UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

SUPPLEMENTARY EXAMINATION 2008/2009

TITLE OF PAPER	:	ELECTRICITY & MAGNETISM
COURSE NUMBER	:	P221
TIME ALLOWED	:	THREE HOURS
INSTRUCTIONS	:	ANSWER ANY FOUR OUT OF FIVE QUESTIONS EACH QUESTION CARRIES 25 MARKS MARKS FOR DIFFERENT SECTIONS OF EACH QUESTION ARE SHOWN IN THE RIGHT-HAND MARGIN

THIS PAPER HAS 7 PAGES, INCLUDING THIS PAGE

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Question 1

Write down an expression for Gauss's law, (Green's theorem), and explain carefully the meaning of each term in the expression. [4]

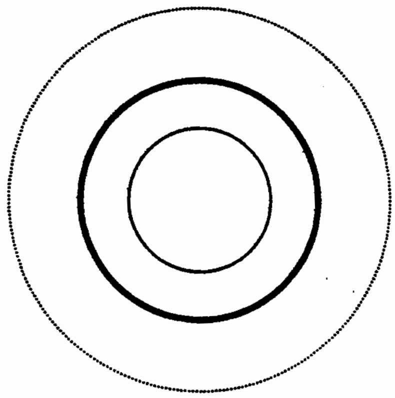
Explain why an arbitrary collection of charges within a small volume appears as a single point charge to an observer situated outside the small volume. [6]

The figure shown below, gives a cross-sectional view of a hollow, spherical piece of metal that contains no charges within its volume. The metallic sphere is shown as the heavy circle; it carries a charge of 1.25×10^{-7} C. Determine the magnitude of the electric field at

(a) a radius within the sphere [radius = 0.5 *m* (solid circle)]

(b) a point just outside the surface of the sphere [radius = 1.0 *m* (heavy circle)]

(c) a radius that is greater than the radius of the sphere [radius = 2.0 *m* (dotted circle)]. [15]



Question 2

A parallel-plate capacitor was constructed from two rectangular plates of aluminium, each of area *A*, separated by a distance *d*. A battery that provided 80*V* was used to charge the capacitor. After the capacitor was fully charged, the battery was disconnected from the capacitor, and a dielectric was inserted between the two aluminium plates. What changes were caused by the insertion of the dielectric? [5]

The dimensions of the capacitor and dielectric were as follows:

A =0.05 m^2
d = 0.06 m
thickness of dielectric = 0.025 m
relative permittivity of the dielectric = 6

Calculate the following quantities

(a) the capacitance before the dielectric slab was inserted [5]
(b) the charge on the plates of the capacitor [5]
(c) the magnitude of the electric field in the dielectric, and in the space between the aluminium rectangular plates and the dielectric [5]
(d) the potential difference between the plates, and the capacitance, when the dielectric was between the plates. [5]

Question 3

What is the principle of superposition? [3]

A positive charge, Q, is moved through a potential difference of ΔV. What is the amount of work that must be expended in order to achieve this change? [3]

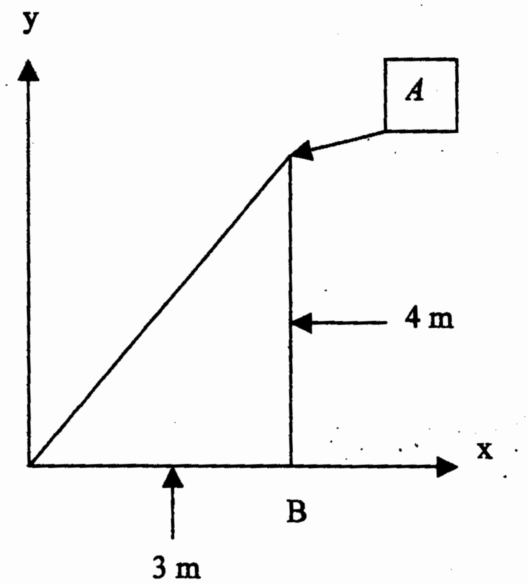
The length of the path taken by the charge between the points with potential difference of ΔV is doubled. By how much has the amount of work expended in moving the charge changed? [2]

An electric field lies in the xy plane and can be represented by the equation

$$\mathbf{E} = k\left[\hat{\mathbf{x}}y + \hat{\mathbf{y}}x\right]$$

where $\hat{\mathbf{x}}$ and $\hat{\mathbf{y}}$ are unit vectors in the x and y-directions respectively. What are the units of k? [2]

Find the increase in potential energy of a positive charge of magnitude 3.20×10^{-19} C when it is moved from a point with co-ordinates $[x = 3.0\ m, y = 4.0\ m]$, point A in the diagram, to the origin of the co-ordinate system. The magnitude of $|k|$ in the expression for E is unity = 1.



[15]

[hint: one possible solution to this problem can be found by taking a line integral of **E** from point A via point B to the origin].

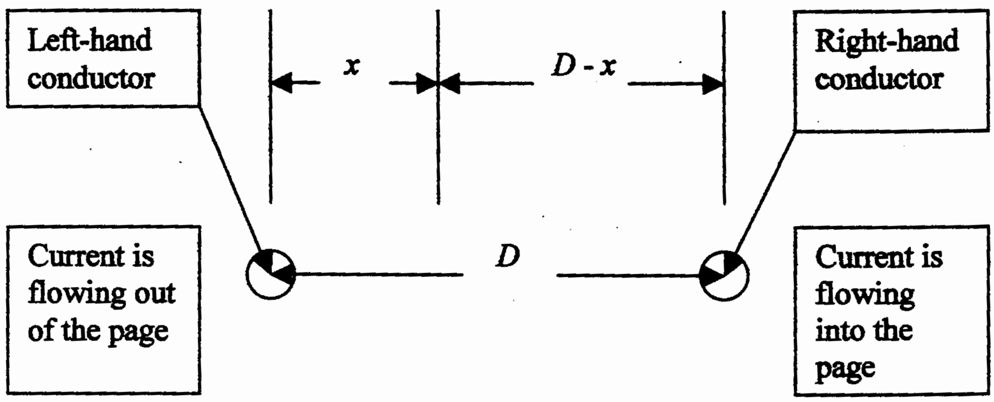
Question 4

Two long, straight, thin, parallel conducting wires carry equal currents I. If these currents are flowing in the same direction, is the force between them attractive or repulsive? Justify your answer by considering the magnetic flux density surrounding the two conductors that is produced by the flowing currents. [5]

The Amp is one of the seven fundamental quantities in the S.I. system of units. Give the definition of the Amp. [5]

The diagram shows two very long, straight, thin parallel conductors carrying steady currents flowing in opposite directions. The wires are perpendicular to the plane of the page. The current in the left-hand conductor is flowing upwards, while the current in the right-hand conductor is flowing downwards.

Find an expression for the magnetic flux density, B, at a distance x from the left-hand conductor as measured along a line connecting the two conductors. The wires are separated by a distance D. [15]



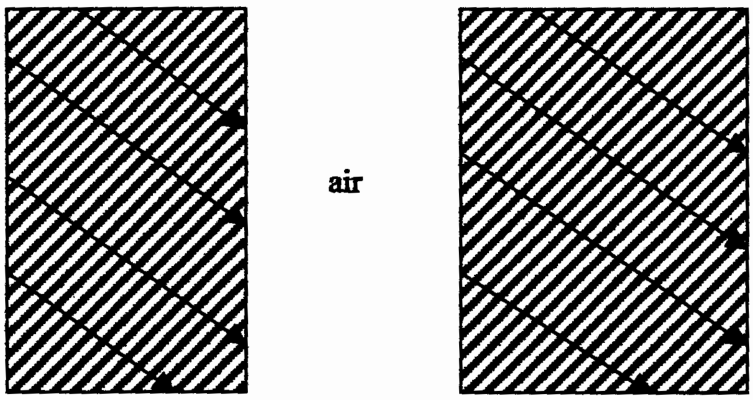
Question 5

A homogeneous, isotropic, linear magnetic material has a relative permeability of μ. What is the relationship between $\boldsymbol{B}$ and $\boldsymbol{H}$ in this material? [2]

Derive the boundary conditions for the tangential and normal components of $\boldsymbol{B}$ and $\boldsymbol{H}$ at a planar interface between the magnetic material and the atmosphere. [8]

[Helpful hint: remember that $\boldsymbol{B}$ is continuous; lines of $\boldsymbol{B}$ do not end: also, the line integral of $\boldsymbol{H}$ around a closed loop is zero, if no current is enclosed within the path of the integral.]

A uniform magnetic flux density of strength 1.2 webers/m² exists within an iron core, which has a relative permeability of 1000. A gap is cut within the material as shown in the figure; the iron is depicted as hatched areas. The arrows in the hatched regions give the direction of $\boldsymbol{B}$ within the magnetic material. $\boldsymbol{B}$ is uniform, and at an angle of 30° to the horizontal. Determine the magnitude and direction of $\boldsymbol{B}$ within the gap. The gap is filled with air at atmospheric pressure. [15]



PHYSICAL CONSTANTS AND UNITS

Acceleration due to gravity	g	9.81 m s^{-2}
Gravitational constant	G	6.673×10^{-11} N m^2 kg^{-2}
Avogadro constant	N_A	6.022×10^{23} mol^{-1}
	(Note: 1 mole = 1 *gram* molecular-weight)	
Ice point	T_{ice}	273.15 K
Gas constant	R	8.314 J K^{-1} mol^{-1}
Boltzmann constant	k, k_B	1.381×10^{-23} J K^{-1} = 0.862×10^{-4} eV K^{-1}
Stefan constant	σ	5.670×10^{-8} W m^{-2} K^{-4}
Rydberg constant	R_∞ $R_\infty hc$	1.097×10^{7} m^{-1} 13.606 eV
Planck constant	h	6.626×10^{-34} J s = 4.136×10^{-15} eV s
$h/2\pi$	$\hbar$	1.055×10^{-34} J s = 6.582×10^{-16} eV s
Speed of light *in vacuo*	c	2.998×10^{8} m s^{-1}
	$\hbar c$	197.3 MeV fm
Charge of proton	e	1.602×10^{-19} C
Mass of electron	m_e	9.109×10^{-31} kg
Rest energy of electron		0.511 MeV
Mass of proton	m_p	1.673×10^{-27} kg
Rest energy of proton		938.3 MeV
One atomic mass unit	u	1.66×10^{-27} kg
Atomic mass unit energy equivalent		931.5 MeV
Electric constant	ϵ_0	8.854×10^{-12} F m^{-1}
Magnetic constant	μ_0	$4\pi \times 10^{-7}$ H m^{-1}
Bohr magneton	μ_B	9.274×10^{-24} A m^2 (J T^{-1})
Nuclear magneton	μ_N	5.051×10^{-27} A m^2 (J T^{-1})
Fine-structure constant	$\alpha = e^2/4\pi\epsilon_0\hbar c$	7.297×10^{-3} = 1/137.0
Compton wavelength of electron	$\lambda_c = h/mc$	2.426×10^{-12} m
Bohr radius	a_0	5.2918×10^{-11} m
angstrom	Å	10^{-10} m