
UNIVERSITI SAINS MALAYSIA

KSCP Semester Examination
Academic Session 2007/2008

June 2008

ZCT 104/3 – Physics IV (Modern Physics)
[Fizik IV(Fizik Moden)]

Duration: 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **SIX** printed pages before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi ENAM muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instruction: Answer only **FIVE** questions out of six questions given.

Arahan: Jawab **LIMA** soalan daripada enam soalan yang disediakan.
Pelajar dibenarkan untuk menjawab samada dalam bahasa Malaysia atau bahasa Inggeris.]

Data

Speed of light in free space, $c = 3.00 \times 10^8 \text{ m s}^{-1}$
 Permeability of free space, $\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$
 Permittivity of free space, $\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
 Elementary charge, $e = 1.60 \times 10^{-19} \text{ C}$
 Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$
 Unified atomic mass constant, $u = 1.66 \times 10^{-27} \text{ kg}$
 Rest mass of electron, $m_e = 9.11 \times 10^{-31} \text{ kg}$
 Rest mass of proton, $m_p = 1.67 \times 10^{-27} \text{ kg}$
 Molar gas constant, $= 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
 Avogadro constant, $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
 Gravitational constant, $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
 Acceleration of free fall, $g = 9.81 \text{ m s}^{-2}$

Instruction: Answer only 5 out of six questions prepared. Each question carries 20 marks.

[Arahan: Jawab hanya 5 soalan daripada 6 soalan yang disediakan. Setiap soalan membawa 20 markah.]

1. (a) As measured by O , a lamp emits a light flash in $x = 100 \text{ km}$, $y = 10 \text{ km}$, $z = 1 \text{ km}$ at $t = 5 \times 10^{-4} \text{ s}$. What is the coordinate x' , y' , z' , and t' of this event as measured by a second observer, O' , who is moving relative to O with a velocity of $-0.8c$ along their common axis $z - z'$?

[Seperti yang disukat oleh O , sebuah lampu mengeluarkan suatu cahaya kilat di $x = 100 \text{ km}$, $y = 10 \text{ km}$, $z = 1 \text{ km}$ pada $t = 5 \times 10^{-4} \text{ s}$. Apakah koordinat x' , y' , z' , dan t' bagi peristiwa ini seperti ditentukan oleh seorang pemerhati kedua, O' yang bergerak relative kepada O dengan halaju $-0.8c$ sepanjang paksi sepunya $z - z'$?]

[8 marks]

- (b) If the proper length of each edge of a cube is l_0 , find its volume when it is moving with a velocity v along one of its edges.

[Jika panjang wajar bagi setiap sisi suatu kubus ialah l_0 , cari isipadunya apabila ia bergerak dengan suatu halaju v sepanjang salah satu sisinya.]

[6 marks]

- (c) An electron is accelerated from rest to a velocity v through a potential difference of 40 kV. Find
[Suatu elektron dipecutkan daripada keadaan rehat ke suatu halaju v melalui suatu beza keupayaan 40 keV. Cari]
- (i) its total energy in MeV, *[jumlah tenaganya dalam MeV,]*
- (ii) its mass, and *[jisimnya, dan]*
- (iii) its momentum. *[momentumnya.]*

[6 marks]

2. (a) The stopping potential of a certain metal is 3.91 V when it is irradiated with monochromatic light of wavelength 150 nm. What is the stopping potential if the metal is irradiated with monochromatic light of wavelength 300 nm.
[Keupayaan penghenti bagi suatu logam tertentu ialah 3.91 V apabila ia disinari dengan cahaya monokromatik yang berjarak gelombang 150 nm. Apakah keupayaan penghenti jika logam itu disinari dengan cahaya monokromatik yang berjarak gelombang 300 nm.]

[5 marks]

- (b) Why X-rays are more penetrative than visible light?
[Mengapa Sinar-X adalah lebih menusuk berbanding cahaya nampak?]

[2 marks]

- (c) X-ray photons are produced from an X-ray machine whose accelerating potential is 50 keV. The X-ray photons with shortest wavelength then incident on a target and undergo Compton scattering.
[Foton sinar-X dihasilkan daripada suatu mesin sinar-X yang mana keupayaan pecutannya ialah 50 keV. Foton sinar-X yang berjarak gelombang terpendek kemudian ditujukan ke atas suatu sasaran dan melalui serakan Compton.]

- (i) Find the angle between the directions of the scattered photons and the incident photons at which the scattered photons have energy of 90% of the incident photons.
[Cari sudut di antara arah foton terserak dengan arah foton tuju yang mana foton terserak itu mempunyai 90% tenaga daripada foton tuju.]

[8 marks]

- (ii) The scattered photons then incident on a crystal with unknown interatomic spacing d . If the second-order Bragg peak is observed at an angle of 12.82° . What is the interatomic spacing d for this crystal?

[Foton yang terserak kemudian ditujukan ke atas suatu hablur yang jarak antara atom d tidak diketahui. Jika puncak Bragg tertib kedua diperhatikan pada suatu sudut 12.82° . Apakah jarak antara atom d bagi hablur ini?]

[5 marks]

3. (a) Show that the de Broglie wavelength for a particle of rest mass m_0 and charge q , accelerated from rest through a potential difference of V volts relativistically is given by

[Tunjukkan bahawa jarak gelombang de Broglie bagi suatu zarah yang berjisim rehat m_0 dan bercas q , dipecutkan daripada keadaan rehat melalui suatu beza keupayaan V volt secara kerelatifan diberi sebagai]

$$\lambda = \frac{h}{\sqrt{2m_0qV\left(1 + \frac{qV}{2m_0c^2}\right)}}$$

where h and c are the Planck's constant and speed of light, respectively.

[di mana h dan c masing-masing ialah pemalar Planck dan halaju cahaya.]

[10 marks]

- (b) A beam of electrons is incident on a slit of variable width. If it is possible to resolve a 1% difference in momentum, what slit width would be necessary to resolve the interference pattern of the electrons if their kinetic energy is 100 MeV?

[Suatu alur elektron ditujukan ke atas suatu celahan yang lebarnya boleh berubah. Jika perbezaan dalam momentum yang mungkin dapat dileraikan ialah 1%, apakah lebar celahan yang bakal perlu untuk meleraikan corak interferens bagi elektron jika tenaga kinetiknya ialah 100 MeV?]

[10 marks]

4. (a) The wavelength of the second line of the Balmer series in the hydrogen spectrum is 4861 \AA (angstrom). Calculate the wavelength of the first line.
[Jarak gelombang garis kedua bagi siri Balmer di dalam spectrum hidrogen ialah 4861 \AA (angstrom). Hitungkan jarak gelombang bagi garis pertama.]

[5 marks]

- (b) An electron of energy 12.5 eV collides with a hydrogen atom in its ground state. Find the maximum amount of energy the incident electron can lose inelastically in this collision? Find the remaining energy of the electron?
[Suatu elektron yang bertenaga 12.5 eV berlanggar dengan suatu atom hidrogen yang berada di keadaan dasar. Cari jumlah tenaga maximum yang elektron tuju itu dapat hilangan dalam perlanggaran tak kenyal ini? Cari baki tenaga bagi elektron itu?]

[5 marks]

- (c) Consider an x-ray of wavelength 0.050 nm scatters from a gold atom target.
[Pertimbangkan sinar-x yang berjarak gelombang 0.050 nm, terserak oleh suatu sasaran atom emas.]

- (i) Can the x-ray be Compton-scattered from an electron bound by as much as 62,000 eV? Explain your answer.
[Bolehkah sinar-x menjalani serakan Compton oleh suatu elektron yang terikat dengan tenaga sebesar 62,000 eV?]

- (ii) What is the largest wavelength of scattered photon that can be observed?
[Apakah jarak gelombang foton terserak yang paling panjang yang mungkin dicerap?]

- (iii) What is the kinetic energy of the most energetic recoil electron and what angle does it occur?
[Apakah tenaga kinetik elektron tersentak yang paling bertenaga, dan pada sudut apakah keadaan ini berlaku?]

[10 marks]

5. (a) In an experiment conducted in the teaching lab in the School of Physics, USM, an electron originated from upper atmosphere is observed to move at the speed of $v = 0.998c$.

[Dalam suatu eksperimen yang dijalankan dalam makmal pengajaran di Pusat Pengajian Sains Fizik, USM, suatu elektron yang berasal daripada atmosfera atas telah dicerap. Elektron tersebut diukur sebagai bergerak pada laju $v = 0.998c$.]

- (i) What is the magnitude of its momentum in unit of MeV/c?
[Apakah magnitude momentumnya dalam unit MeV/c?]

- (ii) What is the total relativistic energy of the electron in unit of MeV?
[Apakah tenaga jumlah kerelatifan elektron tersebut dalam unit MeV?]

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- (iii) What is the kinetic energy of the electron in unit of MeV?
[Apakah tenaga kinetik elektron tersebut dalam unit MeV?]
- (b) What is the kinetic energy of the electron at the $n = 4$ state in the Bohr's model of hydrogen atom in unit of eV? Explain clearly the steps of your working leading to your answer.
[Apakah tenaga kinetik elektron yang berada pada keadaan $n=4$ dalam atom hidrogen model Bohr dalam unit eV? Terangkan dengan jelas langkah-langkah yang membawa kepada jawapan anda.]
 [20 marks]
6. (a) Describe an experiment in which the value of the Planck constant can be measured.
[Perihalkan suatu eksperimen di mana nilai pemalar Planck boleh diukur.]
- (b) Consider an electron and a proton, both moving at the speeds of $c\beta_e$ and $c\beta_p$ respectively.
[Pertimbangkan suatu elektron dan suatu proton, masing-masing bergerak pada laju $c\beta_e$ dan $c\beta_p$]
- (i) What is the ratio of their de Broglie wavelengths, λ_e/λ_p ? [Hint: You have to consider the most general scenario, i.e. relativistic scenario.]
[Apakah nisbah jarak gelombang de Broglie mereka, λ_e/λ_p ? (Petunjuk: Anda harus mempertimbangkan sinario paling am, iaitu, sinario kerelatifan.)]
- (ii) What is the limit of λ_e/λ_p in the case where both are moving at ultra-relativistic speeds?
[Apakah limit λ_e/λ_p dalam kes di mana kedua-dua zarah bergerak dengan laju ultra-kerelatifan?]
- (iii) What is the limit of λ_e/λ_p in the case where both are moving at sub-relativistic speeds?
[Apakah limit λ_e/λ_p dalam kes di mana kedua-dua zarah bergerak dengan laju sub-kerelatifan?]
- Your answer should be expressed in term of m_e , m_p , β_e , β_p and c .
[Jawapan anda harus dinyatakan dalam sebutan m_e , m_p , β_e , β_p dan c .]
 [20 marks]