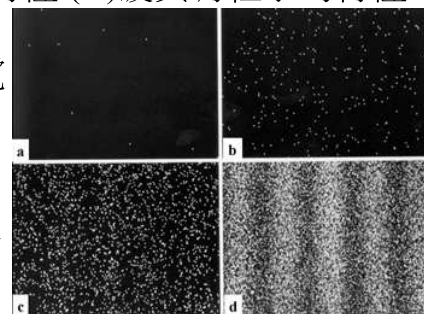


Modern Physics MP-EX03

3_ 1 1927年，柯林頓·戴維森與雷斯特·革末在貝爾實驗室將電子射向鎳結晶，發現其繞射圖譜，這個實驗結果證實了哪一個想法？

(A)光具有粒子的特性 (B)光具有波動的特性 (C)粒子具有波的特性 (D)波具有粒子的特性

3_ 2 1961年Claus Jonsson的電子雙狹縫實驗發現，電子只能走左邊或右邊這兩條路徑，最後抵達屏幕記錄下來，屏幕累積20分鐘(記錄了12000顆電子，如圖)，此實驗在2002年被Physics World雜誌讀者選為最美麗的物理實驗。這個實驗證實了



(A)電子滿足牛頓運動定律 (B)電子滿足狹義相對論的運動描述 (C)電子具有物質波的特性 (D)電子發生輻射現象 (E)電子的角動量空間量子化

3_ 3 根據德布洛依物質波理論，一個質量為 m ，動量為 p ，的質點，其質波的波長為下列哪一個公式？

(A) $\lambda = hp$ (B) $\lambda = p/h$ (C) $\lambda = h/p$ (D) $\lambda = \frac{mh}{p^2}$ (E) $\lambda = \frac{h^2}{mp}$

2_ 4 一個帶電質點它的質量是 m ，電量 q ，最初靜止。受電位差 V 加速後，求德布羅意波長=？

(A) $\sqrt{2mqV}$ (B) $\frac{h}{\sqrt{2mqV}}$ (C) $h\sqrt{2mqV}$ (D) $\frac{2h}{\sqrt{mqV}}$

1_ 5 Evidence for the wave nature of matter is:

A) electron diffraction experiments of Davisson and Germer B) Thompson's measurement of e/m C) Young's double slit experiment D) the Compton effect E) Lenz's law

2_ 6 Consider the following three particles:

1. a free electron with kinetic energy K
2. a free proton with kinetic energy K
3. a free proton with kinetic energy $2K$

Rank them according to the wavelengths of their waves, least to greatest.

A) 1, 2, 3 B) 3, 2, 1 C) 2, 3, 1 D) 1, 3, 2 E) 1, then 2 and 3 tied

2_ 7 A slowly moving proton has its velocity doubled. How does this affect its de Broglie wavelength?

(A)it is divided by 4 (B)it is divided by 2 (C)it is doubled (D) it is quadrupled

2_ 8 A slowly moving proton has its kinetic energy doubled. How does this affect its deBroglie wavelength?

(A)it is divided by $\sqrt{4}$ (B)it is divided by $\sqrt{2}$ (C)it is multiplied by $\sqrt{2}$ (D)it is multiplied by $\sqrt{4}$

1_ 9 An electron and a proton have the same kinetic energy. Which has the greater de Broglie wavelength?

(A)electron (B)proton (C)same

4_ 10 A free electron and a free proton have the same momentum. This means that, compared to the matter wave associated with the proton, the matter wave associated with the electron has:

A) a shorter wavelength and a greater frequency B) a longer wavelength and a greater frequency
C) the same wavelength and the same frequency D) the same wavelength and a greater frequency
E) the same wavelength and a smaller frequency

4_ 11 A free electron and a free proton have the same kinetic energy. This means that, compared to the matter wave associated with the proton, the matter wave associated with the electron has:

A) a shorter wavelength and a greater frequency B) a longer wavelength and a greater frequency
C) a shorter wavelength and the same frequency D) a longer wavelength and the same frequency
E) a shorter wavelength and a smaller frequency

5_ 12 A non-relativistic free electron has kinetic energy K . If its wavelength doubles, its kinetic energy is:

A) $4K$ B) $2K$ C) still K D) $K/2$ E) $K/4$

4_ 13 An electron is in a one-dimensional trap with zero potential energy in the interior and infinite potential energy at the walls. The ratio E_3/E_1 of the energy for $n = 3$ to that for $n = 1$ is:

A) $1/3$ B) $1/9$ C) $3/1$ D) $9/1$ E) $1/1$

3_ 14 A particle is trapped in a one-dimensional well with infinite potential energy at the walls. Three possible pairs of energy levels are:

1. $n = 3$ and $n = 1$
2. $n = 3$ and $n = 2$
3. $n = 4$ and $n = 3$

Order these pairs according to the difference in energy. least to greatest.

A) 1, 2, 3 B) 3, 2, 1 C) 2, 3, 1 D) 1, 3, 2 E) 3, 1, 2

4_15 Identical particles are trapped in one-dimensional wells with infinite potential energy at the walls. The widths L of the traps and the quantum numbers n of the particles are

1. $L = 2L_0, n = 2$

2. $L = 2L_0, n = 4$

3. $L = 3L_0, n = 3$

4. $L = 4L_0, n = 2$

Rank them according to the kinetic energies of the particles, least to greatest.

A) 1, 2, 3, 4 B) 4, 3, 2, 1 C) 1 and 3 tied, then 2, 4 D) 4, 2, then 1 and 3 tied E) 1, 3, then 2 and 4 tied

Problem 16

Use the theory of special relativity to derive the following formula for the momentum of a particle in terms of its kinetic energy (K), mass (m) and speed of light c :

$$pc = \sqrt{A(B + \alpha DE^\beta)}$$

Enter A, B, D, E with ' m, c, K '. α, β are numbers. (06小題)

答案空格編號:16 $\alpha =$ _____

Ans:=2

答案空格編號:17 $\beta =$ _____

Ans:=2

答案空格編號:18 $A =$ _____

Ans:=K

答案空格編號:19 $B =$ _____

Ans:=K

答案空格編號:20 $D =$ _____

Ans:=m

答案空格編號:21 E=_____

$$(pc)^2 = E^2 - (mc^2)^2 = (KE + mc^2)^2 - (mc^2)^2$$

$$= (KE + mc^2 - mc^2)(KE + mc^2 + mc^2) = KE(KE + 2mc^2).$$

Ans:=c

Problem 17

Following previous problem, (a) derive a relativistically correct formula that gives the de Broglie wavelength of a charged particle in terms of the potential difference V through which it has been accelerated.

$$\lambda = \frac{Ac}{\sqrt{B(B + \alpha DE^\beta)}}$$

In answering this problem, you can use 'qV, m, h, c' for A,B,D and E. α, β are numbers. (06小題)

答案空格編號:22 A=_____

Ans:=h

答案空格編號:23 B=_____

Ans:=qV

答案空格編號:24 α =_____

Ans:=2

答案空格編號:25 D=_____

Ans:=m

答案空格編號:26 E=_____

Ans:=c

答案空格編號:27 β =_____

3-12: (a) The kinetic energy of a particle with charge of magnitude q accelerated through a potential difference V will be qV , and the result of Problem 3-10 may be used to find

$$\lambda = \frac{hc}{\sqrt{(qV)(qV + 2mc^2)}}.$$

(b) In this case (taking $q = e$), the square root in the above expression reduces to $\sqrt{eV 2mc^2}$, a factor of c in both numerator and denominator cancels, and

$$\lambda = \frac{h}{\sqrt{2eVm}}.$$

Ans:=2

Problem 18

投手將一顆**150**克的棒球以時速**144**公里/小時丟出，物質波的波長約為__公尺?
(01小題)

答案空格編號:28 $\lambda =$ _____ m

Ans:=1.1E-34

Problem 19

如果一個電子和一個光子的波長都是**2.0Å**，請計算(a)電子的動量, (b)光子的動量, (c)電子的能量, (d)光子的能量 (04小題)

答案空格編號:29 (a)_____ kg.m/s

Ans:=3.31E-24

答案空格編號:30 (b)_____ kg.m/s

Ans:=3.31E-24

答案空格編號:31 (c)_____ eV

Ans:=37.8

答案空格編號:32 (d)_____ eV

Ans:=6200

Problem 20

Find the de Broglie wavelength of (a) an electron whose speed is 1.0×10^8 m/s, and (b) an electron whose speed is 2.0×10^8 m/s. (02小題)

答案空格編號:33 (a) $\lambda =$ _____ pm

Ans:=6.86

答案空格編號:34 (b) $\lambda =$ _____ pm

3-2: (a) At this speed, $v/c = 1/3$, the relativistic expression for the momentum must be used in Equation (3.2), and

$$\lambda = \frac{h}{\gamma m v} = \frac{h \sqrt{1 - \frac{v^2}{c^2}}}{m v} = \frac{(6.626 \times 10^{-34} \text{ J}\cdot\text{s}) \sqrt{1 - (1/3)^2}}{(9.1095 \times 10^{-31} \text{ kg}) (1.0 \times 10^8 \text{ m/s})} = 6.86 \times 10^{-12} \text{ m},$$

or $6.9 \times 10^{-12} \text{ m} = 6.9 \text{ pm}$ to two significant figures.

(b) With $v = 2.0 \times 10^8$ m/s, $v/c = 2/3$, the same calculation gives $\lambda = 2.71 \times 10^{-12} \text{ m} = 2.7 \text{ pm}$ to two significant figures. Note that even though the speed is double that of part (a), the wavelength has decreased by a factor of more than 2, due to the dependence of the momentum on the relativistic factor γ .

Ans:=2.71

Problem 21

Find the kinetic energy of an electron whose de Broglie wavelength is the same as that of a 200-keV x-ray in (a) non-relativistic and (b) relativistic calculations. (02小題)

答案空格編號:35 (a) non-relativistic KE=_____ keV

Ans:=39.14

答案空格編號:36 (a) relativistic KE=_____ keV

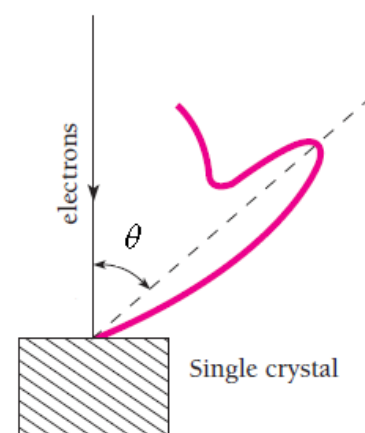
3-8: Because the wavelengths are the same, the product pc is the same for both the electron and the x-ray, and so the kinetic energy of the electron is

$$\begin{aligned} \text{KE} = E - mc^2 &= \sqrt{(pc)^2 + (mc^2)^2} - mc^2 \\ &= \left[\sqrt{(100)^2 + (511)^2} - 511 \right] \text{ keV} = 9.69 \text{ keV}. \end{aligned}$$

Ans:=37.74 (A nonrelativistic calculation gives 9.77 keV.)

Problem 22

A beam of neutrons that emerges from a nuclear reactor contains neutrons with a variety of energies. To obtain neutrons with an energy of 0.050 eV, the beam is passed through a crystal whose atomic planes are 0.20 nm apart. At what angles relative to the original beam will the desired neutrons be diffracted? Calculate the smallest and largest (Between 0 and 90 degrees.) (02小題)



答案空格編號:37 (a)smallest angle, θ = _____ degree

Ans:=18.7

答案空格編號:38 (b)largest angle, θ = _____ degree

3-24: From Equation (2.13), the neutrons will be scattered at angles θ_n , where

$$\theta_n = \arcsin\left(\frac{n\lambda}{2d}\right).$$

The neutrons are nonrelativistic, and so

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m\text{KE}}} = \frac{hc}{\sqrt{2(mc^2)\text{KE}}} \quad \text{and}$$

$$\frac{\lambda}{2d} = \frac{1.240 \times 10^{-6} \text{ eV}\cdot\text{m}}{2(0.20 \times 10^{-9} \text{ m})\sqrt{2(939.57 \times 10^6 \text{ eV})(0.050 \text{ eV})}} = 0.320.$$

The scattering angles are then $\arcsin(0.320) = 18.7^\circ$, $\arcsin(0.640) = 39.8^\circ$ and $\arcsin(0.960) = 73.6^\circ$. (For these results, more significant figures were kept in the intermediate calculations.)

Ans:=73.6

Problem 23

Obtain an expression for the energy levels (in MeV) of a neutron confined to a one-dimensional box 1.00×10^{-14} m wide. What is the neutron's minimum energy? (The diameter of an atomic nucleus is of this order of magnitude.) (01小題)

答案空格編號:39 $KE_{min} = \underline{\hspace{2cm}}$ Mev

Ans:=20.5

Problem 24

A proton in a one-dimensional box has an energy of 400 keV in its first excited state. How wide is the box? Use non-relativistic consideration. (04小題)

答案空格編號:40 (a) Obtain the width by the exact formula for the energy. The width of the box = $\underline{\hspace{2cm}}$ m

Ans:=4.53E-14

答案空格編號:41 (b) the ground state energy $E_1 = \underline{\hspace{2cm}}$ eV

Ans:=1.0E5

答案空格編號:42 (c) the momentum of the proton in the ground state, $p = \underline{\hspace{2cm}}$ kg.m/s

Ans:=7.311E-21

答案空格編號:43 (d) Use uncertainty principle and make the approximation that $\Delta p \simeq p$ to estimate the minimum width = $\underline{\hspace{2cm}}$ m

Ans:=7.211E-15

Problem 25

A proton has a kinetic energy of 1.0 MeV. If its momentum is measured with an uncertainty of 5.0%, what is the minimum uncertainty in its

position? (01小題)

答案空格編號:44 $\Delta x =$ _____

$$K = \frac{mv^2}{2} = \frac{p^2}{2m}: (1 \times 10^6 \text{ eV})(1.6 \times 10^{-19} \text{ J/eV}) = \frac{p^2}{2(1.67 \times 10^{-27} \text{ kg})} \Rightarrow p = 2.312 \times 10^{-20} \text{ kg} \cdot \text{m/s},$$

$$\Delta p = 0.05p = 1.160 \times 10^{-21} \text{ kg} \cdot \text{m/s} \text{ and } \Delta x \Delta p = \frac{h}{4\pi}. \text{ Thus}$$

$$\Delta x = \frac{6.63 \times 10^{-34} \text{ J} \cdot \text{s}}{(1.16 \times 10^{-21} \text{ kg} \cdot \text{m/s})(4\pi)} = 4.56 \times 10^{-14} \text{ m}.$$

Note that non-relativistic treatment has been used, which is justified because the kinetic energy is only $\frac{(1.6 \times 10^{-13}) \times 100\%}{1.50 \times 10^{-10}} = 0.11\%$ of the rest energy.

Ans:=4.56E-14

Problem 26

A certain transverse wave is described by

$$y(x, t) = (6.50 \text{ mm}) \cos 2\pi \left(\frac{x}{28.0 \text{ cm}} - \frac{t}{0.036 \text{ s}} \right)$$

Determine the wave's (a) amplitude; (b) wavelength; (c) frequency; (d) speed of propagation; (e) direction of propagation. (05小題)

答案空格編號:45 (a) amplitude=_____ mm

Ans:=6.5

答案空格編號:46 (b) $\lambda =$ _____ cm

Ans:=28.0

答案空格編號:47 (c) $f =$ _____ Hz

Ans:=27.8

答案空格編號:48 (d) $v =$ _____ m/s

Ans:=7.78

答案空格編號:49 (e) 1=in +x direction, 2=in -x direction

Ans:=1