MP19-L02A

MP19-L02 https://soaring-ycc.com/YC/MP19/ 波的粒子特性 線上習題解答

__D__ 1 可嘗試次數= 2 分數= 1 The units of the Planck constant h are those of: (A) energy (B) power (C) momentum (D) angular momentum (E) frequency

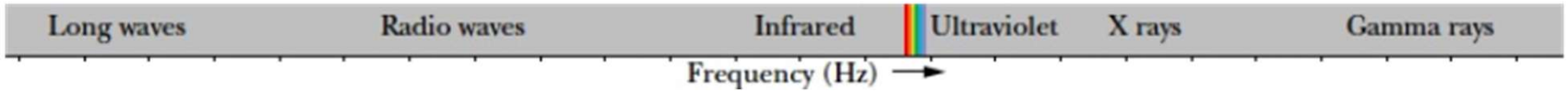
$[h] = \mathrm{J \cdot s}$ $1\,\mathrm{J} = 1\,\mathrm{kg\,m^2\,s^{-2}} = \mathrm{kg\,m^2\,s^{-1}}$ $\boxed{h = 4.136 \times 10^{-15}\ \mathrm{eV \cdot s}}$

$L = |\mathbf{r} \times \mathbf{p}|$ $[L] = \mathrm{m}\left(\mathrm{kg\,m\,s^{-1}}\right) = \mathrm{kg\,m^2\,s^{-1}}$ $[h] = [L]$

__B__ 2 可嘗試次數= 2 分數= 1 In the photoelectric effect (for a given target and a given frequency of the incident light), which of these quantities, if any, depend on the intensity of the incident light beam:[在光電效應中（對於給定的目標和給定的入射光頻率），這些量中哪些（如果有的話）取決於入射光束的強度] (A) the maximum kinetic energy of the electrons, (B) the maximum photoelectric current, (C) the stopping potential, (D) the cutoff frequency?

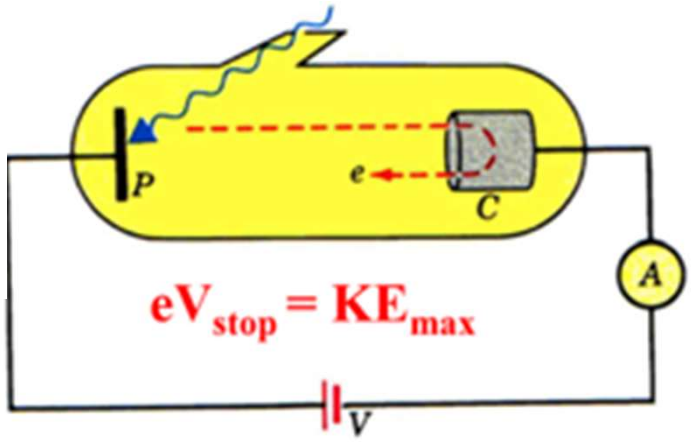
I = N h ν N：單位時間通過垂直於單位面積的光子個數

__C__ 3 可嘗試次數= 2 分數= 1 Which of the following electromagnetic radiations has photons with the greatest energy?[下列哪一種電磁輻射的光子能量最大？] (A) blue light (B) yellow light (C) x-rays (D) radio waves (E) microwaves



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__E__ 4 可嘗試次數= 2 分數= 1 In a photoelectric effect experiment the stopping potential is:[在光電效應實驗中，截止電壓為：] (A) the energy required to remove an electron from the sample (B) the kinetic energy of the most energetic electron ejected (C) the potential energy of the most energetic electron ejected (D) the photon energy (E) the electric potential that causes the electron current to vanish



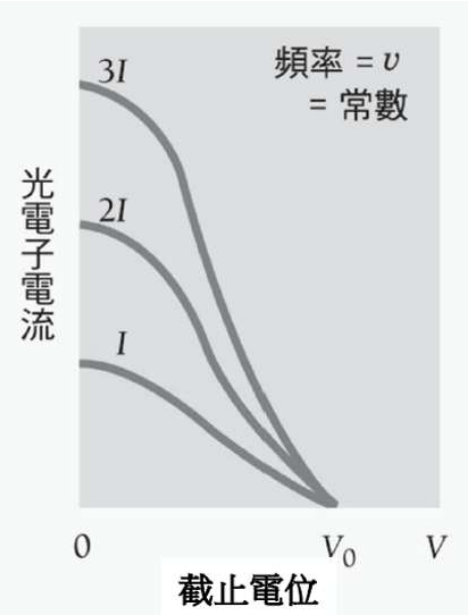
Einstein光電方程式

$$h\nu - \phi = KE_{max} = eV_{stop}$$

ϕ：功函數

__D__ 5 可嘗試次數= 2 分數= 1 In a photoelectric effect experiment at a frequency above cut off, the stopping potential is proportional to:[在高於截止頻率的光電效應實驗中，截止電壓與下列因素成正比：] (A) the energy of the least energetic electron before it is ejected (B) the energy of the least energetic electron after it is ejected (C) the energy of the most energetic electron before it is ejected (D) the energy of the most energetic electron after it is ejected (E) the electron potential energy at the surface of the sample

入射光的頻率固定時，飽和光電流的大小與入射光的強度成正比，但是截止電壓維持不變。



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__D__ 7 可嘗試次數= 2 分數= 1 In a photoelectric effect experiment no electrons are ejected if the frequency of the incident light is less than A/h, where h is the Planck constant and A is:[在光電效應實驗中，如果入射光的頻率小於 A/h，則不會有電子被發射出來，其中 h 是普朗克常數，A 是：] (A) the maximum energy needed to eject the least energetic electron (B) the minimum energy needed to eject the least energetic electron (C) the maximum energy needed to eject the most energetic electron (D) the minimum energy needed to eject the most energetic electron (E) the intensity of the incident light

$$\nu_0 = \frac{\phi}{h}$$

$h = 4.136 \times 10^{-15}\ \text{eV} \cdot \text{s}$

$4.135667696 \times 10^{-15}\ \text{eV s}$

$$E = h\nu$$

__B__ 8 可嘗試次數= 2 分數= 1 The stopping potential for electrons ejected by 6.8×10^{14} Hz electromagnetic radiation incident on a certain sample is 1.8 V. The kinetic energy of the most energetic electrons ejected and the work function of the sample, respectively, are: [頻率為 6.8×10^{14} Hz 的電磁輻射照射到某樣品上時，所激發電子的截止電壓為 1.8 V。所激發電子的動能和樣品的逸出功分別為：] (A) 1.8 eV, 2.8 eV (B) 1.8 eV, 1.0 eV (C) 1.8 eV, 4.6 eV (D) 2.8 eV, 1.0 eV (E) 1.0 eV, 4.6 eV

Einstein光電方程式

$$h\nu - \phi = KE_{max} = eV_{stop}$$

ϕ：功函數

ε=2.8 eV
eV_s =1.8 eV
ϕ=2.8-1.8
=1 eV

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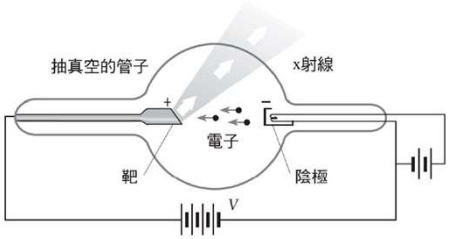
__B__ 9 可嘗試次數= 2 分數= 1 In Compton scattering from stationary electrons the largest change in wavelength that can occur is: [在靜止電子的康普頓散射中，可能發生的最大波長變化是] (A) 2.43×10^{-15} m (B) 4.85×10^{-12} m (C) 2.43×10^{-9} m (D) dependent on the frequency of the incident light (E) dependent on the work function

$$\lambda_C = \frac{h}{m_e c} = 2.426 \times 10^{-12} \text{ m}$$

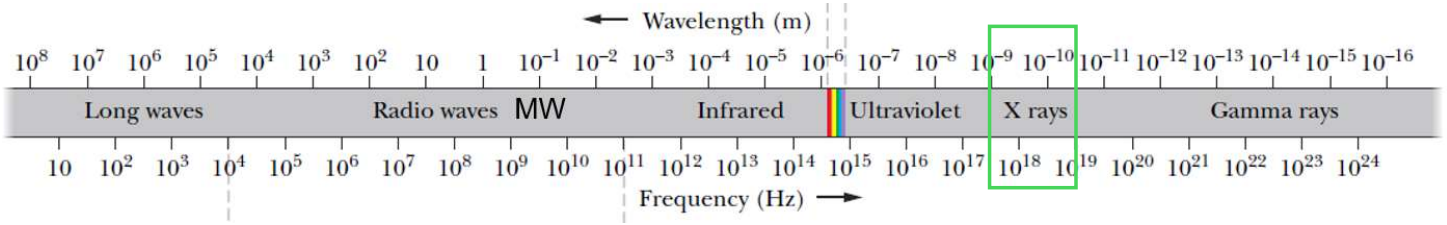
最大波長位移

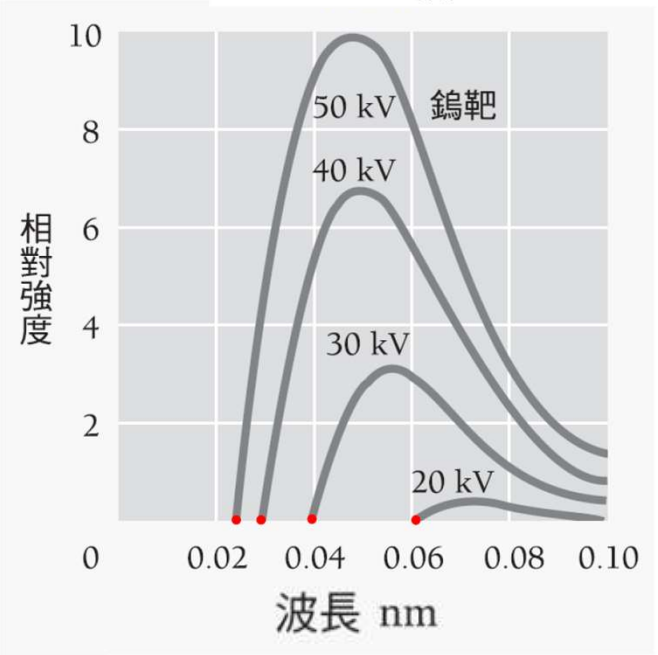
發生在 $\theta = 180°$:

$$\boxed{\Delta\lambda_{max} = 2\lambda_C}$$



__C__ 10 可嘗試次數= 2 分數= 1 What is the unit of the wavelength in the above figure of the X-ray spectra of tungsten at various accelerating potentials? [圖中不同加速電壓下鎢的 X 射線光譜中波長的單位是什麼？] (A)mm (B)μm (C)nm (D)fm (E)cm (F)pm





在不同加速電位下，鎢的 x 射線光譜。

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_C_ 11 可嘗試次數= 2 分數= 1 Which of the following behaviors is best explained by the wave model of light? [下列哪一種行為最能用光的波動模型來解釋？] (A)the photoelectric effect (B)Compton scattering (C)diffraction (D) pair production

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_C_ 12 可嘗試次數= 2 分數= 1 The work function of copper is 4.7 eV. What is the threshold frequency for copper? [銅的逸出功為4.7 eV。銅的閾值頻率是多少？] (A)$3.81 \times 10^{14} Hz$ (B) $2.11 \times 10^{14} Hz$ (C)$1.14 \times 10^{14} Hz$ (D)$3.26 \times 10^{14} Hz$

$h = 4.136 \times 10^{-15}\ \text{eV} \cdot \text{s}$

$$\nu_0 = \frac{\phi}{h} \quad \frac{4.7\ \text{eV}}{4.1 \times 10^{-15}}$$

_C_ 13 可嘗試次數= 2 分數= 1 For a hypothetical piece of metal, it takes an amount of energy E to remove an electron from the surface of the metal. What is the maximum wavelength of light that can photo eject an electron from this metal? [假設有一塊金屬，從其表面移除一個電子需要能量 E。那麼，能夠使該金屬表面電子光致逸出的最大光波長是多少呢？] (A) hf (B) hc (C) hc/E (D) hcE

$$E = hf = \frac{hc}{\lambda} \qquad \lambda = \frac{hc}{E}$$

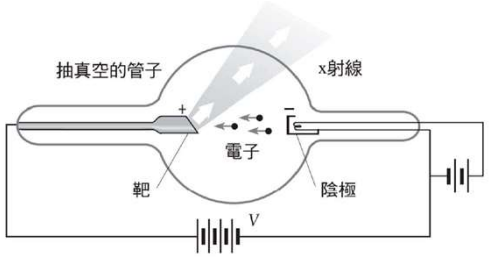
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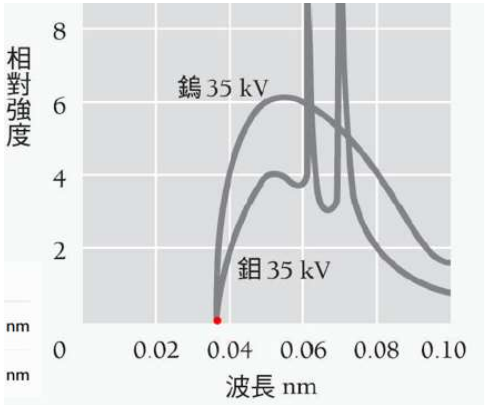
__D__ 14 可嘗試次數= 2 分數= 1 What is the accelerating electric potetnial between target and cathode? [靶材與陰極之間的加速電位是多少？] (A)35 V (B)350 V (C)3500 V (D)35000 V (E)350000 V

$$\lambda = \frac{hc}{E} \qquad \boxed{\lambda(\text{nm}) = \frac{1240}{E(\text{eV})}}$$

鎢 35 kV

=0.3 nm





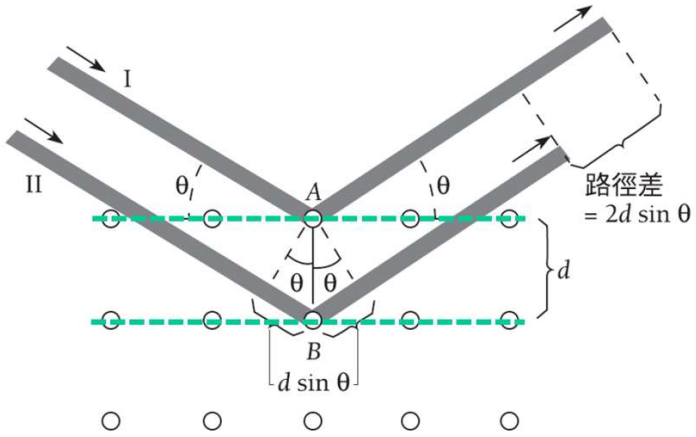
$K = hf - \phi \qquad hf = K + \phi$

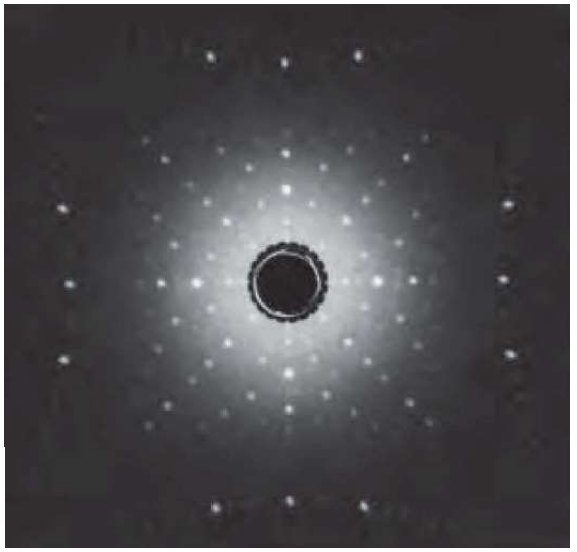
$K' = 2hf - \phi = K + hf > 2K$

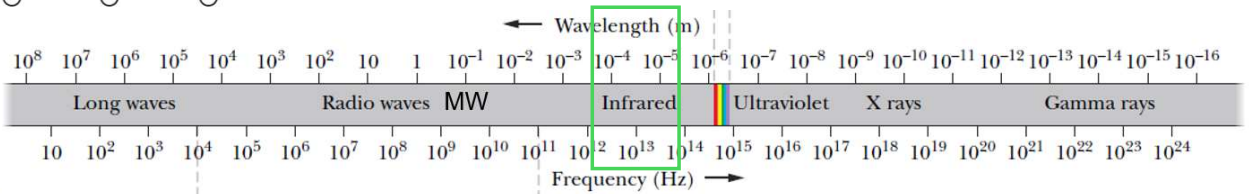
__C__ 15 可嘗試次數= 2 分數= 1 When monochromatic light with a frequency f strikes a metal surface with work function Φ, electrons are ejected with a maximum amount of kinetic energy K. If the frequency of the light is doubled, which of the following statement is true? [當頻率為 f 的單色光照射到逸出功為 Φ 的金屬表面時，電子被激發出來，最大動能為 K。如果光的頻率加倍，下列哪一個敘述是正確的？] (A)The new maximum kinetic energy will be less than double the earlier maximum kinetic energy (B)The new maximum kinetic energy will be exactly double the earlier maximum kinetic energy (C)The new maximum kinetic energy will be more than double the earlier maximum kinetic energy (D)The maximum kinetic energy will not change

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__E__ 16 可嘗試次數= 2 分數= 1 The above figure is a picture of Lau pattern of TiO_2 crystl. What experiment method is used to obtain this picture? [圖為TiO_2晶體的勞氏繞射圖。請問該圖是用什麼實驗方法得到的？] (A)Double slits experiment (B)Photo-electric effect (C)Blackbody radiation (D)Laser (E)X-ray diffraction







__D__ 17 可嘗試次數= 2 分數= 1 Of the following types of electromagnetic radiation, which has the least amount of energy per photon? [在下列幾種電磁輻射中，哪一種每個光子的能量最小？] (A)gamma (B)UV light (C)visible light (D)infrared

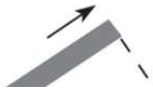
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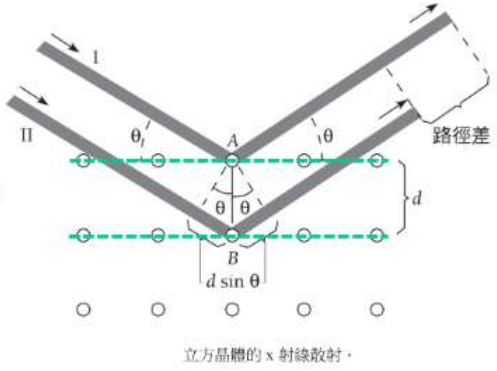
__D__ 18 可嘗試次數= 2 分數= 1 A very small particle has a mass m and a velocity v. It is found to have a wavelength λ. If a second particle has a mass of 2m and a velocity of 2v, what is the wavelength of the second particle? [質量為 m、速度為 v 的微小粒子，其波長為 λ。如果第二個粒子的質量為 2m、速度為 2v，那麼第二個粒子的波長是多少？] (A)2λ (B)λ/2 (C)4λ (D)λ/4

$$\lambda = \frac{h}{p} \qquad p=mv$$

__A__ 19 可嘗試次數= 2 分數= 1 Which of the following is best described by the particle-like behavior of light? [下列何者最能描述光的粒子性？] (A)the photoelectric effect (B)interference (C)diffraction (D)electromagnetic radiation

__B__ 20 可嘗試次數= 2 分數= 1 What is the formula for the dffraction peak? [繞射峰的公式是什麼？] (A)$2d\theta = n\lambda$ (B)$2d\sin\theta = n\lambda$ (C)$d\sin\theta = n\lambda$ (D)$d\sin\theta = 2n\lambda$ (E)$2d\cos\theta = n\lambda$





立方晶體的 x 射線散射。



= 2d sin θ

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Problem 2
PART.1

By Stefan-Boltzmann law, nw you are given 3 data of our Sun: (1)the Sun'a radius $R_s = 7.0 \times 10^8$ m; (2)the average Sun-Earth distance $R = 1.5 \times 10^{11}$m; (3)the power per unit area (at all frequencies) from the Sun is measured at the Earth to be 1400 W/m^2. Assume that the Sun is a blackbody. Determine the Sun's surface temperature.[根據上述史蒂芬-玻爾茲曼定律，已知太陽的三個資料：(1)太陽半徑$R_s = 7.0 \times 10^8$ m；(2)日地平均距離$R = 1.5 \times 10^{11}$ m；(3)在地球上測得太陽單位面積功率（所有頻率）為1400 W/m²。假設太陽為黑體，求太陽表面溫度。]

(02小題)

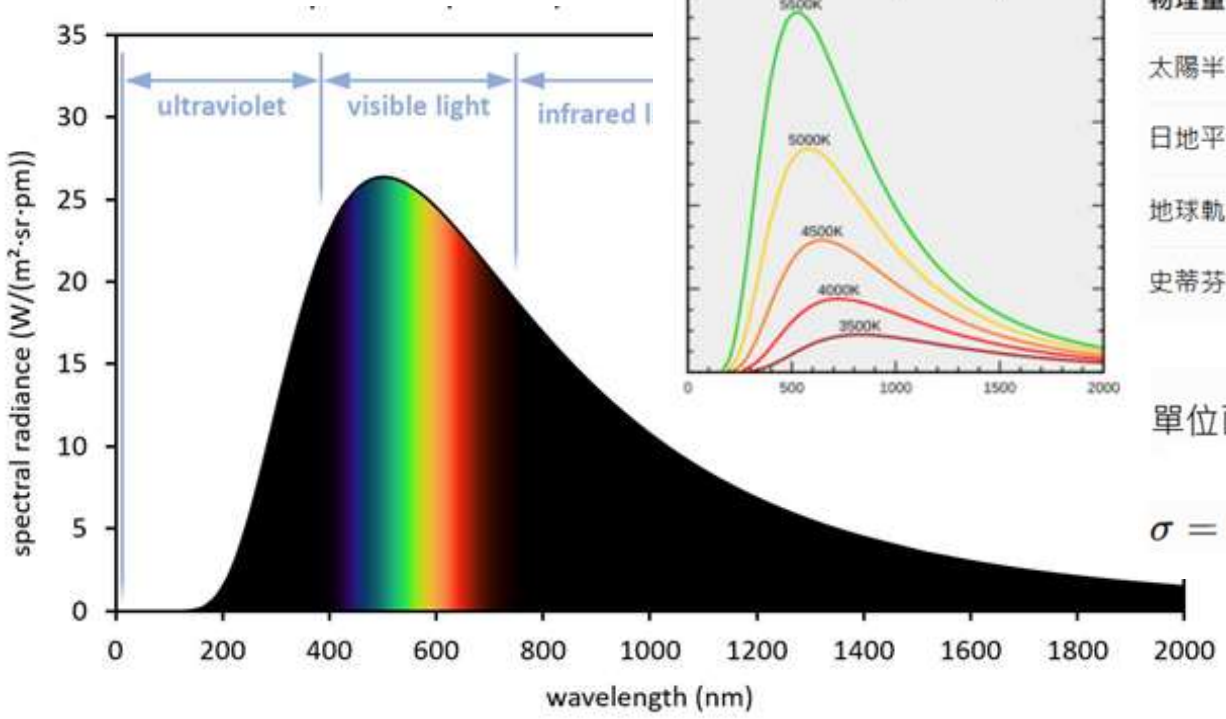
(b) 利用維恩位移定律（Wien's displacement law），求出維恩常數(Wien's constant)。

(a)T=_____ K

21: **ANS:=5800**

Wien's constant =____

22: **ANS:=2.898E-3**



物理量	數值
太陽半徑 R_s	7.0×10^8 m
日地平均距離 R	1.5×10^{11} m
地球軌道處太陽輻射通量 I	1400 W/m^2
史蒂芬–波茲曼常數 σ	5.67×10^{-8} W/(m^{2}K^4)

單位面積的輻射功率 $\frac{P}{A} = \sigma T^4$

$\sigma = 5.6704 \times 10^{-8}\ \mathrm{W\,m^{-2}K^{-4}}$

$\lambda_{\max} T = b$

單位面積的輻射功率 $\frac{P}{A} = \sigma T^4$

$\sigma = 5.6704 \times 10^{-8}\ \mathrm{W\,m^{-2}K^{-4}}$

太陽的總輻射功率（光度，SI單位：W）

$$L = 4\pi R_s^2 \sigma T^4$$

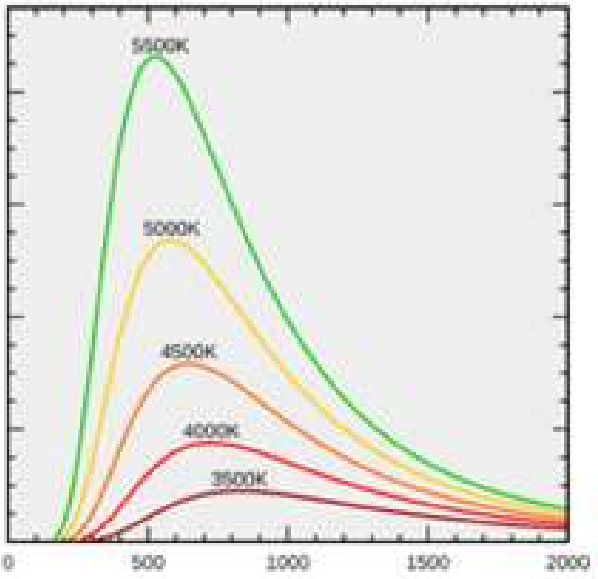
在距離太陽 R 的位置，輻射功率分布於面積 $4\pi R^2$ 的球面上

$$I = \frac{L}{4\pi R^2} = \frac{4\pi R_s^2 \sigma T^4}{4\pi R^2} = \sigma T^4 \left(\frac{R_s}{R}\right)^2$$

*I*稱為輻射通量密度（Radiant Flux Density），也常稱為輻照度（Irradiance）。SI單位：W/m^2

$$T = \left(\frac{I}{\sigma}\right)^{1/4} \sqrt{\frac{R}{R_s}} \approx 5807\ \mathrm{K}$$

$$= \left[\frac{1400(1.5 \times 10^{11})^2}{(5.67 \times 10^{-8})(7.0 \times 10^8)^2}\right]^{1/4}$$



圖中的縱軸是黑體的光譜輻射出射度 $M_\lambda(T)$，橫軸是波長 λ。
則曲線下的面積為：

$$M(T) = \int_0^\infty M_\lambda(T)\, d\lambda$$

$$= \sigma T^4$$

Wien's displacement law

$$\lambda_{\max} T = b$$

$$b = \lambda_{\max} T$$
$$= (5.00 \times 10^{-7})(5800)$$
$$= 2.90 \times 10^{-3}\ \mathrm{m \cdot K}$$

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Problem 2
PART.2
Determine the size of a star

From previous problem. Measurement of the wavelength at which the spectral distribution $R(\lambda)$ from a certain star is maximum indicates that the star's surface temperature is 3000K. If the star is also found to radiate 100 times the power P_{Sun} radiated by the Sun, what is the radius of the star? The Sun's surface temperature is 5800 K. Hint: Use Stefann-Boltzmanns' law $R = \sigma T^4$, here R is the power radiated per unit area. (01小題)

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the ratio $\frac{r_{star}}{r_{Sun}}$ =_____

23: **ANS:=37.4**

確定恆星的大小：測量某恆星光譜分佈最大值對應的波長，可知該恆星表面溫度為 3000K。如果該恆星輻射的功率是太陽的 100 倍，那麼該恆星的半徑是多少？太陽表面溫度為 5800 K。提示：使用史蒂芬-玻爾茲曼定律。

$$R = \sigma T^4$$

Stefan–Boltzmann 定律給出單位面積的輻射功率(稱為輻射通量密度)

恆星的總輻射功率：

$$L = 4\pi R^2 \sigma T^4$$

太陽的總輻射功率：

$$L_s = 4\pi R_s^2 \sigma T_s^4$$

$$\frac{L}{L_s} = \frac{4\pi R^2 \sigma T^4}{4\pi R_s^2 \sigma T_s^4}$$

$$\frac{L}{L_s} = \left(\frac{R}{R_s}\right)^2 \left(\frac{T}{T_s}\right)^4$$

解出恆星半徑：

$$\frac{R}{R_s} = \sqrt{\frac{L}{L_s}} \left(\frac{T_s}{T}\right)^2$$

$$\frac{L}{L_s} = 100, \quad T_s = 5800\ \text{K}, \quad T = 3000\ \text{K}$$

$$\frac{R}{R_s} = \sqrt{100} \left(\frac{5800}{3000}\right)^2$$

$$\frac{R}{R_s} = 10 \times 3.738 = 37.38$$

$$R = 37.38 \times (7.0 \times 10^8)$$

$$R \approx 2.62 \times 10^{10}\ \text{m}$$

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Problem 3

An electron is accelerated from rest by a potential difference of 20 kV, what is the final (a)speed and (b)kinetic energy of the electron? Treat this problem with classical physics. (02小題)

(a) speed=_____ m/s

24: **ANS:=8.39e7**

(b) kinetic energy=_____ J

25: **ANS:=3.2e-15**

一個電子從靜止開始，經過 20 kV的電位差加速。求電子最後的：(a) 速率(b) 動能。本題使用古典物理（非相對論）處理。

$$\Delta V = 20\ \text{kV} = 2.0 \times 10^4\ \text{V}$$
$$e = 1.602 \times 10^{-19}\ \text{C}$$
$$m_e = 9.109 \times 10^{-31}\ \text{kg}$$
$$v_0 = 0$$

電子受到電場加速，電位能的減少轉換為動能的增加。根據能量守恆：

$$\frac{1}{2}m_e v^2 = e\Delta V$$

$$v = \sqrt{\frac{2e\Delta V}{m_e}}$$

$$v = \sqrt{\frac{2(1.602 \times 10^{-19})(2.0 \times 10^4)}{9.109 \times 10^{-31}}}$$

$$v = 8.39 \times 10^7\ \text{m/s}$$

$$K = \frac{1}{2}m_e v^2 = e\Delta V$$

$$K = (1.602 \times 10^{-19})(2.0 \times 10^4)$$

$$K = 3.204 \times 10^{-15}\ \text{J}$$

$$K \approx 3.20 \times 10^{-15}\ \text{J}$$

$$K = 20\ \text{keV}$$

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Problem 4

The maximum wavelength for photoelectric emission in tungsten is 230 nm. What wavelength of light must be used in order for electrons with a maximum energy of 1.5 eV to be ejected? (01小題)

$\lambda =$_____ nm

26: **ANS:=180**

鎢（tungsten）產生光電效應的最大波長為 230 nm。若希望逸出的光電子具有 1.5 eV的**最大動能**，應使用多大波長的入射光？

$\lambda_0 = 230\ \text{nm}$（臨界波長）

$K_{\max} = 1.5\ \text{eV}$

$hc = 1240\ \text{eV} \cdot \text{nm}$

$$hf = W + K_{\max}$$

$$W = \frac{hc}{\lambda_0} \qquad W = \frac{1240}{230} = 5.39\ \text{eV}$$

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + K_{\max}$$

$$\frac{1}{\lambda} = \frac{1}{\lambda_0} + \frac{K_{\max}}{hc}$$

$$\lambda = \frac{hc}{\frac{hc}{\lambda_0} + K_{\max}}$$

$$\lambda = \frac{1240\ \text{eV} \cdot \text{nm}}{6.89\ \text{eV}}$$

$$\lambda \approx 180\ \text{nm}$$

- 臨界波長： 當入射光波長等於 230 nm 時，光子能量剛好足以使電子逸出金屬表面，此時光電子的最大動能為零。
- 光電子的最大動能： 當入射光波長縮短至 180 nm 時，光子能量增加，多出的能量轉換為光電子的最大動能 1.5 eV。

MP19-L02A

Problem 5

1.5 mW of 400-nm light is directed at a photoelectric cell. If 0.10 percent of the incident photons produce photoelectrons, find the current in the cell. (01小題)

current I=_____ μA

27: **ANS:=0.48**

功率為 1.5 mW、波長為 400 nm的光照射到一個光電池上。若入射光子中有 0.10%能夠產生光電子，求光電池中產生的電流。

$P = 1.5\ \text{mW} = 1.5 \times 10^{-3}\ \text{W}$

$\lambda = 400\ \text{nm} = 4.0 \times 10^{-7}\ \text{m}$

$\eta = 0.10\% = 1.0 \times 10^{-3}$

$h = 6.626 \times 10^{-34}\ \text{J} \cdot \text{s}$

$c = 3.00 \times 10^{8}\ \text{m/s}$

$e = 1.602 \times 10^{-19}\ \text{C}$

η為光電子產生效率（量子效率）

每個光子的能量為 $E = hf = \dfrac{hc}{\lambda}$

$$E = \frac{(6.626 \times 10^{-34})(3.00 \times 10^{8})}{4.0 \times 10^{-7}}$$

$$E = 4.97 \times 10^{-19}\ \text{J}$$

光功率 $P = \dfrac{N}{t}E$

$$\frac{N}{t} = \frac{P}{E} = \frac{P\lambda}{hc}$$

$$\frac{N}{t} = \frac{1.5 \times 10^{-3}}{4.97 \times 10^{-19}}$$

$$\frac{N}{t} = 3.02 \times 10^{15}\ \text{s}^{-1}$$

$$\frac{N_e}{t} = \eta\frac{N}{t}$$

$$\frac{N_e}{t} = (1.0 \times 10^{-3})(3.02 \times 10^{15})$$

$$\frac{N_e}{t} = 3.02 \times 10^{12}\ \text{s}^{-1}$$

$$I = \frac{Q}{t} = e\frac{N_e}{t}$$

$$I = (1.602 \times 10^{-19})(3.02 \times 10^{12})$$

$$I = 4.84 \times 10^{-7}\ \text{A} \approx 0.48\ \mu\text{A}$$

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Problem 6

The smallest angle of Bragg scattering in potassium chloride (KCl) is 28.4° for 0.30-nm x-rays. Find the distance between atomic planes in potassium chloride.

氯化鉀（KCl）中布拉格散射的最小角度為28.4°（波長0.30 nm的X射線）。求氯化鉀中原子層間的距離。 (01小題)

---

distance, d=_____ nm

28: **ANS:=0.32**

$$\lambda = 0.30\ \text{nm}$$

$$\theta = 28.4^\circ$$

$n = 1$（第一階繞射）

$$2d\sin\theta = n\lambda$$

其中：

- d：相鄰晶面間距
- θ：X 射線與晶面之間的夾角（布拉格角）
- λ：X 射線波長
- n：繞射階數，$n = 1, 2, 3, \ldots$

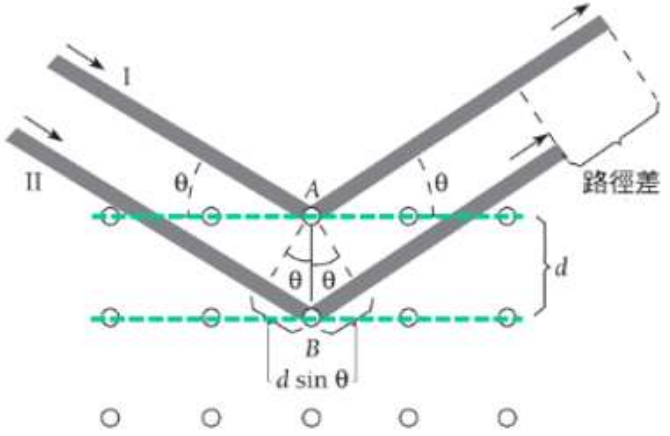
$$d = \frac{\lambda}{2\sin\theta}$$

$$d = \frac{0.30}{2\sin 28.4^\circ}\ \text{nm}$$

$$\sin 28.4^\circ \approx 0.4756$$

$$d = \frac{0.30}{2(0.4756)}\ \text{nm}$$

$$d \approx 0.315\ \text{nm}$$



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Problem 7

Suppose that light of total intensity 1.0 $\mu W/cm^2$ falls on a clean iron sample 1.0 cm^2 in area. Assume that the iron sample reflects 96% of the light and that only 3.0% of the absorbed energy lies in the violet region of the spectrum above the threshold frequency.

假設總強度為 1.0 μW/cm² 的光照射到面積為 1.0 cm² 的潔淨鐵樣品上。假設鐵樣品反射了 96% 的光，並且只有 3.0% 的吸收能量位於閾值頻率以上的紫色光譜區域。 (05小題)

(a) What intensity is actually available for the photoelectric effect? in $\mu W/cm^2$.

$$I = (0.030)(0.040)I_0 = (0.030)(0.040)(1.0\ \mu\text{W/cm}^2) = 1.2\text{nW/cm}^2$$

29: **ANS:=1.2E-3**

(b) Assuming that all the photons in the violet region have an effective wavelength of 250 nm, how many electrons will be emitted per second?

30: **ANS:=1.5E9**

$$\text{Number of electrons/s} = \frac{1.2\times10^{-9}\ \text{W}}{hf} = \frac{\lambda(1.2\times10^{-9})}{hc} = \frac{(250\times10^{-9}\ \text{m})(1.2\times10^{-9}\ \text{J/s})}{(6.6\times10^{-34}\ \text{J}\cdot\text{s})(3.0\times10^{8}\ \text{m/s})} = 1.5\times10^{9}$$

(c) Calculate the current in the phototube in amperes.

$$i = (1.6\times10^{-19}\ \text{C})(1.5\times10^{9}\ \text{electrons/s}) = 2.4\times10^{-10}\ \text{A}$$

31: **ANS:=2.4E-10**

(d) If the cutoff frequency is $f_0 = 1.1\times10^{15}$ Hz, find the work function, Φ, for iron. _____eV

32: **ANS:=4.5**

$$\phi = hf_0 = (4.14\times10^{-15}\ \text{eV}\cdot\text{s})(1.1\times10^{15}\ \text{s}^{-1}) = 4.5\ \text{eV}$$

(e) Find the stopping voltage for iron if photoelectrons are produced by light with $\lambda = 250$ nm. V_s =_____ volt.

33: **ANS:=0.46**

$$eV_s = hf - \phi = \frac{hc}{\lambda} - \phi = \frac{(4.14\times10^{-15}\ \text{eV}\cdot\text{s})(3.0\times10^{8}\ \text{m/s})}{250\times10^{-9}\ \text{m}} - 4.5\ \text{eV} = 0.46\ \text{eV}$$

the stopping voltage is 0.46 V.

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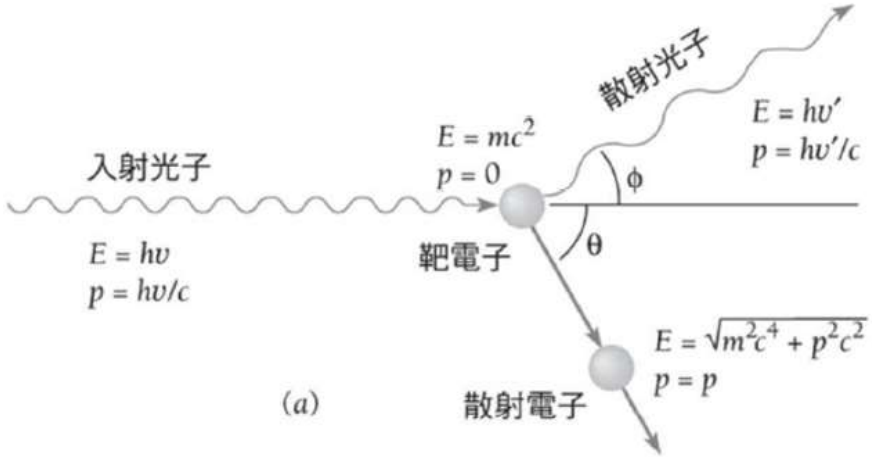
Problem 8

X-rays of wavelength $\lambda = 0.200$ nm are aimed at a block of carbon. The scattered x-rays are observed at an angle of 45.0 degree to the incident beam. Calculate the shift of wavelength of the scattered x-rays at this angle.

波長為 $\lambda = 0.200$ nm 的 X 射線照射到一塊碳塊上。散射的 X 射線與入射光束成 45.0° 角。計算該角度下散射 X 射線的波長偏移量。 (01小題)

$\Delta\lambda =$_____ nm

34: **ANS:=0.00071**



$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta) \qquad \theta = 45.0°,$$

$$= \frac{6.63 \times 10^{-34}\,\text{J}\cdot\text{s}}{(9.11 \times 10^{-31}\,\text{kg})(3.00 \times 10^{8}\,\text{m/s})}(1 - \cos 45.0°)$$

$$= 7.11 \times 10^{-13}\,\text{m} = 0.00071\,\text{nm}$$

$$\lambda = \Delta\lambda + \lambda_0 = 0.200711\,\text{nm}$$

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Problem 9

(a)Why are x-ray photons used in the Compton experiment, rather than visible-light photons? To answer this question, we shall first calculate the Compton shift for scattering at 90 degree from graphite for the following cases: (1) very high energy γ-rays from cobalt, $\lambda = 0.0106$ A; (2) x-rays from molybdenum, $\lambda = 0.712$ Å; and (3) green light from a mercury lamp,$\lambda = 5461$ Å.

（a）為什麼康普頓實驗中使用的是X射線光子，而不是可見光光子？為了回答這個問題，我們首先計算以下情況下X射線在石墨表面90度散射的康普頓位移：（1）來自鈷的極高能量γ射線，λ=0.0106 Å；（2）來自鉬的X射線，λ=0.712 Å；（3）來自汞燈的綠光，λ=5461 Å。 (05小題)

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

=0.2425 nm

=0.02425 A

35: **ANS:=2.29**

(2) $\frac{\Delta\lambda}{\lambda_0}$ =_____

$$\frac{\Delta\lambda}{\lambda_0} = \frac{0.0243\ \text{Å}}{0.0106\ \text{Å}} = 2.29$$

$$\frac{\Delta\lambda}{\lambda_0} = \frac{0.0243\ \text{Å}}{5461\ \text{Å}} = 4.45 \times 10^{-6}$$

X-rays from molybdenum:

36: **ANS:=0.0341**

(3) $\frac{\Delta\lambda}{\lambda_0}$ =_____

$$\frac{\Delta\lambda}{\lambda_0} = \frac{0.0243\ \text{Å}}{0.712\ \text{Å}} = 0.0341$$

37: **ANS:=4.45E-6**

$$E = hf = \frac{hc}{\lambda} = \frac{12\,400\ \text{eV}\cdot\text{Å}}{0.712\ \text{Å}} = 17\,400\ \text{eV}$$

(b)The so-called free electrons in carbon are actually electrons with a binding energy of about 4 eV. For x-rays with $\lambda_0 = 0.712$ Å what is its photon energy? _____eV

38: **ANS:=17400**

(c)Can we ignore the binding energy of the electrons in carbon? 1=Yes, 2=No.

39: **ANS:=1**

Therefore, the electron binding energy of 4 eV is negligible in comparison with the incident x-ray energy.