NATIONAL UNIVERSITY OF SINGAPORE

PC1432 PHYSICS IIE

(Semester II: AY 2013-14)

Time allowed: 2 hours

INSTRUCTIONS TO CANDIDATES

1. This examination contains **six** short questions in Part I and **three** long questions in Part II.

2. The three long questions are found in an accompanying question paper.

3. Please answer all questions.

4. The answers to all the questions are to be written **in the space provided in the question booklet** itself. Only this question booklet is to be submitted at the end of the examination.

5. Several blank pages are available at the end of this question booklet. These can be used if additional space is needed for any answer. If you do so however, please indicate the question and part numbers clearly.

6. Only non-programmable electronic scientific calculators are permitted for this examination.

7. A list of constants and formulae is found in an accompanying formulae paper.

8. Part I carries 40% of the total mark and Part II carries 60%.

9. This is a closed book examination.

Question	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total	

Matriculation No:_____

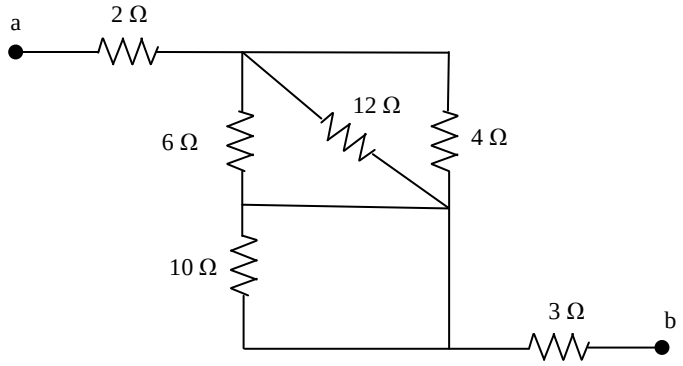
Seat no.: _____

Part I: Short questions

Please answer all **six** questions in this section in the space provided. Each question carries a total of 4 marks.

1. What is the equivalent resistance between points a and b in the figure below?

[4 marks]



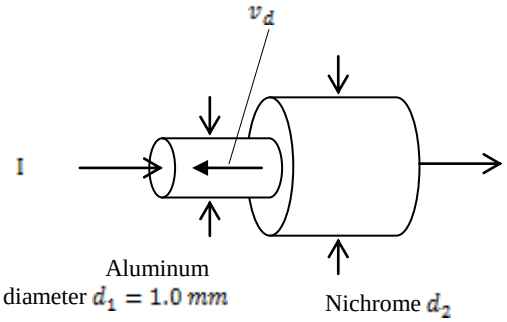
ANSWER:

2.

(a) What diameter should the nichrome wire in the figure below be in order for the electric field strength to be the same in both wires? [3 marks]

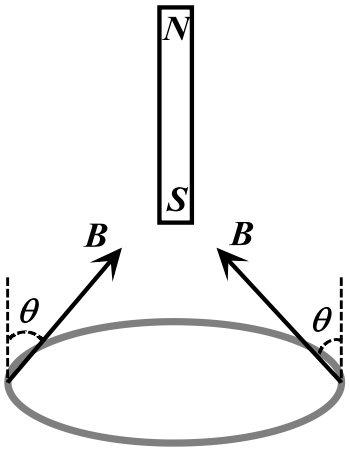
(b) Suppose $I = 5.0A$, what is the drift velocity in Aluminum? [1 mark]

Conductivity of Aluminum is $\sigma_1 = 3.5 \times 10^7 (\Omega m)^{-1}$
Conductivity of Nichrome is $\sigma_2 = 6.7 \times 10^5 (\Omega m)^{-1}$
Free electron density of aluminum is $n = 1.8 \times 10^{29} / m^3$



ANSWER:

3. A horizontally oriented coil of wire of radius 5.0 cm and carrying a current, i, is being levitated by the south pole of a vertically oriented bar magnet suspended above the center of the coil. If the magnetic field on all parts of the coil makes an angle θ of 45.0° with the vertical, determine the magnitude and the direction of the current needed to keep the coil floating in midair. The magnitude of the magnetic field is $B = 0.01$ T, the number of turns in the coil is $N = 10,$ and the total coil mass is 10.0 g. [4 marks]



ANSWER:

4. Polarizers are placed in a row, each with their polarizing axes at a 10° interval from the previous polarizer. Unpolarized light (of intensity I_0) is incident on this series of polarizers. What is the *minimum* total number of polarizers needed for the light intensity to be reduced to at least 1/4 of its original intensity I_0?

[4 marks]

ANSWER:

5.

(a) An experiment is carried out in which a collection of hydrogen atoms in a gas are all raised to the same excited state. The resulting emission lines are viewed with a diffraction grating spectrometer that is capable of detecting photons in the ultraviolet (UV), visible and infrared (IR) range. If only 3 distinct emission lines are observed, what is the initial state n of the hydrogen atoms? Explain your answer. [1 mark]

(b) The same experiment is carried out, this time with a strong magnetic field present. How many emission lines will now be detected? Explain your answer. [3 marks]

ANSWER:

6. An electron is trapped in a vacancy in a crystal lattice.

   (a) Explain qualitatively why this trapped electron cannot have zero energy. [1 mark]

   (b) If the n=2 allowed energy level is 50 eV, then calculate the approximate lateral dimension of the lattice vacancy. [2 marks]

   (c) Explain any assumptions you make in this calculation. [1 mark]

ANSWER:

Part II: Long questions

Please answer all **three** (3) questions found in the accompanying question paper in the space provided below. Each question carries a total of 12 marks.

ANSWER for 7:

ANSWER for 7 (cont):

ANSWER for 8:

ANSWER for 8 (cont):

ANSWER for 9:

ANSWER for 9 (cont):

Spare page: ANSWER for _____:

Spare page: ANSWER for _____:

Spare page: ANSWER for _____:

Part II: Long questions

This section of the examination comprises **three** questions 7–9 printed on pages numbered i to iii. Please answer all three questions in the space provided in your examination booklet. Each question carries a total of 12 marks.

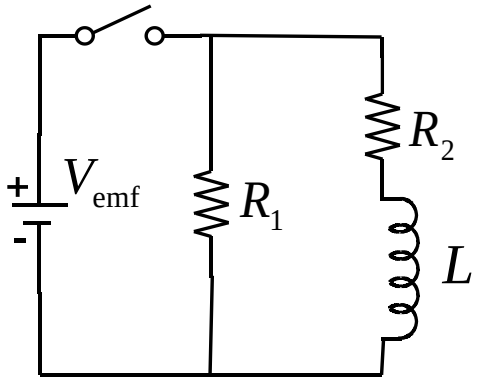
7. A sphere of radius R has charge q.

(a) What is the infinitesimal increase in electric potential energy dU if an infinitesimal amount of charge dq is brought from infinity to the surface of the sphere? [4 marks]

(b) An uncharged sphere can acquire total charge Q by the incremental transfer of charge dq. Use your answer to part (a) to find an expression for the potential energy of a sphere of radius R with total charge Q. [4 marks]

(c) Your answer to part (b) is the amount of energy needed to assemble a charged sphere. It is often called the *self-energy* of the sphere. What is the self-energy of a proton, assuming it to be a charged sphere with a diameter of $1.0 \times 10^{-15} m$? [4 marks]

8. A 9.00-V battery is connected through a switch to two identical resistors and an ideal inductor, as shown in the figure. Each of the resistors has a resistance of 100 Ω, and the inductor has an inductance of 3.00 H. The switch is initially open.



(a) Immediately after the switch is closed, what is the current in resistor R_1 and in resistor R_2? [2 marks]

(b) At 50 ms after the switch is closed, what is the current in resistor R_1 and in resistor R_2? [3 marks]

(c) After a long time (> 10.0 s), the switch is opened again. Immediately after the switch is opened, what is the current in resistor R_1 and in resistor R_2? [2 marks]

(d) At 50 ms after the switch is opened, what is the current in resistor R_1 and in resistor R_2? [5 marks]

9.

(a) In a Compton scattering experiment, the scattering of X-ray photons from carbon is observed at an angle of 90 degrees: 2 peaks are observed in the X-ray spectrum. Explain briefly the origins of both peaks? [2 marks]

(b) A hospital CT scanner uses X-rays of energy 100 keV. The X-rays are transmitted through the body, and image contrast is achieved due to an increase in X-ray scattering from areas of higher density in the body (eg the bone).

Suppose a 100keV X-ray photon is scattered through an angle of 30 degrees. Calculate:

(i) The energy (in keV) of the scattered X-ray. [3 marks]

(ii) The energy (in keV) of the recoiling electron. [1 mark]

(c) What are the main implications of your results of b(ii) regarding associated biological damage? Explain your answer. [2 marks]

(d) Although an X-ray photon can be completely absorbed by an electron within an atom via the photoelectric effect, show that the photon can never be completely absorbed by a free electron. [4 marks]

[Hints: Assume that the free electron is at rest and use the equations describing the conservation of momentum and the conservation of energy. Remember also that it is impossible for an electron to travel faster than the speed of light].

- End of Part II -