum wells.

CONCEPTS :

- Use a single quantum well to calculate the "atomic orbital"
- Basis states = The atomic orbital at each lattice site
- Write the Hamiltonian in the LCAO basis (matrix elements often called α & β)
- Write the eigenstates in terms of the LCAO basis. One value of k for each eigenstate.
- Fill the eigenstates with non-interacting e^-s (spin up & spin down)
- Partially-filled band = metal
  Filled band = semiconductor or insulator.
- Use dispersion relation to understand bandgap and density of states.
- Light absorption by electronic transitions requires a filled state & empty state separated by E_{photon}.

EXAMPLE QUESTIONS:

- Write out $\Psi(x,t)$ for an LCAO eigenstate
- Sketch $\text{Re}\{\Psi(x)\}$ at $t=0$ for an LCAO eigenstate.
- Find allowed k given Boundary conditions.
- List eigenenergies of a 5-well system in terms of α & β.
- Calculate $g(E)$ from a dispersion relation

EXAMPLE QUESTIONS FOR FINAL:

True/False Questions

T F The typical speed of sound in a solid crystal is 300 ms^{-1}

T F The heat capacity of a diamond at room temp is much higher than the heat capacity of the same diamond at 10K.

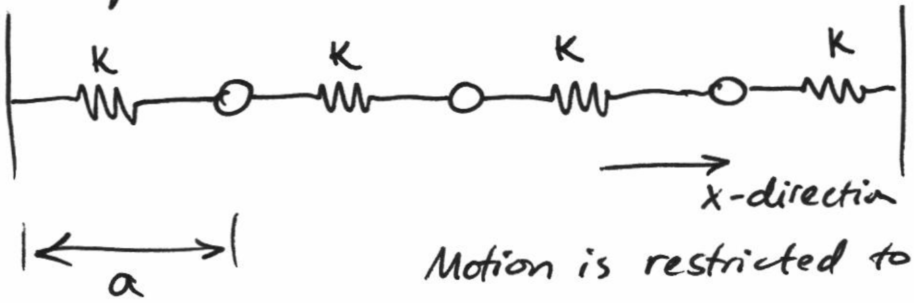
Short answer questions

- What is the ratio of ω_{Debye} for crystals made of different isotopes: Compare a crystal of ^{202}Hg to ^{198}Hg.

  Note: Isotope means that proton number is identical, but neutron number is different.

- At least one short answer question will be identical to a quiz question

Long answer question

• 

Motion is restricted to x-direction.

For normal modes

$$x_1(t) = c_1 A \sin \omega t$$
$$x_2(t) = c_2 A \sin \omega t$$
$$x_3(t) = c_3 A \sin \omega t$$

a) For each normal mode, find an appropriate set of coefficients $\{c_1, c_2, c_3\}$

b) Find the natural freqs in terms of K & m.

- White board exercises we did in class are good material for exam questions

- Simplified versions of HW problems are good material for exam questions