UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2005/2006

Jun 2006

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

Duration: 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **TWENTY EIGHT** pages before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **DUA PULUH LAPAN** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

Instruction:
Answer ALL questions in Section A and Section B.

Please answer the objective questions from Section A in the objective answer sheet provided. Please submit the objective answer sheet and the answers to the structured questions separately.

Students are allowed to answer all questions in Bahasa Malaysia or in English.

*[**Arahan**: Jawab **SEMUA** soalan dalam Bahagian A dan Bahagian B.*

Sila jawab soalan-soalan objektif daripada bahagian A dalam kertas jawapan objektif yang dibekalkan. Sila serahkan kertas jawapan objektif dan jawapan kepada soalan-soalan struktur berasingan.

Pelajar dibenarkan untuk menjawab samada dalam bahasa Malaysia atau bahasa Inggeris.]

Data

Speed of light in free space, $c = 3.00 \times 10^{8}$ m s^{-1}
Permeability of free space, $\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
Permittivity of free space, $\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
Elementary charge, $e = 1.60$ x 10^{-19} C
Planck constant, $h = 6.63 \times 10^{-34}$ J s
Unified atomic mass constant, $u = 1.66 \times 10^{-27}$ kg
Rest mass of electron, $m_e = 9.11 \times 10^{-31}$ kg
Rest mass of proton, $m_p = 1.67 \times 10^{-27}$ kg
Molar gas constant, = 8.31 J K^{-1} mol^{-1}
Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}
Gravitational constant, $G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
Acceleration of free fall, $g = 9.81$ m s^{-2}

Section A: Objectives. [20 marks]
[Bahagian A: Soalan-soalan objektif]

Instruction: Answer all 20 objective questions in this Section.
[Arahan: Jawab kesemua 20 soalan objektif dalam Bahagian ini.]

1. Which of the following statements is (are) true regarding the Bohr model of hydrogen-like atom?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai model Bohr untuk atom bak-hidrogen?]

I. It predicts the ionization energy for hydrogen. (T)
[Ia meramalkan tenaga pengionan untuk hydrogen.]

II. It cannot account for the spectra of more complex atoms. (T)
[Ia tidak dapat menerangkan spektrum atom-atom yang lebih kompleks.]

III. It is unable to predict many subtle spectral details of hydrogen and other simple atoms such as energy level splittings due to spin-orbital interactions. (T)
[Ia gagal untuk meramalkan banyak butir-butir halus hidrogen dan atom-atom ringkas lain seperti belahan paras-paras tenaga disebabkan oleh interaksi spin-orbit.]

IV. The notion of electrons in well-defined orbits around the nucleus is consistent with the uncertainty principle. (F)
[Fikiran bahawa elektron mengelilingi nukleus dalam orbit yang tepat tertakrif adalah konsisten dengan prinsip ketidakpastian.]

A. I, II, III   B. II, III, IV   C. I, II, III, IV
D.(None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: A. Serway pg. 1359, modified.

2. Which of the following statements is (are) true regarding the spectrum of hydrogen atom, according to the Bohr model?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai spektrum atom hidrogen menurut model Bohr?]

I. The Balmer series emission spectrum of a hydrogen atom lies in the visible region of the electronmagnetic spectrum.
[Spektrum pancaran siri Balmer atom hidrogen terletak dalam rantau nampak spektrum elektromagnetik.]

II. The Lyman series emission spectrum of a hydrogen atom lies in the ultraviolet region of the electronmagnetic spectrum.
[Spektrum pancaran siri Lyman atom hidrogen terletak dalam rantau ultraungu spektrum elektromagnetik.]

III. The Paschen series emission spectrum of a hydrogen atom lies in the infrared region of the electronmagnetic spectrum.
[Spektrum pancaran siri Paschen atom hidrogen terletak dalam rantau infra merah spektrum elektromagnetik.]

IV. The Balmer series absorption spectrum of a hydrogen atom lies in the visible region of the electronmagnetic spectrum.
[Spektrum serapan siri Balmer atom hidrogen terletak dalam rantau nampak spektrum elektromagnetik.]

A. I, II, III, IV B. I, II, III C. II, IV
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*
ANS: A (ALL)

3 Which of the following statements is (are) true regarding the wave function of a quantum particle?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai fungsi gelombang bagi suatu zarah kuantum?]

I. The wavefunction is directly measurable.
[Fungsi gelombang dapat diukur secara terus.]

II. The square of the wavefunction is a measure of the probability of observing the quantum particle within a region in space.
[Kuasadua fungsi gelombang merupakan satu sukatan kebarangkalian untuk memerhatikan zarah kuantum di dalam suatu rantau ruangan.]

III. The square of the wavefunction is a measure of the energy of the quantum particle.
[Kuasadua fungsi gelombang merupakan satu sukatan untuk tenaga zarah kuantum.]

IV. The wavefunction of a free particle is zero everywhere.
[Fungsi gelombang suatu zerah bebas adalah sifar di mana-mana.]

A. I, III B. II, IV C. I ONLY
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: D, II only. **[My own question.]**

4. Which of the following statements is (are) true regarding the linear momentum of an object?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai momentum linear agi suatu objek?]

I. The object's momentum is dependent on its speed.
[Momentum objek bersandar kepada lajunya.]

II. The object's momentum is dependent on the frame in which it is being measured.
[Momentum objek bersandar kepada rangka dalam mana ia diukur.]

III. In special theory of relativity, there is an upper limit to the magnitude of an object's linear momentum.
[Dalam teori kerelatifan wujudnya limit atas ke atas magnitud momentum linear suatu objek.]

IV. In non-relativistic theory of classical mechanics, there is no upper limit to the magnitude of its linear momentum.
[Dalam teori mekanik klasik bukan kerelatifan tidak wujud limit atas ke atas magnitud momentum linear suatu objek.]

A. I, III B. I, II, IV C. I ONLY
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: B [My own question.]

5. Which of the following statements is (are) true regarding the kinetic energy of an object?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai tenaga kinetik suatu objek?]

I. The kinetic energy of an object is the energy associated with the motion of the object.
[Tenaga kinetik suatu objek adalah tenaga yang berkaitan dengan pergerakan objek.]

II. In special theory of relativity, the kinetic energy of an object cannot be larger than its rest energy.
[Dalam teori kerelatifan, tenaga kinetik suatu objek tidak boleh melebihi tenaga rehatnya.]

III. The relativistic expression of kinetic energy reduces to that of the classical theory of machanics in the limit $v << c$.
[Ungkapan tenaga kinetik keretatifan terturun kepada ungkapan mekanik teori klasik dalam limit $v<<c$.]

IV. The classical expression of kinetic energy reduces to that of the special theory of relativity in the limit $v << c$.
[Ungkapan tenaga kinetik klasik terturun kepada ungkapan kerelatifan dalam limit $v<<c$.]

A. I, II, III B. I, II, IV C. I, III
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: C [My own question.]

6. Consider a proton and an electron, both moving at a common speed, v. Let K_p and K_e denote the the proton and electron's kinetic energy respectively. Which of the following statements is (are)?
[Pertimbangkan suatu proton dan suatu elektron, kedua-duanya bergerak dengan laju yang sama, v. Biar K_p dan K_e masing-masing menandakan tenaga kinetik proton dan elektron. Yang manakah kenyataan(-kenyataan) berikut adalah benar?]

I. $K_p = (m_p/m_e)K_e$ for $v << c$. *[$K_p = (m_p/m_e)K_e$ untuk $v << c$.]*
II. $K_p = (m_p/m_e)K_e$ for v close to c. *[$K_p = (m_p/m_e)K_e$ untuk v mendekati c.]*

III. $K_p > K_e$ for all values of $v < c$. *[$K_p > K_e$ untuk semua nilai $v < c$.]*

IV. The ratio of K_p/K_e depends on the magnitude of v. *[nisbah K_p/K_e bergantung kepada magnitud v.]*

A. I, II, III B. IV only C. II , III

D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: A [IV is false. My own question.] $\frac{\gamma m_P c^2}{\gamma m_e c^2} = \frac{K_P + m_P c^2}{K_e + m_e c^2} \Rightarrow \frac{K_P}{K_e} = \frac{m_P}{m_e}$

7. Let say you have found a map revealing a huge galactic treasure at the opposite edge of the Galaxy 200 ly away. Is there any chance, from the relativistic point of view, for you to travel such a distance from Earth and arrive at the treasure site by traveling on a rocket within your lifetime of say, 60 years?
[Katakan anda telah menjumpai satu peta yang membongkar harta karun galaktik sejauh 200 tahun cahaya di sebelah sisi Galaksi yang bertentangan. Dari segi teori kerelatifan, adakah wujud apa-apa peluang supaya anda dapat menjelajahi jarak tersebut dari Bumi dengan menaiki roket dan sampai ke tempat harta karun dalam masa hayat anda, katakan 60 tahun?]

A. No, it is impossible to reach the treasure site within our lifespan of 60 years because it takes a minimum of 200 year of traveling time to reach there.
[Tidak. Adala tidak mungkin untuk sampai ke tempat harta karun dalam masa hayat 60 tahun kerana tempoh penjelajahan untuk sampai ke sana adalah sekurang-kurangnya 200 tahun.]

B. No, it is impossible to reach the treasure site within our lifespan of 60 years because we can’t travel faster than the speed of light.
[Tidak. Adala tidak mungkin untuk sampai ke tempat harta karun dalam masa hayat 60 tahun kerana kita tidap mungkin bergerak lebih pantas daripada laju cahaya.]

C. Yes, it is possible to reach the treasure site within our lifespan of 60 years because theory of relativity allows the rocket to travel faster than the speed of light.
[Ya. Adala mungkin untuk sampai ke tempat harta karun dalam masa hayat 60 tahun kerana teori kerelatifan membenarkan roket bergerak lebih pantas daripada laju cahaya.]

D. Yes, it is possible to reach the treasure site within our lifespan of 60 years because the traveling time to reach there could be significantly smaller than 200 years due to relativistic effect.
[Ya. Adala mungkin untuk sampai ke tempat harta karun dalam masa hayat 60 tahun kerana tempoh penjelajahan untuk sampai ke sana boleh jadi jauh lebih singkat daripada 200 tahun disebabkan oleh kesan kerelatifan.]

ANS: D [My own question, pg. 1 in lecture note]

8. Which of the following statements is (are) true according to the special theory of relativity?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai teori kerelatifan?]

I. A massless particle must always travel at the speed of light.
[Suatu zarah tanpa jisim mesti sentiasa bergerak dengan laju cahaya.]

II. A particle with non-zero mass must always travel at the speed smaller than that of light.
[Suatu zarah dengan jisim bukan sifar mesti sentiasa bergerak dengan laju yang kurang daripada laju cahaya.]

III. The length of a moving object along its direction of motion is shorter than that measured at rest.
[Panjang suatu objek dalam arah gerakannya adalah lebih pendek daripada panjangnya yang diukur semasa ia rehat.]

IV. The rest mass of an object is greater when it is moving than at rest.
[Jisim rehat bagi suatu objek adalah lebih besar semasa ia bergerak berbanding dengan jisim rehatnya semasa ia rehat .]

A. I, III, IV B. I, II, III, IV C. I, II, III
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: C [My own question.]

9. When two particles collide relativistically, *[Bila dua zarah berlanggar secara kerelatifan,]*

I. the total rest energy is conserved. *[jumlah tenaga rehat adalah terabadikan.]*
II. the total rest mass is conserved. *[jumlah jisim rehat adalah terabadikan.]*
III. the total kinetic energy is an invariant. *[jumlah tenaga kinetik adalah tak varian.]*

A. I , II, III B. II, III C. I , II
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: D. None of I, II, III is true.

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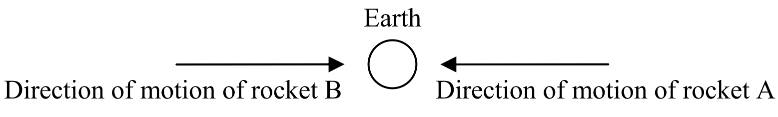
10. Consider two rockets moving in opposit directions towards the Earth. See figure below. Rocket A is moving towards Earth at a speed of 0.5c (relative to Earth) while rocket B with a speed of 0.51c (relative to Earth). Which of the following statements is (are) true?
[Pertimbangkan dua roket yang bergerak dalam dua arah bertentangan, masing-masing menghadap ke Bumi. Rujuk gambarajah. Roket A bergerak menuju ke arah Bumi dengan laju 0.5c (relatif kepada Bumi) manakala roket B dengan laju 0.51c (relatif kepada Bumi). Yang manakah kenyataan(-kenyataan) berikut adalah benar?]



I. The magnitude of the relative velocity of rocket A with respect to rocket B is less than 1.01 c.
[Magnitud halaju relatif roket A merujuk kepada roket B adalah kurang daripada 1.01c.]

II. The magnitude of the relative velocity of rocket A with respect to rocket B is less than c.
[Magnitud halaju relatif roket A merujuk kepada roket B adalah kurang daripada c.]

III. The magnitude of the relative velocity of rocket A with respect to rocket B is equal to c.

[Magnitud halaju relatif roket A merujuk kepada roket B adalah sama dengan c.]

IV. The magnitude of the relative velocity of rocket A with respect to rocket B is equal to 1.01 *c*.
[Magnitud halaju relatif roket A merujuk kepada roket B adalah sama dengan 1.01c.]

A. I, II B. I, III C. IV only
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*
ANS: A [PYQ, 05/06 Final, Q15, modified]

11. For a blackbody, the total intensity of energy radiated over all wavelengths, *I*, is expected to rise with temperature according to the *Stefan's law*: $I = \sigma T^4$, where σ is the Stefan's constant. How does the total intensity of thermal radiation vary when the temperature of a black body is doubled?
[Bagi suatu jasad hitam, jumlah keamatan tenaga terpancarkan untuk semua jarak gelombang, I, dijangka akan meningkat jika suhu meningkat, menurut hukum Stefan, $I = \sigma T^4$*, di mana* σ *adalah pemalar Stefan. Bagaimanakah jumlah keamatan pancaran terma berubah bila suhu jasad hitam menjadi dua kali lebih besar?]*

A. The total intensity of thermal radiation increase by 2 times.
[Jumlah keamatan pancaran terma bertambah sebanyak 2 kali.]
B. The total intensity of thermal radiation increase by 4 times.
[Jumlah keamatan pancaran terma bertambah sebanyak 4 kali.]
C. The total intensity of thermal radiation increase by 16 times
[Jumlah keamatan pancaran terma bertambah sebanyak 16 kali.]
D. The total intensity of thermal radiation remains the same.
[Jumlah keamatan pancaran terma adalah sama.]

ANS:C, Tut 2 04/05, P1

12. In the spectral distribution of blackbody radiation, the wavelength λ_{max} at which the intensity reaches its maximum value decreases as the temperature is increased, in inverse proportional to the temperature: $\lambda_{max} \propto 1/T$. This is called the *Wein's displacement law*. It explains the observation that when a blackbody is heated up to 1800K it starts to glow and appears dim red. According to Wein's law, when the temperature continue to increase, the colour would change from dim red towards blue and then white hot. What is the change of the apparent colour to human eye when temperature drops from 450K to 370 K?
[Dalam taburan spektrum pancaran jasad hitam, jarak minimum λ_{max} *pada mana keamatan mencapai nilai maksimumnya akan berkurang bila suhu dinaikkan mengikut* $\lambda_{max} \propto 1/T$*. Ini dipanggil hukum sesaran Wein. Ia menerangkan cerapan bahawa semasa suatu jasad hitam dipanaskan kepada 1800K, ia mula berbara dan kelihatan merah pudar. Menurut hukum Wein, jika suhu terus meningkat, warnanya akan berubah daripada merah pudar kepada biru dan kemudiannya panas putih. Apakah perubahan warna ketara kepada mata manusia bila suhu jatuh daripada 450K kepada 370 K?]*

A. It changes from red hot to blue hot. *[Ia berubah daripada merah panas kepada biru panas.]*
B. It changes from red hot to dark. *[Ia berubah daripada merah panas kepada hitam.]*
C. Its apparent colour doesn't change. *[Warna ketaranya tidak berubah.]*

D. It changes from white hot to red hot. *[Ia berubah daripada putih panas kepada merah panas.]*

ANS:C, http://library.wolfram.com/webMathematica/Astronomy/Blackbody.jsp
(BB at temperature lower than 1800 K doesn't appear to have any 'colour' to our human eye.)

13. Which of the following statements is (are) true regarding X-rays?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai sinaran-X?]

I. X-ray can be used to determine the geometry of the lattice of a crystal. (T)
[Sinaran-X boleh digunakan untuk menentukan geometri kekisi sesuatu hablur.]

II. X-rays can be produced by bombarding a metal target with electrons accelerated by an electric potential field of 10,000 V. (T)
[Sinaran-X boleh dihasilkan dengan menghentam suatu sasaran logam dengan elektron yang dipecutkan oleh suatu medan keupayaan elektrik 10,000 V.]

III. Tungsten and molybdenum, two types of material usually used as target material in an X-rays tube, give off different λ_{min} of X-rays when the X-ray tube is operating at a common potential V. (F)
[Tungsten dan molibdenum, dua jenis bahan yang biasanya digunakan sebagai bahan sasaran dalam tiub sinaran-X, mengeluarkan λ_{min} sinaran-X yang berbeza semasa tiub sinaran-X beroperasi pada keupayaan yang sama.]

IV. X-rays behave like wave in Braggs diffraction of X-ray by a crystal lattice. (T)
[Sinaran-X berkelakuan seperti gelombang dalam belauan sinaran-X Braggs oleh kekisi bablur.]

A. I, II, III, IV   B. I, II, III   C. I, II, IV
D. None of A, B, C.

ANS: C. (My Own Question)

14. Which of the following statements is (are) true regarding light?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai cahaya?]

I. Light behaves like wave in a diffraction experiment. (T)
[Cahaya berkelakuan seperti gelombang dalam eksperimen belauan.]

II. Light behaves like particle in a photoelectric experiment. (T)
[Cahaya berkelakuan seperti zarah dalam eksperimen fotoelektrik.]

III. Light behaves like particle in a Compton scattering experiment. (T)
[Cahaya berkelakuan seperti zarah dalam eksperimen serakan Compton.]

IV. Light can manifest both particle and wave nature in a single experiment. (F)
[Cahaya boleh memperlihatkan kedua-dua tabii zarah dan gelombang dalam satu eksperimen yang sama.]

A. I, II, III B. II, III, IV C. I, III, IV
D. None of A,B, C.
ANS: A. (My Own Question)

15. Which of the following statements is (are) true regarding photoelectric effect?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai kesan fotoelektrik?]

I. The photoelectric effect requires special theory of relativity for an explaination.
[Kesan fotoelektrik memerlukan teori kerelatifan untuk penerangannya.]

II. In a typical photoelectric effect experiment the energy involved is usually relativistic.
[Dalam suatu eksperimen kesan fotoelektrik yang tipikal, tenaga yang terlibat biasanya adalah relativistik.]

III. The probability of photoelectric effect to occur in a metal target would diminish when the energy of the striking photon becomes increasingly relativistic.
[Kebarangkalian kesan fotoelektrik berlaku di dalam sararan logam akan menyusut bila tenaga foton yang menghentum menjadi semakin relativistik.]

IV. The saturation photoelectric current increases as the energy of incident photons increases (with the radiation fixed at a constant intensity).
[Arus fotoelektrik tepu bertambah semasa tenaga foton tuju bertambah (dengan sinaran ditetapkan pada keamatan malar).]

A. I, II, III, IV B. I, II, III C. I, II, IV
D. None of A, B, C.
ANS: D. Only III is true.

…/12 -

16. Consider a matter particle with rest mass m_0, moving with a speed v. Which of the following statements is (are) true regarding its de Broglie wave? Take $\gamma = 1/\sqrt{1-(v/c)^2}$.
[Pertimbangkan suatu zarah jirim berjisim rehat m_0, bergerak dengan laju v. Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai gelombang de Broglienya? Ambil $\gamma = 1/\sqrt{1-(v/c)^2}$.]

I. The de Broglie wavelength of the matter particle is $\lambda = h/(\gamma m_0 v)$ regardless of whether the particle is relativistic or not (T).
[Jarak gelombang de Broglie zarah jirim ialah $\lambda = h/(\gamma m_0 v)$, tidak kira samada zarah tersebut adalah dalam keadaan kerelatifan atau tidak].

II. The de Broglie wavelength of the matter particle is $\lambda = h/(\gamma m_0 v)$ even if v is non relativistic (T).
[Jarak gelombang de Broglie zarah jirim ialah $\lambda = h/(\gamma m_0 v)$ walaupun zarah tersebut adalah dalam keadaan bukan kerelatifan.]

III. The de Broglie wavelength of the matter particle is $\lambda = h/(m_0 v)$ if v is non-relativistic (T).

[Jarak gelombang de Broglie zarah jirim ialah $\lambda = h/(m_0 v)$ jika zarah tersebut adalah dalam keadaan bukan kerelatifan.]

IV. If the matter particle is relativistic, the de Broglie wavelength is larger than $h/(\gamma m_0 v)$. (F)
[Jika zarah jirim adalah dalam keadaan kerelatifan, jarak gelombang de Broglie zarah adalah lebih besar daripada $\lambda = h/(\gamma m_0 v)$.]

A. I, II, III B. II, III C. II, III, IV D. None of A, B, C.

ANS: A. (My Own Question, modified from PYQ 05/06 Test II, Q14)
For both cases of relativistic and non-relativistic, their dB wavelengths are correctly given by $\lambda = h/(\gamma m_0 v)$.

17. Which of the following statements are (is) true
[Yang manakah kenyataan(-kenyataan) berikut adalah benar?]

I. $hc \approx 1240\,\text{keV}\cdot\text{nm}$ (Planck constant × speed of light)

II. $m_e \approx 511\text{keV}/c^2$ (electron's mass)

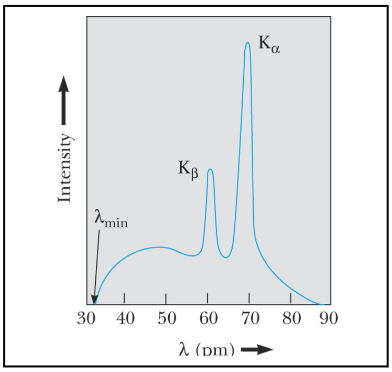
III. $\gamma = 1/\sqrt{1-\left(\frac{v}{c}\right)^2} \approx 1$ for the typical speed v of a car on the PLUS highway.

IV. $a_0 \approx 0.53\text{pm}$ (Bohr's radius)

A. I, II, IV B. II, III C. I, II, III, IV
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: B. PYQ 05/06 Final, Q21, modified.

18. The figure below shows the x-ray spectrum of a metal target from a x-ray tube. Which of the following statements are (is) true?
[Gambarajah berikut memaparkan spektrum sinaran-X daripada sasaran logam suatu tiub sinaran-X. Yang manakah kenyataan(-kenyataan) berikut adalah benar?]



I. The broad continuous spectrum cannot be explained by classical electromagnetic theory.
[Spektrum selanjar yang lebar tidak dapat diterangkan oleh teori elektromagnet klasik.]

II. The existence of $\lambda_{\min}$ in the spectrum can well be explained in terms of classical theories.
[Kewujudan $\lambda_{\min}$ dalam spektrum dapat diterangkan dengan baiknya oleh teori-teori klasik.]

III. $\lambda_{\min}$ is dependent on the energy of the borbarding electrons.
[$\lambda_{\min}$ adalah bersandar pada tenaga elektron yang menghentum sasaran logam.]

IV. The broad continuous spectrum demonstrates a proof for the photon theory for X-rays.
[Spektrum selanjar yang lebar memperlihatkan bukti kepada teori foton untuk sinaran-X.]

A. I, III, IV B. I, II, III, IV C. III Only
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANS: C. PYQ 05/06 Final, Q27, modified.

19. Which of the following statements are (is) true regarding a quantum particle in an (ideal) infinite squre well?
[Yang manakah kenyataan(-kenyataan) berikut adalah benar mengenai zarah kuantum di dalam telaga segiempat infinit (yang ideal)?]

I. The rest energy of the particle is equal to the zero point energy.
[Tenaga rehat zarah adalah sama dengan tenaga titik sifar.]

II. The zero point energy tends to zero if the width of the well increase indefinitely.
[Tenaga titik sifar menokok kepada sifar jika lebar telaga bertambah tak terhingga.]

III. On theory, the largest allowed energy level of the particle in the well is infinity.
[Secara teori, paras tenaga terizinkan yang tertinggi bagi zarah dalam telaga ialah infiniti.]

IV. The zero point energy tends to zero if the temperature of the particles tends to absolute zero.
[Tenaga titik sifar menokok kepada sifar jika suhu zarah menokok kepada sifar.]

A. II, III B. II, III, IV C. I, II, III
D. (None of A, B, C) *[Jawapan tidak terdapat dalam pilihan-pilihan A, B, C]*

ANN: A [My own question]

20. Consider a photon of wavelength λ undergoes pair creation process into a pair of particles-antiparticles, each with rest mass *m*. If one of the particles is measured to have kinetic energy of K_1, what is the kinetic energy of the other particle?
[Pertimbangkan suatu foton dengan jarak gelombang λ yang melakukan penghasilan berpasangan kepada suatu pasangan zarah-antizarah, dengan jisim rehat mereka m. Jika tenaga kinetik salah satu zarah diukur sebagai K_1, apakah tenaga kinetik bagi zarah yang satu lagi?]

A. $\frac{hc}{\lambda} - K_1 - 2mc^2$ B. $\frac{hc}{\lambda} + K_1 + 2mc^2$ C. $\frac{hc}{\lambda} + K_1 - 2mc^2$

D. $\frac{hc}{\lambda} - K_1 + 2mc^2$

ANS: A. [My own question]

Section B: Structural Questions. [80 marks]
[Bahagian B: Soalan-soalan Struktur]

Instruction: Answer ALL FOUR (4) questions in this Section. Each question carries 20 marks.
[Arahan: Jawab KESEMUA EMPAT (4) soalan dalam Bahagian ini. Setiap soalan membawa 20 markah].

1. [20 marks]

(a) Derive the theoretical Rydberg constant in the Bohr model. Show that it is given by: *[Terbitkan pemalar Rydberg secara teori dalam model Bohr. Tunjukkan bawaha ia diberikan oleh:]*

$$R_\infty = \frac{2\pi^2 \left(ke^2\right)^2 \left(m_e c^2\right)}{\left(hc\right)^3}, \text{ where } k = \frac{1}{4\pi\varepsilon_0}.$$

[10/20]

(b) Determine, in Angstroms *[Hitungkan, dalam unit Angstroms]*

(i) the shortest and, *[jarak gelombang yang terpendek, dan]*

[5/20]

(ii) the longest wavelengths of the Lyman series of hydrogen.
[jarak gelombang yang terpanjang untuk hidrogen dalam siri Lyman.]

[5/20]

Solution

(a) Schaum series Modern Physics, pg. 104, 105

Mechanical stability:

$$\frac{ke^2}{r^2} = \frac{mv^2}{r} \Rightarrow kv^2 = \left(mvr\right)v \qquad \text{Eq(1)}$$

Quantization of orbital momentum:

$$L = pr = \left(mv\right)r = n\hbar \qquad \text{Eq(2)}$$

Eq(2) →Eq(1):

$$ke^2 = n\hbar \Rightarrow v = \frac{ke^2}{n\hbar} \qquad \text{Eq. (3)}$$

Eq(3) →Eq(2):

$$r = \frac{n\hbar}{mv} = \frac{n\hbar}{m}\frac{n\hbar}{ke^2} = \frac{n^2\hbar^2}{mke^2} \qquad \text{Eq. (4)}$$

Total energy:

$$E = K + V = \frac{mv^2}{2} - \frac{ke^2}{r} \qquad \text{Eq, (5)}$$

Eq(3), Eq(4) $\rightarrow$Eq(5):

$$E = \frac{m}{2}\left(\frac{ke^2}{n\hbar}\right)^2 - m\left(\frac{ke^2}{n\hbar}\right)^2 = -\frac{m}{2}\left(\frac{ke^2}{n\hbar}\right)^2 \equiv \frac{E_0}{n^2};$$

where ground state energy is $E_0 = -\frac{m}{2}\left(\frac{ke^2}{\hbar}\right)^2$.

Energy of photon during transition from n_i to n_f is

$$\frac{hc}{\lambda} = \Delta E = E_i - E_f = \frac{E_0}{n_i^2} - \frac{E_0}{n_f^2} = -E_0\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\Rightarrow \frac{1}{\lambda} = -\frac{E_0}{hc}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \equiv R_\infty\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$R_\infty = -\frac{E_0}{hc} = \frac{m}{2hc}\left(\frac{ke^2}{\hbar}\right)^2 \times \frac{c^2}{c^2} = \frac{2\pi^2 mc^2 (ke^2)^2}{(hc)^3}$$

(b) Schaum series Modern Physics, pg. 107, Q11.1.

In Lyman series, emission wavelengths are given by

$$\Rightarrow \frac{1}{\lambda} = -\frac{E_0}{hc}\left(\frac{1}{1^2} - \frac{1}{n_i^2}\right) = \frac{13.6\text{eV}}{1240\text{eV}\cdot\text{nm}}\left(1 - \frac{1}{n_i^2}\right)$$

(i) For shortest wavelenght, $n_i = \infty$,

$$\frac{1}{\lambda_{shortest}} = \frac{13.6\text{eV}}{1240\text{eV}\cdot\text{nm}}\left(1 - \frac{1}{\infty}\right) = \frac{13.6\text{eV}}{1240\text{eV}\cdot\text{nm}} \Rightarrow \lambda_{shortest} = \frac{1240\text{eV}\cdot\text{nm}}{13.6\text{eV}} = 91.2\text{nm}$$

(ii) For longest wavelenght, $n_i = 2$,

$$\frac{1}{\lambda_{longest}} = \frac{13.6\text{eV}}{1240\text{eV}\cdot\text{nm}}\left(1 - \frac{1}{2^2}\right) = \left(\frac{3}{4}\right)\frac{13.6\text{eV}}{1240\text{eV}\cdot\text{nm}} \Rightarrow \lambda_{longest} = \left(\frac{4}{3}\right)\frac{1240\text{eV}\cdot\text{nm}}{13.6\text{eV}} = 121.6\text{nm}$$

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2. [20 marks]

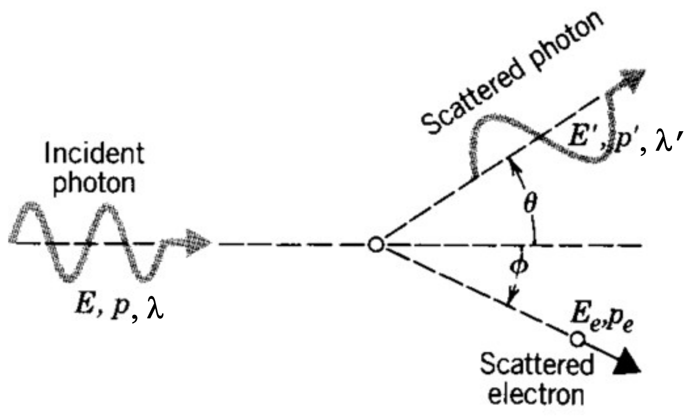


Figure 1

(a) Consider figure 1. A photon with initial energy *E*, momentum *p* and wavelength λ is scattered by an initially stationary electron of rest mass m_e. The scattered angle, energy, momentum and wavelength of the scattered photon are as indicated in the figure. So are the energy and momentum of the recoiled electron.

[Pertimbangkan rajah 1. Suatu foton dengan tenaga awal E, momentum p dan jarak gelombang λ, diserakkan oleh suatu elektron (berjisim rehat m_e) yang pada awalnya dalam keadaan rehat. Sudut serakan, tenaga, mementum dan jarak gelombang foton yang terserak adalah seperti yang ditunjukkan di dalam rajah. Begitu juga bagi tenaga, sudut dan momentum elektron yang tersentak.]

(i) Write down the conservation of momentum for the above process.
[Tuliskan keabadian momentum untuk pross tersebut.]

[4/20]

(ii) Write down the conservation of energy for the above process.
[Tuliskan keabadian tenaga untuk proses tersebut.]

[6/20]

(b) X-rays of wavelength λ_0 =0.200 000 nm are Compton scattered from a block of material.

[Sinaran-X dengan jarak gelombang λ_0 =0.200 000 nm diserakkan secara Compton daripada suatu blok jirim.]

(i) If the scattered x-rays are observed at an angle of 45° to the incident beam, what is the Compton shift?
[Jika sinaran-X yang terserak dicerap pada sudut 45° kepada sinaran tuju, apakah anjakan Comptonnya?]

[5/20]

(ii) What is the Compton shift of the x-rays photon if x-rays of wavelength 0.520 000 nm is used instead?
[Apakah anjakan Compton foton jika sinaran-X berjarak gelombang λ_0 =0.520 000 nm digunakan?]

[$2\frac{1}{2}$/20]

(iii) If the detector is moved so that the scattered x-rays are detected at a larger angle of say, 60°. Does the wavelength of the scattered x-rays increase or decrease as the angle increases?
[Jika pengesan digerakkan supaya sinaran-X terserak dikesan pada suatu sudut yang lebih besar, katakan 60°. Adakah jarak gelombang terserak akan bertambah atau berkurang?]

[2½/20]

ANS:

(a) Lecture note page 55.

(I) Mom conservation in y : $p'\sin\theta = p_e \sin\phi$

Mom conservation in x : $p - p'\cos\theta = p_e \cos\phi$

(II) Conservation of total relativistic energy:

$cp + m_e c^2 = cp' + E_e$

(b) Serway, pg. 1300, example 40.4

(I) $\Delta\lambda = \frac{h}{m_e c}\left(1 - \cos 45^\circ\right) = 7.10 \times 10^{-13}$ m.

(II) same., 7.10×10^{-13} m.

(III) scattered wavelength increases.

3. [20 marks]

(a) A proton or a neutron can sometimes “violate” conservation of energy emitting and then reabsorbing a pi meson, which has a mass of 135 MeV/c^2. This is possible as long as the pi meson is reabsorbed within a short enough time Δt consistent with the uncertainty principle. Consider p→ p + π.

[Suatu proton atau neutron kadang-kala akan ‘mencanggah’ keabadian tenaga dengan memancar dan kemudiannya menyerap balik suatu meson pi yang berjisim 135 MeV/c^2. Ini adalah mungkin selagi meson pi tersebut diserap balik dalam suatu selang masa singkat Δt yang konsisten dengan prinsip ketidakpastian. Pertimbangkan p→p + π.]

(i) By what amount ΔE is energy conservation violated? (Ignore any kinetic energies.)

[Seberapa bankyakah ketidakpastian tenaga ΔE yang telah mencanggahi keabadian tenaga? (Abaikan tenaga kinetik.)]

[4/20]

(ii) For how long a time Δt can the pi meson exist?

[Untuk berapa lamakah Δt yang boleh meson pi wujud?]

[4/20]

(iii) Assuming pi meson to travel at very nearly the speed of light, how far from the proton can it go?

[Andaikan meson pi itu bergerak pada laju yang amat menyamai laju cahaya, berapa jauhkah daripada proton itu yang dapat pi meson pergi?]

[2/20]

(b) By treating it non-relativistically, find the de Broglie wavelength of a proton with kinetic energy 1.00-MeV.
[Dengan pertimbangan secara tak-relativistik, hitungkan jarak de Broglie suatu proton yang tenaga kinetiknya 1.00-MeV.]

[10/20]

Solution
(a) (Krane, P22, pg. 133)

(i) $\Delta E = m_\pi c^2 = 135\,\text{MeV} = 2.16\times 10^{-9}\,\text{J}.$

(ii) $\Delta t \geq \dfrac{\hbar}{2\Delta E} = 2.40\times 10^{-24}\,\text{s}.$

(iii) distance $= c\Delta t \leq = 0.73\times 10^{-15}\,\text{m}.$

(b) (Beiser, Ex. 6, pg. 117)

3-6: The proton's kinetic energy is only about 0.1% of its rest energy, so a nonrelativistic calculation will suffice. The wavelength is

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2m\,\text{KE}}} = \frac{hc}{\sqrt{2\,(mc^2)\,\text{KE}}}$$
$$= \frac{1.240\times 10^{-12}\ \text{MeV}\cdot\text{m}}{\sqrt{2\,(939.3\ \text{MeV})\,(1.00\ \text{MeV})}} = 2.86\times 10^{-14}\ \text{m}.$$

Note the conversion of units in the product hc in the above calculation.

4. [20 marks]

(a) Consider a relativistic object of momentum, p, total energy, E, and rest mass, m_0.
[Pertimbangkan suatu objek relativistik dengan momentum p, jumlah tenaga E, dan jisim rehatnya m_0.]

(i) Write down the equation relating the magnitude of relativistic momentum, total energy, and the rest mass this object.
[Tuliskan persamaan yang menghubung-kaitkan magnitud momentum relativistik, jumlah tenaga dan jisim rehat objek tersebut.]

[3/20]

(ii) Sketch the graf of E vs. p. Lable and indicate on your graph the value of rest energy E_0.
[Lakarkan graf E lawn p. Lable dan tunjukkan pada lakaran anda nilai tenaga rehat, E_0.]

[3/20]

(iii) What is the momentum of the object when the momentum is such that pc equal to half of the object's total energy? Express your answer in terms of m_0 and c.
[Apakah momentum objek tersebut jika momentumnya adalah sedemikian rupa sehingga pc bersamaan dengan separuh daripada jumlah tenaga objek tersebut? Ungkapkan jawapan anda dalam sebutan m_0 dan c.]

[3/20]

(iv) What is the corresponding speed, v in (iii)?
[Apakah laju yang berkaitan dalam (iii)?]

[5/20]

(b)
(i) A meter stick moves with a velocity of $0.6c$ relative to you along the direction of its length. How long will it take for the meter stick to pass you?
[Suatu pembaris meter bergerak dalam arah panjang pembaris tersebut pada halaju 0.6c relatif kepada anda. Berapa lamakah masa yang diambil pembaris meter itu untuk melepasi anda?]

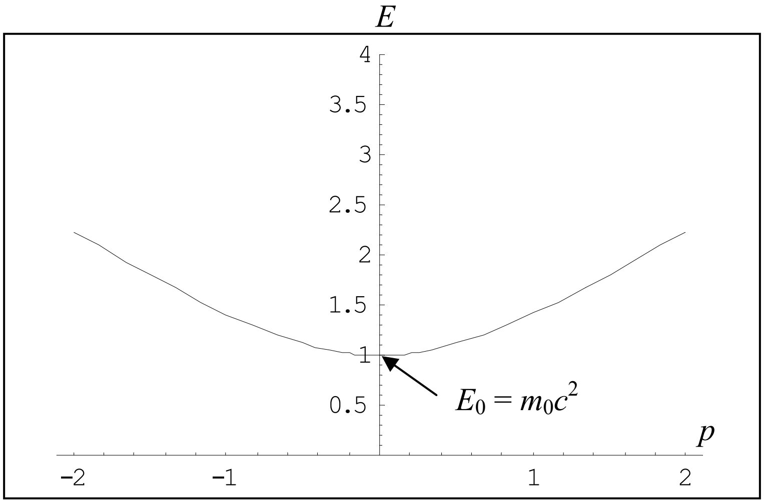
[6/20]

Ans:

(a) My own question.

(i) $E^2 = m_0^{\,2}c^4 + p^2c^2$

(ii)



(iii)

$$E^2 = m_0^{\,2}c^4 + p^2c^2$$
$$(2pc)^2 = m_0^{\,2}c^4 + p^2c^2$$
$$3p^2c^2 = m_0^{\,2}c^4$$
$$p = m_0c/\sqrt{3}$$

(iv)

$$p = \gamma m_0 v$$

$$p^2 = \gamma^2 v^2 m_0{}^2$$

$$\frac{m_0{}^2 c^2}{3} = \frac{v^2 m_0{}^2}{1-(v/c)^2}$$

$$v = c/2.$$

(b) Schaum's series Modern Physics, pg. 27, Q6.1.

The length of the meter stick as measured by you is improper length, given by

$$L = L_0\sqrt{1-(v/c)^2} = (1\text{m})\sqrt{1-(0.6)^2} = 0.8\text{m}$$

The time for the meter stick to pass you is then found from

Distance = velocity × time

0.8 m = $0.6c \times \Delta t$

Δt = 4.44×10^{-9} s.

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