GLASGOW COLLEGE UESTC

Final Exam Paper

Physics II (Course Code)

Date: (remember to complete when info available from Ruoli)
Time: (remember to complete when info available from Ruoli)

Attempt all PARTS. Total 100 marks
Use one answer sheet for each of the questions in this exam.
Show all work on the answer sheet.
Make sure that your University of Glasgow and UESTC Student Identification Numbers are on all answer sheets.
An electronic calculator may be used provided that it does not allow text storage or display, or graphical display.
All graphs should be clearly labelled and sufficiently large so that all elements are easy to read.
The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

Useful constants

Speed of light $c=2.998\times 10^{8}$ m/s

Permittivity of free space $\varepsilon_0 = 8.85\times 10^{-12} C^2/N\cdot m^2$

Permeability of free space $\mu_0 = 4\pi\times 10^{-7} T\cdot m/A$

Elementary mass $1u = 1.66\times 10^{-27}$ kg

Elementary charge $e = 1.60\times 10^{-19} C$

Planck constant $h = 6.63\times 10^{-34} J\cdot s$

Continued overleaf

Q1 Multiple choice. (2×5=10marks)

Choose the one alternative that best complete the statement or answers the questions.

(B) **1.** In an *RC* circuit, the capacitor begins to discharge. During the discharge, in the region of space between the plates of the capacitor, there is___________________.

(A) conduction current but no displacement current.

(B) displacement current but no conduction current.

(C) both conduction and displacement current.

(D) no current of any type but electromagnetic field.

(E) no current of any type and no electric field.

(B) **2.** The figure Q1.2 shows a circular loop of wire falling toward a wire carrying a current to the right. What is the direction of the induced current in the loop of wire?

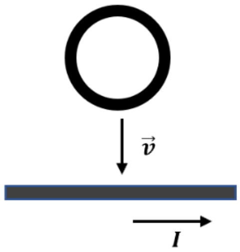


Figure Q1.2

(A) Counterclockwise. **(B)** Clockwise. **(C)** Zero.

(D) Impossible to determine. **(E)** The direction depends on the falling speed.

(D) **3.** For any given scattering angle θ, equation $\lambda' - \lambda_0 = \frac{h}{m_e c}(1 - \cos\theta)$ gives the same value for the **Compton shift** for any wavelength. Keeping that in mind, for which of the following types of radiation is the fractional shift in wavelength at a given scattering angle the largest?

(A) Radio waves. **(B)** Microwaves. **(C)** Visible light.

(D) X-rays. **(E)** Infrared light.

(B) **4.** Which of the following changes would ***not*** increase the probability of transmission of a particle through a potential barrier?

(A) Decreasing the width of the barrier.

(B) Increasing the width of the barrier.

(C) Increasing the temperature.

(D) Decreasing the height of the barrier.

(E) Increasing the kinetic energy of the incident particle.

(D) **5.** Two spacecraft A and B are moving in **opposite** directions. An observer on the Earth measures the speed of spacecraft A to be **0.750*c*** and the speed of spacecraft B to be **0.850*c***. The velocity of spacecraft B as observed by the crew on spacecraft A is_______.

Continued overleaf

(A) 0.750c; **(B)** 0.850c; **(C)** 1.600c; **(D)** 0.996c; **(E)** 1.000c

Q2 **Fill-in questions (4×5=20 marks)**

1. Write out the Maxwell's equations and a brief explanation.

__$\oint \vec{E} \cdot d\vec{S} = Q/\varepsilon_0$_____ __electric field has source_____

__$\oint \vec{B} \cdot d\vec{S} = 0$__________ _no magnetic charges/monopoles____

__$\oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$____ __changing magnetic field can produce electric field _

__$\oint \vec{B} \cdot d\vec{l} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$__changing electric field can produce magnetic field __

2. X-rays of wavelength $\lambda_0 = 0.200000$nm are scattered from a block of material. The scattered x-rays are observed at an angle of 45.0° to the incident beam, and the wavelength is _____0.200710 nm____________.

3. The following *pairs* of energies—particle ①: *E*, 2*E*; particle ②: *E*, 3*E*; particle ③: 2*E*, 4*E*—represent the rest energy and total energy of three different particles.

(a) Rank the particles from greatest to least according to their masses._ ③> ②> ①

(b) Rank the particles from greatest to least according to their kinetic energy. ③= ②> ①

(c) Rank the particles from greatest to least according to their speed. _②> ①=③

4. A painting (1.0m×1.5m) is hanging on a spaceship with *v*=0.9c relative to Earth.

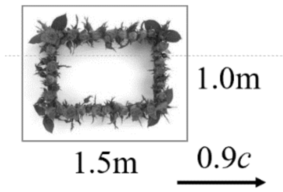


Figure Q2.4

(a) What are the dimensions as seen in spaceship? ___1.5m×1.0m_________

(b) What are the dimensions as seen on Earth? ______ 1.0m×0.65m _______

5. (a) How many sets of quantum numbers are possible for a hydrogen atom for ***n*=*3***? ______18________.

(b) List all possible sets of quantum numbers for the hydrogen atom associated with the ***3p*** subshell.

(3, 1, -1, +1/2) (3, 1, -1, -1/2) (3, 1, 0, +1/2) (3, 1, 0, -1/2)

(3, 1, 1, +1/2) (3, 1, -1, 1/2)

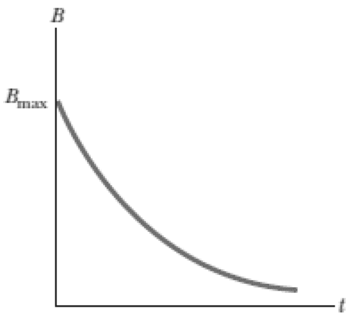
Continued overleaf

Q3 {12marks}

A loop of wire enclosing an area A is placed in a region where the magnetic field is perpendicular to the plane of the loop. The magnitude of $\vec{\boldsymbol{B}}$ varies in time according to the expression $\boldsymbol{B} = \boldsymbol{B}_{max}\boldsymbol{e}^{-at}$, where $\boldsymbol{a}$ is a constant. That is, at $t = 0$, the field is $\boldsymbol{B}_{max}$, and for $t > 0$, the field decreases exponentially (Fig. Q3).

(a) Find the induced ***emf*** in the loop as a function of time.

(b) Draw the emf in the loop as a function of time (in the right rectangle of Fig. Q3).



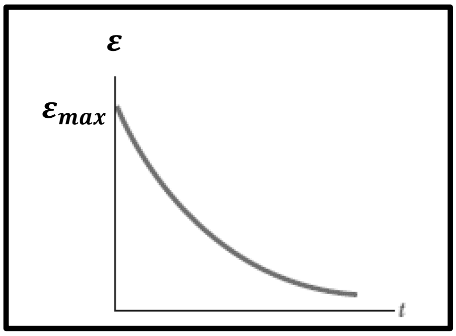


Figure Q3

Solution:

(a) $\varepsilon = -d\Phi_B/dt$ {3 marks}

$\varepsilon = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}(AB_{max}e^{-at}) = -AB_{max}\frac{d}{dt}(e^{-at}) = aAB_{max}e^{-at}$ {4 marks}

(b) t=0, $\varepsilon_{max} = aAB_{max}$

The plot of B-t shown in the figure. {5 marks}

Continued overleaf

Q4 {16 marks}

The current in a solenoid (N loops, length L, μ_0) changes as $dI/dt = C > 0$. A triangle coil (OA=OB=AB=$\boldsymbol{l}$) is placed at the center of the solenoid.

Find the ***emf*** (a) in the straight wire OA； (b) in the coil AOB； (c) in the straight wire AB.

(d) Determine the mutual inductance ***M*** of the solenoid and the triangle coil.

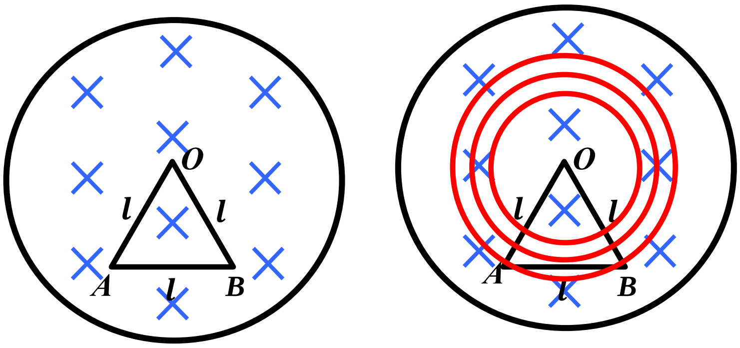


Figure Q4

Solution:

(a)Induced ***emf*** in the straight wire OA

$\varepsilon_{oA} = \int_O^A \vec{E}_i \cdot d\vec{l}$ {2 marks}

As the induced electric field produced by changing current are circles （direction：counterclockwise） at center O there.

$\because \vec{E}_i \perp d\vec{l}, \ \therefore \ \varepsilon_{oA} = 0$ {2 marks}

(a) Magnetic flux in the coil

$\Phi_B = \int \vec{B} \cdot d\vec{S} = B \cdot \frac{\sqrt{3}}{4} l^2$ {2 marks}

For a solenoid $B = \mu_0 nI = \frac{\mu_0 N}{L} I$ {2 marks}

Induced emf in the coil AOB {2 marks}

$$\varepsilon_{AOB} = -\frac{d\Phi_B}{dt} = -\frac{\sqrt{3}}{4}\frac{\mu_0 N l^2}{L}\frac{dI}{dt} = -\frac{\sqrt{3}}{4}\frac{\mu_0 N l^2}{L} C$$

(b) For the coil, $\varepsilon_{AOB} = \varepsilon_{OA} + \varepsilon_{OB} + \varepsilon_{AB}$

As $\varepsilon_{oA} = \ \varepsilon_{oB} = 0$

Induced emf in the straight wire AB, $\varepsilon_{AB} = \varepsilon_{AOB} = -\frac{\sqrt{3}}{4}\frac{\mu_0 N l^2}{L} C$ {4 marks}

(c) the mutual inductance M {2 marks}

$$\varepsilon_{AOB} = -M\frac{dI}{dt}$$

$$\therefore M = \frac{\sqrt{3}}{4}\frac{\mu_0 N l^2}{L}$$

Continued overleaf

Q5 {18 marks}

A Speedy Proton (^{1}H, the mass is 1.007u).

(a) Find the rest energy of a proton in units of electron volts (eV).

(b) If the total energy of a proton is three times its rest energy, what is the speed of the proton?

(c) Determine the kinetic energy of the proton in units of electron volts (eV).

(d) What is the proton's momentum?

Solution: (a) the rest energy of a proton $E_0 = m_0c^2$ {2marks}

$= 1.007u \times (2.998 \times 10^8)^2 = 938MeV$ {3marks}

(b) $E = 3m_0c^2$

$E = \frac{m_0c^2}{\sqrt{1-u^2/c^2}} \rightarrow 3 = \frac{1}{\sqrt{1-u^2/c^2}}$ {3marks}

$u = \frac{\sqrt{8}}{3}c = 0.943c = 2.83 \times 10^8 m/s$ {2marks}

(c) $E_k = E - E_0 = 3m_0c^2 - m_0c^2 = 2m_0c^2$

$E_k = 2 \times 938MeV = 1.87 \times 10^3 MeV$ {3 marks}

(d) the proton's momentum

$E^2 = p^2c^2 + (m_0c^2)^2$ {3marks}

$p = \sqrt{8} \times \frac{m_0c^2}{c} = \sqrt{8} \times \frac{938MeV}{c} = 2.65 \times 10^3 MeV/c$ {2 marks}

Q6 {12 marks}

In a photoelectric effect experiment it is observed that no current flows unless the wavelength is less than 570nm.

(a) What is the work function ***W_0*** of this material?

(b) What is the stopping voltage required if light of wavelength 400nm is used?

Solution: (a) At the threshold wavelength, the kinetic energy of the photoelectric is zero.

So we have $E_{max} = hf - W_0 = 0$ {3 marks}

$W_0 = \frac{hc}{\lambda_{max}} = (1.24 \times 10^3 eV \cdot nm)/(570nm) = 2.18eV$ {3 marks}

(b)The stopping voltage is the voltage that gives a potential energy change equal to the maximum kinetic energy: $E_{max} = eV_0 = hf - W_0$ {3 marks}

$(1e)V_0 = \frac{(1.24\times10^3 eV\cdot nm)}{400nm} - 2.18eV_0 = 0.92eV$

So the stopping voltage is 0.92V. {3marks}

Continued overleaf

Q7. {12 marks}

An electron is trapped in an infinitely deep potential well of width ***L***. Determine the probability of finding the electron within ***L*/4** of either wall if it is (a) in the ground state, (b) in the n=4 state. [Hint: Evaluate $\int_0^{L/4}|\psi|^2 dx + \int_{3L/4}^{L}|\psi|^2 dx$]

(c) What is the classical prediction?

Solution： An electron is trapped in an infinitely deep potential well

The wave function is {3 marks}

$$\psi_n(x) = \sqrt{\frac{2}{L}}\sin\left(\frac{n\pi}{L}x\right)$$

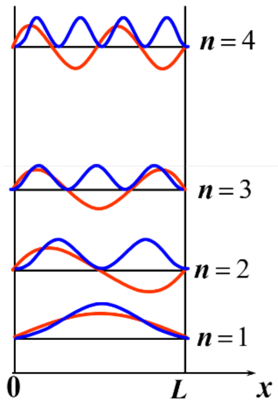
(a) in the ground state, n=1

$$p1 = \int_0^{L/4} |\psi_1|^2\, dx + \int_{3L/4}^{L} |\psi_1|^2\, dx$$

$$= \frac{2}{L}\left(\int_0^{L/4} \sin^2\left(\frac{\pi}{L}x\right) dx + \int_{3L/4}^{L} \sin^2\left(\frac{\pi}{L}x\right) dx\right)$$

$$= \frac{2}{L}\left[\left(\frac{L}{8} - \frac{L}{4\pi}\right) + \left(\frac{L}{8} - \frac{L}{4\pi}\right)\right] = \left(\frac{1}{2} - \frac{1}{\pi}\right) = 18.2\%$$ {3 marks}

(b) in the state, n=4



$$p = \int_0^{L/4} |\psi_4|^2\, dx + \int_{3L/4}^{L} |\psi_4|^2\, dx$$

$$= \frac{2}{L}\left(\int_0^{\frac{L}{4}} \sin^2\left(\frac{4\pi}{L}x\right) dx + \int_{\frac{3L}{4}}^{L} \sin^2\left(\frac{4\pi}{L}x\right) dx\right)$$

$p2 = 50.0\%$ {3 marks}

(c) For the classical prediction,

The probability to find the free electron an infinitely deep potential well should be the same, $p1 = p2 = 50.0\%$ {3 marks}

End of question paper