UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

School of Chemistry & Physics
Pietermaritzburg Campus
November 2014: Second Semester Examination
PHYS120: Electricity And Magnetism, Optics, and Atomic and Nuclear Physics

BAR CODE

Student No.:										Seat Number:	

SECTION A Short Questions				SECTION B Electricity and Magnetism				SECTION C Optics and Atomic and Nuclear Physics			
Quest	Marks			Quest	Marks			Quest	Marks		
	Int	Ext	Max		Int	Ext	Max		Int	Ext	Max
1-20			60	B1			12	C1			4
				B2			6	C2			11
				B3			12	C3			7
				B4			12	C4			8
				B5			4	C5			10
				B6			8	C6			5
				B7			6	C7			5
								C8			10
Totals			60				60				60

GRAND TOTAL	INT	EXT	MAX
			180

School of Chemistry & Physics, University of KwaZulu-Natal, Pietermaritzburg Campus:

November 2014 Second Semester Examination: PHYS110 - Electricity and Magnetism, Optics, and Atomic and Nuclear Physics

TIME: 3 hours	MAXIMUM MARKS: 180

Internal Examiner(s):	Moderating Board:
Dr M Cavero and Mr K Singh	Dr S Yacoob & Prof M Tame (Westville Campus)

General instructions

1. Answer ALL questions on the question paper. Pencil may be used provided this is clearly visible. All answers must be in legible handwriting.
2. **It is the candidate's responsibility to ensure that this paper has 19 numbered pages, including the data sheet.**
3. Do your rough work for a question on the back of the previous page. Rough work will not necessarily be marked. See instruction 7 below.
4. The last page of this exam is an information sheet and is printed separately on yellow paper.
5. No part of this exam paper may be torn off.
6. Marks have been allocated in such a way that 1 mark corresponds approximately to one minute of time. Candidates are advised not to spend a disproportionate amount of time on any question.
7. Should a candidate require more space to answer a question than has been provided, this must be indicated clearly, by, for example, 'PTO' or 'See back of page 7', etc.
8. Where appropriate, candidates are advised to show working for their answers to all questions, and in particular those of Section A.

Rule 9 (1)(e) WARNING: CANDIDATES WILL BE DISQUALIFIED IF:

(a) they introduce, or attempt to introduce, into any place where an examination is about to be conducted or is being conducted, any paper, book, note, document or instrument, the use of which is not authorized by the examiner or the examination officer.

(b) they possess, use, or attempt to use during an examination, any paper, book, note, document or instrument the use of which is not authorized by the examiner or the examination officer.

(c) they remove or attempt to remove from the examination room, any examination book or writing paper supplied by the University for the purposes of answering an examination.

(d) they communicate or attempt to communicate any information relating to the examination to another candidate while the examination is in progress.

(e) they use a false name or identity number in an examination.

(f) they commit any other fraudulent, deceitful or dishonest practice which would mislead or deceive the examiner or examination officer.

IF A STUDENT IS FOUND GUILTY BY A STUDENT DISCIPLINE COURT OF CONTRAVENING THE ABOVE RULE -9(1)(e) - SHE/HE WILL SUFFER ONE OR MORE OF THE FOLLOWING CONSEQUENCES:

(i) Disqualification from entry to any examination.

(ii) Cancellation or forfeiture of examination results.

(iii) Deprivation of a degree, diploma or certificate obtained as a result of the offence.

SECTION A — SHORT QUESTIONS (3 marks each) — 60 MARKS

1. An isolated object is estimated to have a total of 3.13×10^{12} excess electrons. What is the charge of this object?

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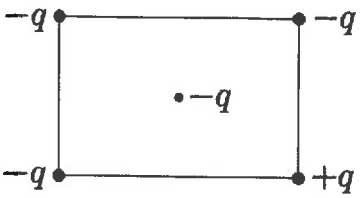
2. Four stationary point charges are located at the corners of a rectangle as shown below. A fifth charge is placed at the centre of the rectangle. Draw, on the diagram below, the resultant force that acts on the charge at the centre of the rectangle.



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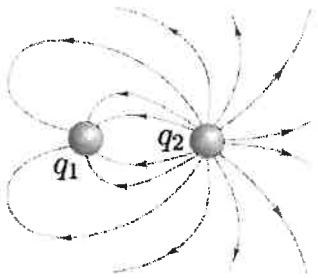
3. The diagram above shows the electric field pattern in the region around two charges q_1 and q_2. State whether q_1 and q_2 are positive or negative and how the magnitude of their charges compare with one another.



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4. The potential difference between Q and P (ie V_{QP}) is 120.0 V. Determine the work done in moving an electron from P to Q.

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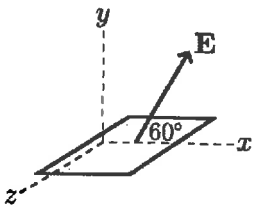
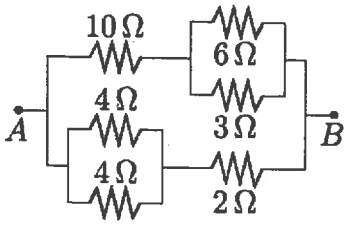
5. A charge of $2.0 \times 10^{-7}\,\mathrm{C}$ is between two parallel metal plates, separated by 50 mm. The potential difference across the plates is 1.0 kV. Calculate the magnitude of the force the charge experiences due to the electric field between the plates.

6. A flat sheet of paper of sides 21.0 cm and 29.5 cm, lies in the xz-plane as shown alongside, in the presence of an electric field $\mathbf{E}$, of magnitude $200\,\mathrm{N\,C^{-1}}$. The electric field makes an angle of 60° to the xz-plane. Calculate the electric flux through the sheet of paper.



7. A 3.0 µF, 4.0 µF and 12 µF capacitor are connected in series with each other and in series with a 24 V battery. What is the voltage drop across the 12 µF capacitor?

8. For the combination of resistors alongside, what is the equivalent resistance between points A and B?



9. The resistance in a copper wire of length 2.00 m and radius 0.321 mm is measured to be 0.105 Ω. Determine the resistivity of copper.

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10. The maximum current in a series *RLC* circuit is 0.255 A, where the maximum voltage across all of the components is 150 V. If the applied voltage leads the current with a phase angle of 64.0°, what is the average power delivered to the circuit?

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11. Calculate the refractive index of an equilateral triangular prism made of silicate flint glass for violet light, when the angle of minimum deviation for violet light is 52.2°.

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12. Light travelling in glass (with refractive index 1.52) reaches the glass-air interface. What is the critical angle for total internal reflection within the glass?

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13. An object is placed very far away from a spherical mirror of radius 25.0 cm. Calculate the distance of the image from the mirror.

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14. Newton's rings are formed with yellow light between the curved surface of a plano-convex lens and a flat glass plate. If the radius of the 4th ring is 0.137 cm, what is the radius of the 10th dark ring?

15. Light in air is incident on a slab of crown glass of refractive index 1.52. If the reflected light is completely polarized, calculate the angle of incidence.

16. Complete the following nuclear reactions:

(i) $^{35}_{17}\mathrm{Cl} + \ldots \rightarrow {}^{32}_{16}\mathrm{S} + {}^{4}_{2}\mathrm{He}$

(ii) $^{22}_{11}\mathrm{Na} + \ldots \rightarrow {}^{6}_{3}\mathrm{Li} + {}^{17}_{8}\mathrm{O}$

(iii) $^{7}_{3}\mathrm{Li} + \ldots \rightarrow 2\,{}^{4}_{2}\mathrm{He}$

17. What is the energy of a photon of wavelength 660 nm?

18. The electron in a hydrogen atom makes a transition in the Paschen series from the $n = 5$ to the $n = 3$ energy level. Given that $R = 1.097 \times 10^{7}\,\mathrm{m}^{-1}$, calculate the wavelength of the emitted photon.

19. The atomic mass of copper is 64 u and its density is $8930\,\mathrm{kg\,m^{-3}}$. How many atoms are there in a volume of 1 cubic metre of copper?

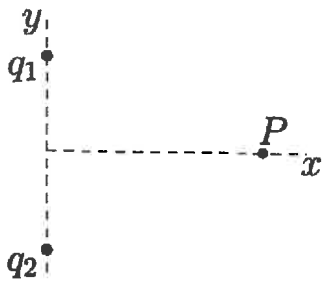
20. Calculate the de Broglie wavelength of a cricket ball travelling at $120\,\mathrm{km\,h^{-1}}$, with a mass of 0.157 kg.

/60

SECTION B **ELECTRICITY AND MAGNETISM** **60 MARKS**

QUESTION B1

Two isolated charges $q_1 = -2.00\,\text{nC}$ and $q_2 = -2.00\,\text{nC}$ are placed at positions (0, 3.00) m and (0, -3.00) m respetively, as shown alongside.



(a) Determine the electric field at the point P, which is at position (4.00, 0) m. (6)

(b) Calculate the total electric potential at P due to q_1 and q_2. (4)

(c) Calculate the potential energy stored in the system, (2)

/12

Question B2

An uncharged capacitor and resistor are connected in series to a battery. Let $\mathcal{E} = 12.0\,\text{V}$, $C = 5.00\,\mu\text{F}$ and $R = 8.00 \times 10^5\,\Omega$.

(a) Calculate the time constant of the circuit. (2)

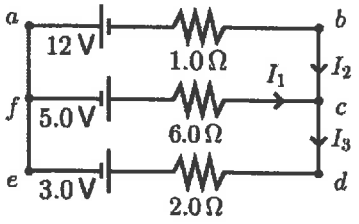
(b) Find the charge on the capacitor after 6.00 s (2)

(c) Find the potential difference across the capacitor at this time. (2)

/6

Question B3

(a) For the circuit shown above, write down three Kirchhoff equations which could be used to find the currents I_1, I_2 and I_3. (DO NOT SOLVE FOR I_1, I_2 and I_3.) (5)



(b) Given that $I_1 = 1.8\,\text{A}$, determine the values of I_2 and I_3. (4)

(c) Find the potential difference V_{fc}. Which point, c or f, is at a higher potential? (3)

/12

Question B4

A resistor ($R = 30.0\,\Omega$), inductor ($L = 0.240\,\text{H}$) and capacitor ($C = 200\,\mu\text{F}$) are connected in series to a $250\,\text{rad}\,\text{s}^{-1}$ source.

(a) Calculate the impedance in the circuit. (4)

(b) If the maximum voltage across the combination is 250 V, calculate the maximum current in the circuit. (2)

(c) Calculate the phase angle. (2)

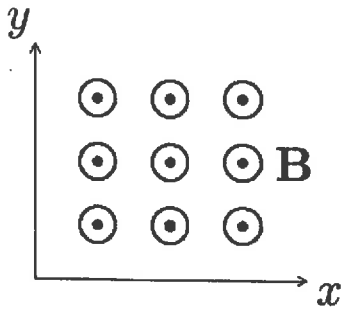
(d) Calculate the maximum voltage across the capacitor. (2)

(e) Calculate the rms current in the circuit. (2)

/12

QUESTION B5

A uniform magnetic field **B** is normal to the plane of the paper as shown in the diagram above. Let the magnitude of the magnetic field be $B = 3.00 \times 10^{-2}\,\mathrm{T}$. A negatively charged particle (charge $q = -2.00\,\mu\mathrm{C}$) travelling with velocity $\mathbf{v} = -4.00 \times 10^{5}\,\hat{\mathbf{x}}\,\mathrm{m\,s^{-1}}$ enters the field. Calculate the force **F** on the particle.



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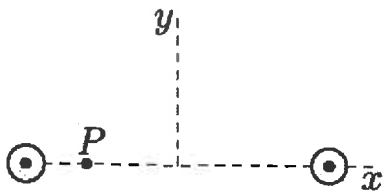
QUESTION B6

Two long, straight wires (into/out of the plane of the paper) carry equal currents as shown alongside. The wires are placed at (-10.0, 0) and (10.0, 0), where x and y are in centimetres.

(a) If the current in each wire is 1.00 A, calculate the magnetic field at the point P, which is at position (-6.00, 0). (5)

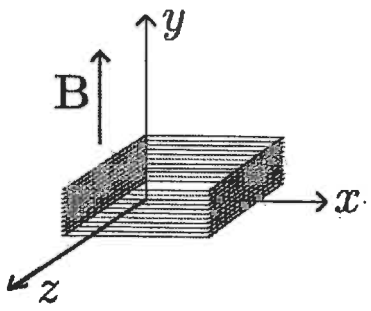


(b) Find the magnitude of the force per unit length exerted by one wire on the other and state whether the force is attractive or repulsive. (3)

/8

Question B7

A square coil of wire with 25 turns (with side length 12.0 cm) is placed in the xz plane, as shown alongside, in the presence of a magnetic field which is perpendicular to the coil.



(a) State Faraday's law of magnetic induction in words. (2)

(b) If the magnetic field changes from 0.500 T to 0 T in 8.00 s, find the induced emf in the coil. (4)

/6

SECTION C **OPTICS AND ATOMIC AND NUCLEAR PHYSICS** **60 MARKS**

Question C1

The wavelength of light from a laser is 575 nm in air but 238 nm inside a diamond. Calculate the refractive index of the diamond and the speed of the light in it.

/4

QUESTION C2

A double-convex converging lens, of focal length 10 cm, forms an image when an object is placed 30 cm from it.

(a) Determine the position of the image, and state whether it is real or virtual. (3)

(b) Find the magnification, and state whether the image is upright or inverted. (3)

(c) Let the refractive index of this lens be 1.50. If once surface has twice the radius of curvature of the other, calculate the two radii. (5)

/11

QUESTION C3

In a double-slit experiment (where the slits are 0.200 mm apart), light of wavelength 633 nm is used to form an interference pattern on a screen.

(a) Find the position of second order bright and second order dark fringes. (4)

(b) If the third order bright fringe is 9.49 mm, from the central fringe, what is the distance between the slits and the screen? (3)

/7

Question C4

(a) State Huygen's Principle. (2)

(b) A laser of wavelength 600 nm is shone through a narrow slit, with an interference pattern being seen on a screen 1.50 m away.

(i) If consecutive order minima are observed at 0.286° and 0.430°, determine the width of the slit. (3)

(ii) Calculate the distance y_1 from the central maximum to the first minimum. (3)

/8

QUESTION C5

(a) Show that the atomic mass unit is approximately equal to 930 MeV. (3)

(b) For $^{235}_{92}$U calculate

(i) the mass defect (in u), (3)

(ii) the binding energy (in MeV), (1)

(iii) the binding energy per nucleon. (1)

(c) In a nuclear reactor, high-energy neutrons are released via the fission process. Name two substances that are generally used as the neutron moderator material to slow these neutrons down. (2)

/10

QUESTION C6

Suppose enriched uranium fuel containing 1.6% of the fissionable isotope $^{235}_{92}$U is used as fuel for a ship. The water exerts an average frictional drag of 1.2×10^5 N on the ship. Assuming an energy release of 160 MeV per fission and that the ships engine has an efficiency of 25%, calculate how far the ship could travel on 1.0 kg of fuel.

/5

QUESTION C7

(a) If X-rays of wavelength 1.0×10^{-10} m are directed at a certain crystal and produce a third-order Bragg diffraction for an angle of incidence of 60°, calculate the spacing of the inter-atomic planes responsible. (2)

(b) What minimum voltage would be required across an X-ray tube in order to generate X-rays of the above wavelength? (3)

/5

QUESTION C8

(a) Show that the number of radioactive nuclei (N) remaining after a time t is given by

$$N = N_0 e^{-\lambda t} \tag{I}$$

where N_0 is the number of atoms present initially and λ is the decay constant. (4)

(b) Using Equation (I) above, show that the half-life (T) is given by

$$T = \frac{\ln 2}{\lambda}$$

(3)

(c) If rubidium-86 has a half-life of 18.6 days, how long will it take for $\frac{7}{8}$ of a given sample to decay? (3)

/10