

Chapter 2

11

$$\left. \begin{aligned} \lambda &= \frac{h}{p} \\ E &= \frac{p^2}{2m} \Rightarrow p = \sqrt{2Em} \end{aligned} \right\} \lambda = \frac{h}{\sqrt{2Em}}$$

Electron wave!

$$E = 4(eV) = 4 \times 1.602 \times 10^{-19} \text{ (J)} \equiv \left( \frac{\text{Kg} \cdot \text{m}^2}{\text{s}^2} \right)$$

$$h = 6.625 \times 10^{-34} \text{ (J} \cdot \text{s)}$$

$$m = 9.11 \times 10^{-31} \text{ (Kg)}$$

$$\lambda = \frac{h}{\sqrt{2Em}} \left[ \frac{\text{Kg} \cdot \text{m}^2 \cdot \text{s} \cdot \text{s}}{\text{s}^2 \cdot \text{Kg}^{\frac{1}{2}} \cdot \text{m} \cdot \text{Kg}^{\frac{1}{2}}} \right] \equiv [\text{m}]$$

$$\lambda = 0.6131 \times 10^{-9} \text{ (m)} = \underline{6.13 \text{ (Å)}} = 6.13 \times 10^{-10} \text{ (m)} = 6.13 \times 10^{-8} \text{ (cm)}$$

$$\left. \begin{aligned} E &= \frac{p^2}{2m} \\ p &= \frac{h}{\lambda} \end{aligned} \right\} E = \frac{h^2}{2m\lambda^2} \left[ \frac{\text{Kg}^2 \cdot \text{m}^4 \cdot \text{s}^2}{\text{s}^4 \cdot \text{m}^2} \right] \equiv \left[ \frac{\text{Kg} \cdot \text{m}^2}{\text{s}^2} \right] \equiv [\text{J}]$$

$$\lambda = 600 \text{ (nm)} = 6 \times 10^{-7} \text{ (m)}$$

$h$  and  $m$  see above

Electron wave

$$E = 6.69 \times 10^{-25} \text{ [J]} = \underline{4.176 \times 10^{-6} \text{ (eV)}}$$

Note:  
 In case of  $\lambda = \text{const.}$ :  
 a smaller mass  
 causes a larger energy.

(2/3) Electromagnetic waves (light) can be perceived by cones and rods at the retina of the human eye. Electron waves do not stimulate the cones and rods. Electron waves need a "phosphor" (ZnS) or a diffraction device for detection.

$$\left. \begin{aligned} E &= \nu \cdot h \\ c &= \nu \cdot \lambda \end{aligned} \right\} E = \frac{c}{\lambda} h \left[ \frac{\text{m} \cdot \text{Kg} \cdot \text{m}^2 \cdot \text{s}}{\text{s} \cdot \text{s}^2 \cdot \text{m}} \right] \equiv [\text{J}]$$

$$c = 2.998 \times 10^8 \left( \frac{\text{m}}{\text{s}} \right)$$

$$h = 6.625 \times 10^{-34} \text{ (J} \cdot \text{s)}$$

$$\lambda = 600 \text{ (nm)} = 6 \times 10^{-7} \text{ (m)}$$

$$E_{ph} = 2.066 \text{ (eV)}$$

$$= \underline{3.31 \times 10^{-19} \text{ (J)}}$$

Light wave!

The difference is the mass and the velocity (see also 2/2)

Mass of electron  $m_{el} = 9.11 \times 10^{-31} \text{ Kg}$ ;  $v_{el} = \sqrt{\frac{2E}{m}} = 1.2 \times 10^3 \left( \frac{\text{m}}{\text{s}} \right)$

Apparent mass of photon  $(m_{ph})_{eff} = \frac{E}{c^2} = 3.68 \times 10^{-36} \text{ Kg}$ ;  $v_{ph} = c = 3 \times 10^8 \left( \frac{\text{m}}{\text{s}} \right)$  (photon has no rest mass)

2/5  $E = \frac{1}{2} m v^2$   
 $\lambda = \frac{h}{\sqrt{2Em}}$  }  $\lambda = \frac{h}{m v}$   $\left[ \frac{g \text{ cm}^2 \text{ s}}{s \text{ g cm}} \right] = [\text{cm}]$

$h = 6.626 \times 10^{-27} \left[ \frac{g \text{ cm}^2}{s} \right]$

$v = 200 \left[ \frac{\text{km}}{\text{h}} \right] = 200 \times 10^5 \left[ \frac{\text{cm}}{\text{h}} \right] = \frac{2 \times 10^7}{3600} \left[ \frac{\text{cm}}{\text{s}} \right]$

$m = 50 [\text{g}]$

$\lambda = 2.38^5 \times 10^{-32} [\text{cm}] = 2.38 \times 10^{-24} [\text{Å}]$

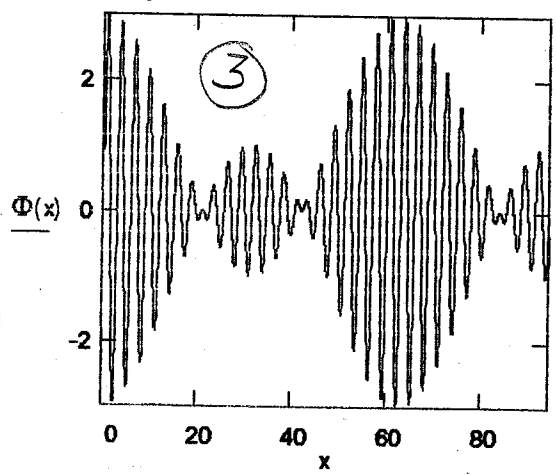
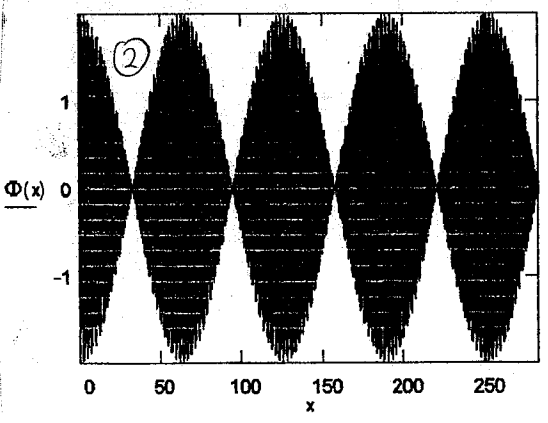
2/7  $E = \nu h$   
 $E = m c^2$   
 $p = m c$   
 $c = \lambda \nu$  }  $\nu h = m c^2 = m c \cdot c = p \cdot c = p \lambda \nu$   
 $\rightarrow \lambda h = p \lambda \lambda \rightarrow \boxed{h = p \cdot \lambda}$

2/8

$\Phi(x) = \sum_i \sin((k+i) \cdot x)$

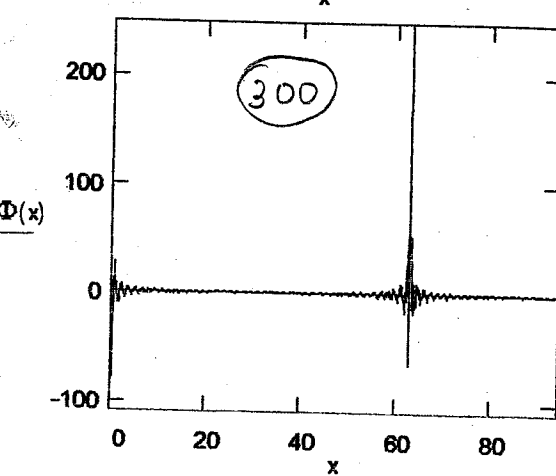
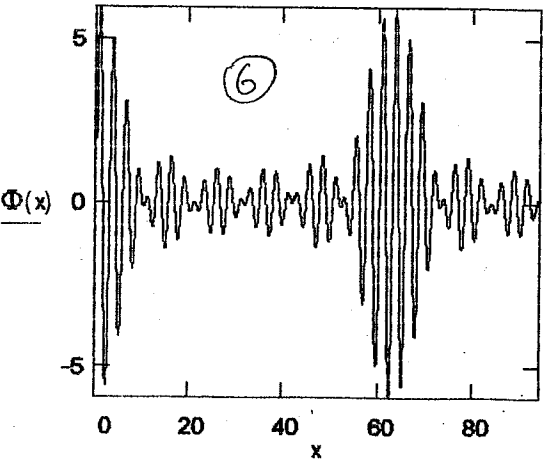
Superposition of  $\psi$  waves.  
 The number of  $\psi$ -waves is given in the graph.

$i = 1, 1.1, \dots, 1.1$   
 $h = 100$   
 $x = 0, 0.1, \dots, 30\pi$



$i = 1, 1.1, \dots, 1.2$   
 $h = 1$   
 $x = 0, 0.02, \dots, 30\pi$

$i = 1, 1.1, \dots, 1.1$   
 $h = 100$   
 $x = 0, 0.15, \dots, 30\pi$



$i = 1, 1.1, \dots, 1.5$   
 $h = 1$   
 $x = 0, 0.02, \dots, 30\pi$

# Chapter 3

3/1 see Appendix A1

3/2 A Vibration is a time or space dependent periodic disturbance  
 A Wave is a time and space dependent periodic disturbance

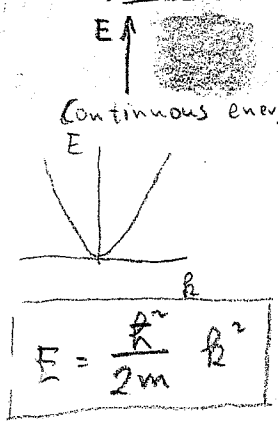
3/3 The damped vibration has a velocity-dependent term:  $m \frac{d^2u}{dt^2} + \gamma \frac{du}{dt} + ku = 0$

3/4  $\psi^* = a - bi$   
 $\psi^* = -2Ai \sin dx$

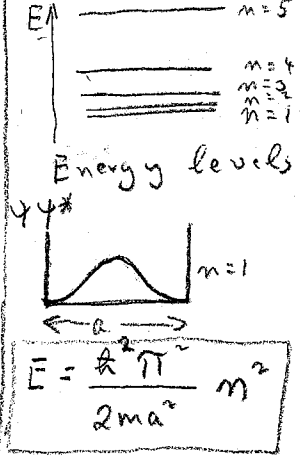
# Chapter 4

4/1

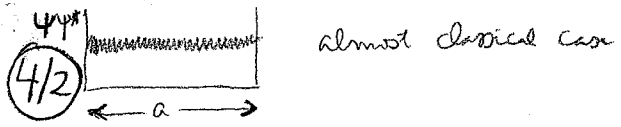
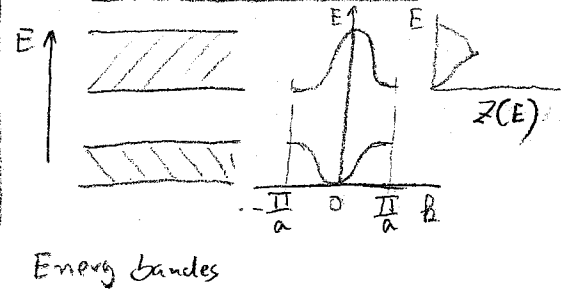
a) Free electron case



b) Bound Electron case



c) Electrons in crystals



4/3 I)  $\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2} E \psi = 0$   
 Sol.  $\psi(x) = A e^{ikx}$   
 where  $\hbar = \sqrt{\frac{2mE}{\hbar^2}}$

II)  $\frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2} (E - V_0) \psi = 0$   
 Sol.  $\psi(x) = A e^{ikx}$   
 where  $\hbar = \sqrt{\frac{2m(E - V_0)}{\hbar^2}}$

This is possible only for  $V_0 = 0$  i.e.  $\psi(x) = A e^{ikx}$  is a particular solution of the problem which is that for free electrons.