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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2020/2021

COURSE NAME	:	ELECTROMAGNETIC FIELDS AND WAVES
COURSE CODE	:	BEJ 20303 / BEB20303
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	JULY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	**ANSWER ALL QUESTIONS** **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **TWENTY-FOUR (24)** PAGES

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ANSWER ALL QUESTIONS

1) [**1 mark**] The electrostatic field is conservative as it has the following characteristics **EXCEPT** that:

(a) Its circulation is identically zero
(b) it is the gradient of a scalar potential
(c) Its curl is identically zero
(d) The potential difference between any two points is zero

2) [**2 marks**] A capacitor is made with seven metals and separated by sheets of Mica having a thickness of 0.3 mm and a relative permittivity, er of 6. The area of one side of each plate is 500 cm^2. A potential difference of 400 V is maintained across the terminals of the capacitor. Calculate the capacitance, C.

(a) 0.0531 μF
(b) 0.531 μF
(c) 5.31 μF
(d) 53.1 μF

3) [**2 marks**] A homogenous dielectric with a relative permitivity, εr of 2.5 fills Region 1 (x < 0) while Region 2 (x > 0) is a free space. If $\mathbf{D_1} = 12\hat{\mathbf{x}} - 10\hat{\mathbf{y}} + 4\hat{\mathbf{z}}$ cC/m^2.

(a) $\mathbf{D_2} = 12\hat{\mathbf{x}} - 4\hat{\mathbf{y}} - 1.6\hat{\mathbf{z}}$ cC/m^2
(b) $\mathbf{D_2} = 12\hat{\mathbf{x}} + 4\hat{\mathbf{y}} - 1.6\hat{\mathbf{z}}$ cC/m^2
(c) $\mathbf{D_2} = 12\hat{\mathbf{x}} - 4\hat{\mathbf{y}} + 1.6\hat{\mathbf{z}}$ cC/m^2
(d) $\mathbf{D_2} = 12\hat{\mathbf{x}} + 4\hat{\mathbf{y}} + 1.6\hat{\mathbf{z}}$ cC/m^2

4) [**3 marks**] A perfect conductor could not contain an electrostatic field inside it. How does this behavior will affect the properties of a conductor?

i. Electric field net field inside the conductor is zero
ii. Volume charge density is zero
iii. Potential difference between any points is zero
iv. Current is Zero
v. Magnetic field is zero
vi. magnetic flux line is zero

(a) i, ii and iii

(b) i, iii and iv

(c) ii, iv and vi

(d) iii, v and vi

5) [**2 marks**] Which of the following are **NOT** true about the equipotential surface?

i. Every point on the equipotential surface has the same potential difference.
ii. The field lines and equipotential surface are orthogonal with each other.
iii. No work is done when the charge moves along an equipotential line.
iv. No work is done when the charge moves between the lower to higher potential lines.

(a) i and ii

(b) i and iii

(c) i and iv

(d) ii and iii

6) [**2 marks**] Two point charges, Q1 and Q2 each with a charge of 1 nC and 2 nC are separated at a distance apart. Which of the following statements are true?

i. The force on Q1 is repulsive.
ii. The force on Q2 is the same in magnitude as that on Q1.
iii. As the distance between them decreases, the force on Q1 increases linearly.
iv. The force on Q2 is along the line joining them.

(a) i, ii, iii

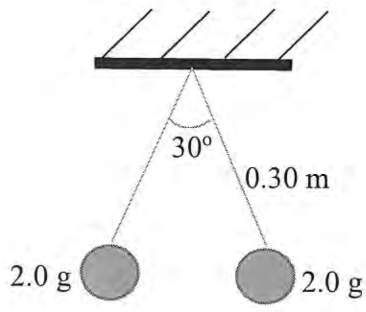
(b) i, ii, iv

(c) ii, iii, iv

(d) i, iii, iv

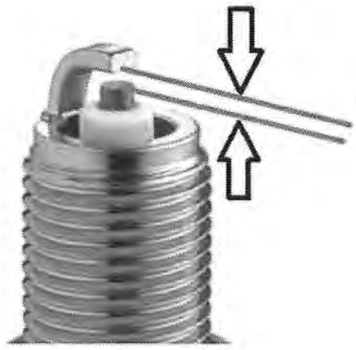
7) [**3 marks**] **TWO** (**2**) identical, small spheres of mass 2.0 g are fastened to the ends of a 0.60 m long light, flexible, insulating fishing line. The fishing line is suspended by a hook in the ceiling at its exact centre. The spheres are each given an identical electric

charge. They are in static equilibrium, with an angle of 30° between the string halves, as shown. Calculate the magnitude of the charge on each sphere.



(a) 1.2×10^{-7} C
(b) 2.2×10^{-7} C
(c) 3.2×10^{-7} C
(d) 4.2×10^{-7} C

8) [**2 marks**] A spark plug in a bike or a car is used to ignite the air-fuel mixture in the engine. It consists of two electrodes separated by a gap of around 0.6 mm gap as shown in the figure. To create the spark, an electric field of magnitude 3×10^6 Vm^{-1} is required. What potential difference must be applied to produce the spark?

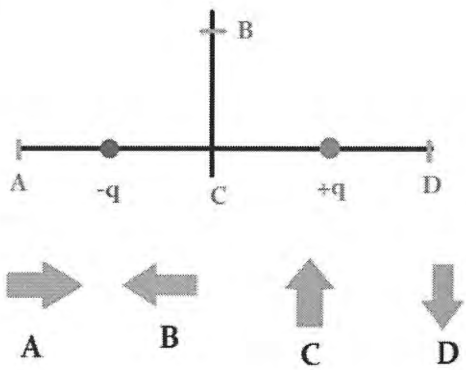


(a) 1700 V
(b) 1800 V
(c) 1900 V
(d) 2000 V

9) **[2 marks]** During a thunder storm, the cloud and the ground is as if become a parallel plate capacitor. Lightning will occur when the electric field between the cloud and ground exceeds the dielectric breakdown of the air (3×10^6 Vm^{-1}). If the cloud is 1000 m above the ground, determine the electric potential difference between the cloud and ground

(a) 3.0 Giga V
(b) 3.5 Giga V
(c) 3.7 Giga V
(d) 4.0 Giga V

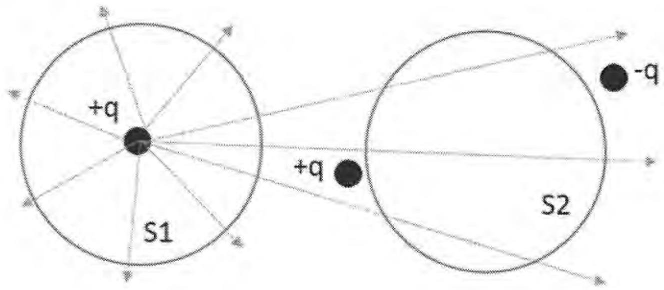
10) **[1 mark]** Two point charges -q and +q are located as shown in the Figure below. What is the direction of electric field at point A?



(a) A
(b) B
(c) C

(d) D

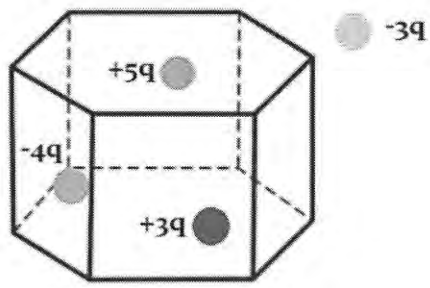
11) [**2 marks**] Calculate the electric field intensity through the closed surface S1 and S2 as shown in Figure below



i. q
ii. (q*q)4 π ε R
iii. q/ε
iv. 0
v. ∞

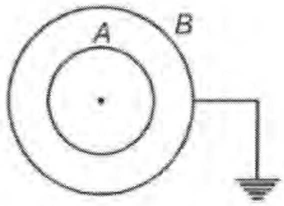
(a) i and ii
(b) i and iv
(c) ii and v
(d) iii and iv

12) [**2 marks**] Using Gauss's Law, calculate the electric field intensity through the closed surface as shown in Figure below



(a) $-3q/8.85*10^{-12}$
(b) $4q/8.85*10^{-12}$
(c) 5q
(d) 3q

13) [**1 mark**] There are two concentric metallic shells shown in Figure below. If A is positively charged, the electric



(a) The Potential at common centre is zero

(b) Potential outside B is positive

(c) Field outside is zero

(d) Field at common centre is non-zero

14) [**1 mark**] The principle of magnetism is widely used in the following application:

(a) magnetic memory

(b) motors and generators

(c) microphones and speakers

(d) all of the above

15) [**1 mark**] Magnetic fields can be visualized by:

(a) continuous interaction between electrons and holes

(b) sprinkling iron filings on a piece of paper suspended over a bar magnet

(c) boundary conditions between a dielectric material and a free space medium

(d) combination between line charge distribution and surface charge distribution

16) [**1 mark**] An electrostatic field is produced by____________________ and the magnetostatic field is generated by____________________.

(a) stationary charges, a constant current flow

(b) Moving charges, dielectric materials

(c) steady currents, electric flux density

(d) volume charge distribution, convection currents

17) [**1 mark**] The following two major laws can be used in magnetostatic fields:

(a) Biot Savart's law and Gauss's law

(b) Kirchhoff's law and Gauss's law

(c) Ampere's law and Faraday's law

(d) Biot Savart's law and Ampere's law

18) **[1 mark]** When a magnet is in motion relative to a coil, the induced Electromotive Force (EMF)

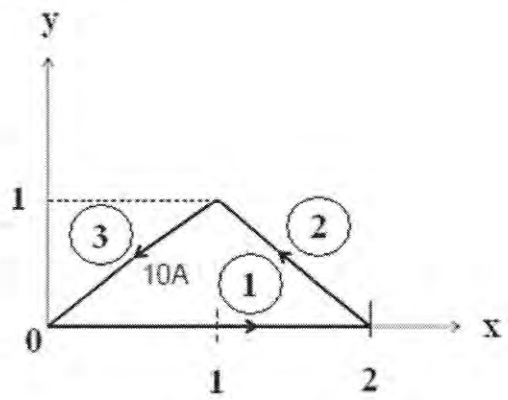
(a) resistance of the coil

(b) motion of the magnet

(c) number of turns of the coil

(d) pole strength of the magnet

19) **[1 mark]** Figure below shows a conducting triangular loop of 10A located in cartesian coordinate system. Determine magnetic field intensity at (0, 0, 5) due to side 1 of the loop.



(a) -55.1$\mathbf{a}_y$ mA/m

(b) 45.7$\mathbf{a}_x$ mA/m

(c) -59.1$\mathbf{a}_y$ mA/m

(d) 49.5$\mathbf{a}_x$ mA/m

20) **[1 mark]** Ampere's Circuital Law states that ___________________over any closed path equals to ______________ enclosed by the path.

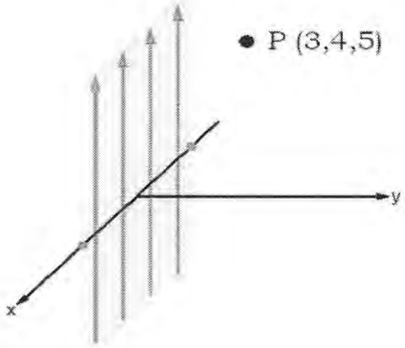
(a) the total charge distribution, the net electric flux density

(b) the line integral of magnetic field intensity, the net current

(c) the Electromotive Force (EMF), the electric potential

(d) the electric current density, total flux density

21) **[1 mark]** Figure below shows an infinite sheet of current located in cartesian coordinate system with K = 6az A/m exists on the x-z plane at y = 0. Determine **H** at an observation point P(3,4,5).



(a) $-3\mathbf{a}_x$ A/m

(b) $6\mathbf{a}_y$ A/m

(c) $13\mathbf{a}_x$ A/m

(d) $-30\mathbf{a}_x$ A/m

22) **[1 mark]** For $\vec{H} = 10^3 r\hat{\phi}$ A/m, determine magnetic flux Φ, passing through surface for portion $\phi = \pi/2$, $2 \le r \le 4$, and $0 \le z \le 2$.

(a) 150.8×10^{-4} Wb

(b) 125.5×10^{-5} Wb

(c) 105.2×10^{-4} Wb

(d) 105.4×10^{-5} Wb

23) **[1 mark]** The point charge $Q = 18$ nC has a velocity of 5×10^6 m/s in the direction $\mathbf{a}_u = 0.6\mathbf{a}_x + 0.75\mathbf{a}_y + 0.3\mathbf{a}_z$. Calculate the magnitude of the force exerted on the charge by the field $\mathbf{B} = -3\mathbf{a}_x + 4\mathbf{a}_y + 6\mathbf{a}_z$ mT

(a) 653.7 μN

(b) 535 μN

(c) 525.3 μN

(d) 625.5 μN

24) **[1 mark]** An electron moving with a speed of 2×10^{6} m/s through a magnetic field with magnetic flux density of 2.5T experience a magnetic force of magnitude 4×10^{-13} N. What is the angle between the magnetic field and the electron's velocity?

(a) 30°
(b) 150°
(c) 30° or 150°
(d) 25°

25) **[1 mark]** The magnetic flux linkage is defined as _______________ linking a given surface bounded by the contour of the circuit carrying the current.

(a) the total field distribution
(b) the magnetic flux
(c) the magnetic field lines
(d) the electric field lines

26) **[1 mark]** Determine the flux crossing the portion of the plane $\pi/4$ defined by 0.01 m $\leq \rho \leq$ 0.05 m and $0 \leq z \leq$ 2m in free space. A current filament of 2.5A is along the z axis in the direction of $\mathbf{a}_z$

(a) 1.61×10^{-6} Wb
(b) 1.25×10^{-4} Wb
(c) 2.65×10^{-4} Wb
(d) 1.75×10^{-6} Wb

27) **[1 mark]** The magnetic flux density in a region of free space is given by $\mathbf{B} = -3x\mathbf{a}_x + 5y\mathbf{a}_y - 2z\mathbf{a}_z$. Find the total force on a rectangular loop which lies in the plane z = 0 and is bounded by x =1, x = 3, y = 2 and y = 5. All dimensions are in cm.

(a) $-36\mathbf{a}_z$ mN
(b) $-46\mathbf{a}_z$ μN

(c) $26\mathbf{a}_z$ mN

(d) $46\mathbf{a}_z$ μN

28) [**1 mark**] The inductance of a coil will increase under all the following conditions except

(a) when more length for the same number of turns is provided

(b) when the number of turns of the coil increase

(c) when more area for each turn is provided

(d) when permeability of the core increases

29) [**1 mark**] A fine magnet wire with a thin insulative enamel coating is used in which the magnet wire is evenly wrapped 200 turns along the 10cm length of a 1cm diameter wooden dowel ($\mu \approx \mu_0$). Determine the inductance.

(a) 45.9 μH

(b) 39.5 μH

(c) 42.5 μH

(d) 29.7 μH

30) [**1 mark**] Boundary conditions for normal components **B** and **H** are obtained by applying ____________________on a small cylindrical Gaussian surface.

(a) Biot Savart's law

(b) Gauss's law

(c) Faraday's law

(d) Ampere's law

31) [**1 mark**] Given the permeability be $4\mu\text{H/m}$ in region 1 where $z > 0$ and $7\mu\text{H/m}$ in region 2 where $z \leq 0$. If there is a surface current density $\mathbf{K} = 80\mathbf{a}_x$ A/m at $z = 0$ and if $\mathbf{B_1} = 2\mathbf{a}_x - 3\mathbf{a}_y + \mathbf{a}_z$ mT. Determine $\mathbf{B_2}$.

(a) $3.5\mathbf{a}_x - 4.69\mathbf{a}_y + \mathbf{a}_z$ mT

(b) $2.5\mathbf{a}_x + 3.35\mathbf{a}_y + 2\mathbf{a}_z$ mT

(c) $-3.5\mathbf{a}_x + 3.69\mathbf{a}_y + 3\mathbf{a}_z$ mT

(d) $4.5\mathbf{a}_x - 2.36\mathbf{a}_y + \mathbf{a}_z$ mT

32) [**1 mark**] In order to determine boundary conditions for tangential components of **B** and **H**,______________________can be applied to a small path.

(a) Biot Savart's law

(b) Gauss's law

(c) Faraday's law

(d) Ampere's law

33) [**1 mark**] The magnetic field intensity is given by $\mathbf{H}_1 = 6\mathbf{a}_x + 2\mathbf{a}_y + 3\mathbf{a}_z$ A/m. In a medium with $\mu_{r1} = 6000$ that exists for $z < 0$, find $\mathbf{H}_2$ in a medium with $\mu_{r2} = 3000$.

(a) $\mathbf{H}_2 = 6\mathbf{a}_x + 2\mathbf{a}_y + 3\mathbf{a}_z$ A/m

(b) $\mathbf{H}_2 = 6\mathbf{a}_x + 2\mathbf{a}_y + 6\mathbf{a}_z$ A/m

(c) $\mathbf{H}_2 = 3\mathbf{a}_x + 2\mathbf{a}_y + 3\mathbf{a}_z$ A/m

(d) $\mathbf{H}_2 = 6\mathbf{a}_x + 2\mathbf{a}_y + 2\mathbf{a}_z$ A/m

34) [**1 mark**] Ferromagnetic materials include the following except

(a) iron

(b) cobalt

(c) nickle

(d) glass

35) [**1 mark**] An infinite slab magnetic material for which $\mu_r = 2.5$ is given in a region $0 \le z \le 2m$. If $\mathbf{B} = 10y\mathbf{a}_x - 5x\mathbf{a}_y$ mWb/m^2 in slab, determine electric current density, J.

(a) $-4.78\mathbf{a}_z$ kA/m^2

(b) $3.75\mathbf{a}_z$ kA/m^2

(c) $-2.75\mathbf{a}_z$ kA/m^2

(d) $6.75\mathbf{a}_z$ kA/m^2

36) **[1 mark]** The magnetic field of a material is influenced by

(a) degree of relative permeability

(b) characteristics of loss performance

(c) electric field distribution

(d) degree of dielectric permittivity

37) **[1 mark]** A conductor is located at $x = 0.4$m, $y = 0$ and $0 < z < 2$m carrying 5A current in positive z direction, along $\mathbf{B} = 2.5\mathbf{a}_z$ T. Determine torque at z axis.

(a) $15\mathbf{a}_z$ N.m

(b) $10\mathbf{a}_z$ N.m

(c) $25\mathbf{a}_z$ N.m

(d) $35\mathbf{a}_z$ N.m

38) **[1 mark]** In paramagnetic material, the orbital and spin moments are not equal and there exists a net __________________________.

(a) current distribution

(b) permittivity and permeability

(c) magnetic dipole moment

(d) external field distribution

39) **[1 mark]** The concept of displacement current was a major contribution to

(a) Lorentz

(b) Faraday

(c) Lenz

(d) Maxwell

40) **[1 mark]** Magnetic lines always exist in a closed loop or circle then divergence of magnetic field will be

(a) 0

(b) 1

(c) infinite

(d) does not exist

41) **[1 mark]** The fields or waves will be ________ for time varying currents

(a) Electrical

(b) Electromagnetic

(c) Electrostatic

(d) Magnetostatic

42) **[2 marks]** Find the displacement current when the flux density is given by $D = t^3$ at 5 seconds.

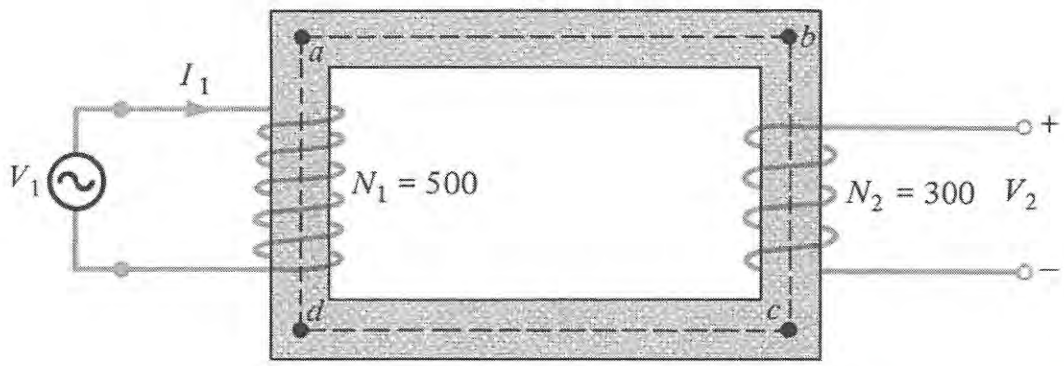
(a) 3

(b) 5

(c) 25

(d) 75

43) **[2 marks]** A magnetic core of uniform cross section 4 cm^2 is connected to a 240 V , 60 Hz generator as shown in figure below. Calculate the induced Electromotive Force (EMF), V_2 in the secondary coil.



(a) 72 V

(b) 132 V

(c) 138 V

(d) 144 V

44) **[1 mark]** The law that the induced electromotive force, emf and current always oppose the cause producing them is due to

(a) Coulomb

(b) Newton

(c) Lenz

(d) Faraday

45) **[1 mark]** In Faraday's laws of electromagnetic induction, an Electromotive Force (EMF) is induced in a conductor whenever it

a) Cuts magnetic flux

b) Lies perpendicular to the magnetic flux

c) Lies in a magnetic field

d) Moves parallel to the direction of the magnetic field

46) **[2 marks]** Determine the transformer electromotive force, emf for the loop located in the x-y plane that has an dimension of 3 m in length and 2 m in width. The magnetic flux density is $\mathbf{B} = -0.5t\hat{\mathbf{z}}$.

(a) 0.5 V

(b) 1 V

(c) 1.5 V

(d) 3 V

47) **[1 mark]** Magnitude of induced Electromotive Force (EMF) is proportional to

(a) rate of change of current

(b) rate of change of magnetic flux

(c) rate of change of voltage

(d) rate of change of resistance

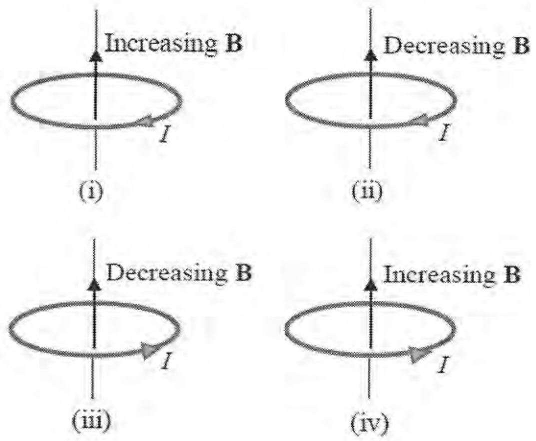
48) **[2 marks]** Determine the force due to a current element of length 3 cm and flux density of 15 Tesla. The current through the element is 3 A.

(a) 0.6 N
(b) 1.35 N
(c) 1.67 N
(d) 5 N

49) **[1 mark]** A loop is rotating about the y-axis in a magnetic field $\mathbf{B} = B_o \sin \omega t\, \hat{\boldsymbol{x}}$ Wb/m^2. The voltage induced in the loop is due to

(a) Transformer emf
(b) A combination of motional and transformer emf
(c) Motional emf
(d) None of the above

50) **[2 marks]** Assuming that each loop is stationary and the time-varying magnetic field B induces current I, which of the configurations in Figure below are correct?

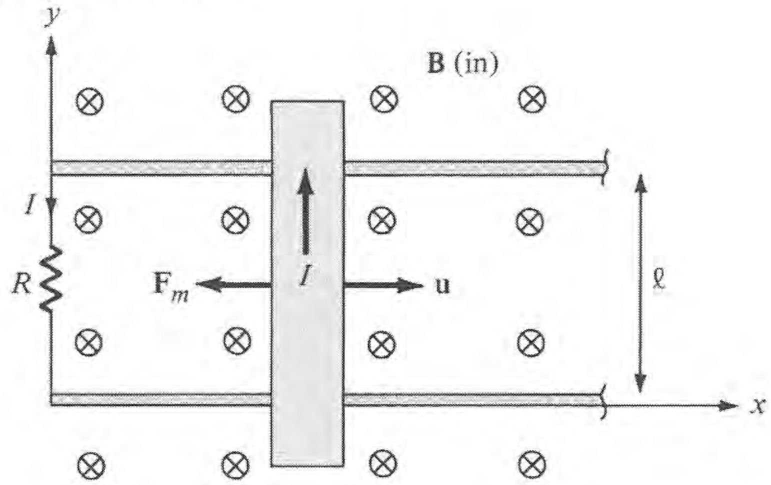


(a) (i) and (ii)
(b) (i) and (iv)

(c) (i) and (iii)

(d) (ii) and (iv)

51) **[2 marks]** Consider the loop of figure below. If $\mathbf{B} = 0.5\hat{\mathbf{z}}$ Wb/m^2, R = 20 Ω, distance, ℓ = 10 cm, and the rod is moving with a constant velocity of $8\hat{\mathbf{x}}$ m/s, find the current through resistor.



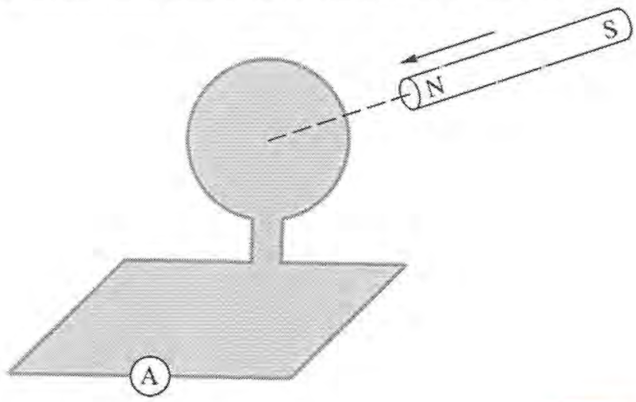
(a) 2 mA

(b) 4 mA

(c) 20 mA

(d) 40 mA

52) **[2 marks]** Figure below shows a bar magnet is thrust toward the center of a coil of 10 turns and resistance 15 Ω. If the magnetic flux through the coil changes from 0.45 Wb to 0.64 Wb in 0.02 s. The observer view is from the side near the magnet. Determine the magnitude and direction of the induced current?



(a) 6 A

(b) 15 A

(c) 21 A

(d) 36 A

53) [**1 mark**] Harmonic electromagnetic fields refer to fields varying sinusoidally with respect to time. Is it true / false ?

(a) True

(b) False

54) [**2 marks**] Find the curl of electric field , E when the magnetic flux density , B is given as 12t.

(a) 6

(b) -6

(c) 12

(d) -12

55) [**1 mark**] Which is **TRUE** for Faraday's Law Application

a) Separation of fine particles

b) Electric generators

c) Magnetic Tape

d) Solenoid Inductor

56) [**1 mark**] What parameter that defines the distance travelled by a wave in one period?

(a) Frequency

(b) Period

(c) Speed of wave

(d) Wavelength

57) [**2 marks**] Consider an oscillator which has a charged particle and oscillates about its mean position with a frequency of 300 MHz. The wavelength of electromagnetic waves produced by this oscillator is?

(a) 1 m

(b) 10 m

(c) 100 m

(d) 1000 m

58) **[1 mark]** The electric and magnetic fields of an electromagnetic wave are:

(a) in phase and perpendicular to each other

(b) out of phase and not perpendicular to each other

(c) in phase and not perpendicular to each other

(d) out of phase and perpendicular to each other(space not align with others)

59) **[1 mark]** Which one of the following is not part of the electromagnetic spectrum?

(a) Sound wave

(b) Microwaves

(c) Gamma rays

(d) Radio waves

60) **[1 mark]** In a vacuum, all electromagnetic waves have the same:

(a) amplitude

(b) frequency

(c) wavelength

(d) speed

61) **[1 mark]** Skin depth phenomenon is found in which materials?

(a) Insulators

(b) Dielectrics

(c) Conductors

(d) Semiconductors

62) **[1 mark]** For conductors, the loss tangent will be

(a) Zero

(b) Unity

(c) Maximum

(d) Minimum

63) **[2 marks]** Electromagnetic waves travelling in a medium having relative permeability, $\mu_r = 1.3$ and relative permittivity, $\varepsilon_r = 2.14$. The speed of electromagnetic waves in the medium must be:

(a) $1.8 \times 10^8\ ms^{-1}$

(b) 1.8×10^4 ms^{-1}

(c) 1.8×10^6 ms^{-1}

(d) 1.8×10^2 ms^{-1}

64) **[2 marks]** The electric field component of a wave in free space is given by

$\boldsymbol{E} = 10cos(10^7t + kz)\boldsymbol{a_y}$ V/m

It can be inferred that

(a) The wave propagates along $\boldsymbol{a_y}$.

(b) The wavelength $\lambda = 188.5$ m.

(c) The wave amplitude is 10 mV/m.

(d) The wave number $k = 0.33$ rad/m.

65) **[1 mark]** If ***E*** and ***B*** represent electric and magnetic field vector of the electromagnetic waves, then the direction of propagation of the EM wave is that of:

(a) **E × B**

(b) **E . B**

(c) **B . E**

(d) **B × E**

66) **[2 marks]** Given that $\mathbf{H} = 0.5e^{-0.1x}sin(10^6t - 2x)\boldsymbol{a_z}$ A/m, which of these statements is incorrect?

(a) $\alpha = 0.1$ Np/m

(b) $\beta = 2$ rad/m

(c) $\omega = 10^6$ rad/s

(d) The wave is polarized in the z-direction.

67) **[2 marks]** What is the maximum strength of the B -field in an electromagnetic wave that has a maximum E -field strength of 1000 V/m?

(a) 3.33×10^{-8}

(b) 3.33×10^{-6} T

(c) 3.33×10^{-4} T

(d) 3.33×10^{-2} T

68) **[1 mark]** In electromagnetic waves the phase difference between electric field vector and magnetic field vector is:

(a) zero

(b) $\pi/2$

(c) π

(d) $\pi/3$

69) [**1 mark**] The velocity of electromagnetic radiation in a medium of permittivity, ε_0 and permeability, μ_0 is given by:

(a) $\sqrt{\varepsilon_0/\mu_0}$

(b) $\sqrt{\varepsilon_0\mu_0}$

(c) $1/\sqrt{\varepsilon_0\mu_0}$

(d) $\sqrt{\mu_0/\varepsilon_0}$

70) [**1 mark**] What is the major factor for determining whether a medium is free space, a lossless dielectric, a lossy dielectric, or a good conductor?

(a) Attenuation constant

(b) Constitutive parameters (σ, ε, μ)

(c) Loss tangent

(d) Reflection coefficient

71) [**2 marks**] In a certain medium, $\boldsymbol{E} = 10cos(10^8t - 3y)\boldsymbol{a}_x$ V/m. What type of medium is it?

(a) Free space

(b) Lossy dielectric

(c) Lossless dielectric

(d) Perfect conductor

72) [**2 marks**] The power of a wave of with voltage of 140 V and a characteristic impedance of 50 ohm is

(a) 1.96 W

(b) 19.6 W

(c) 196 W

(d) 19600 W

73) [**1 mark**] Which of the following electromagnetic waves is used in medicine to destroy cancer cells?

(a) IR-rays

(b) Visible rays

(c) Gamma rays

(d) Ultraviolet rays

-END OF QUESTIONS -

FINAL EXAMINATION

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COURSE NAME : ELECTROMAGENTIC FIELDS AND WAVES COURSE CODE : BEJ 20303/ BEB20303

FORMULA

	Cartesian	**Cylindrical**	**Spherical**
Coordinate parameters	x, y, z	r, ϕ, z	R, θ, ϕ
Vector $\vec{A}$	$A_x\hat{\mathbf{x}} + A_y\hat{\mathbf{y}} + A_z\hat{\mathbf{z}}$	$A_r\hat{\mathbf{r}} + A_\phi\hat{\boldsymbol{\phi}} + A_z\hat{\mathbf{z}}$	$A_R\hat{\mathbf{R}} + A_\theta\hat{\boldsymbol{\theta}} + A_\phi\hat{\boldsymbol{\phi}}$
Magnitude $\vec{A}$	$\sqrt{A_x^{\ 2} + A_y^{\ 2} + A_z^{\ 2}}$	$\sqrt{A_r^{\ 2} + A_\phi^{\ 2} + A_z^{\ 2}}$	$\sqrt{A_R^{\ 2} + A_\theta^{\ 2} + A_\phi^{\ 2}}$
Position vector, $\overrightarrow{OP}$	$x_1\hat{\mathbf{x}} + y_1\hat{\mathbf{y}} + z_1\hat{\mathbf{z}}$ for point $P(x_1, y_1, z_1)$	$r_1\hat{\mathbf{r}} + z_1\hat{\mathbf{z}}$ for point $P(r_1, \phi_1, z_1)$	$R_1\hat{\mathbf{R}}$ for point $P(R_1, \theta_1, \phi_1)$
Unit vector product	$\hat{\mathbf{x}}\bullet\hat{\mathbf{x}} = \hat{\mathbf{y}}\bullet\hat{\mathbf{y}} = \hat{\mathbf{z}}\bullet\hat{\mathbf{z}} = 1$ $\hat{\mathbf{x}}\bullet\hat{\mathbf{y}} = \hat{\mathbf{y}}\bullet\hat{\mathbf{z}} = \hat{\mathbf{z}}\bullet\hat{\mathbf{x}} = 0$ $\hat{\mathbf{x}}\times\hat{\mathbf{y}} = \hat{\mathbf{z}}$ $\hat{\mathbf{y}}\times\hat{\mathbf{z}} = \hat{\mathbf{x}}$ $\hat{\mathbf{z}}\times\hat{\mathbf{x}} = \hat{\mathbf{y}}$	$\hat{\mathbf{r}}\bullet\hat{\mathbf{r}} = \hat{\boldsymbol{\phi}}\bullet\hat{\boldsymbol{\phi}} = \hat{\mathbf{z}}\bullet\hat{\mathbf{z}} = 1$ $\hat{\mathbf{r}}\bullet\hat{\boldsymbol{\phi}} = \hat{\boldsymbol{\phi}}\bullet\hat{\mathbf{z}} = \hat{\mathbf{z}}\bullet\hat{\mathbf{r}} = 0$ $\hat{\mathbf{r}}\times\hat{\boldsymbol{\phi}} = \hat{\mathbf{z}}$ $\hat{\boldsymbol{\phi}}\times\hat{\mathbf{z}} = \hat{\mathbf{r}}$ $\hat{\mathbf{z}}\times\hat{\mathbf{r}} = \hat{\boldsymbol{\phi}}$	$\hat{\mathbf{R}}\bullet\hat{\mathbf{R}} = \hat{\boldsymbol{\theta}}\bullet\hat{\boldsymbol{\theta}} = \hat{\boldsymbol{\phi}}\bullet\hat{\boldsymbol{\phi}} = 1$ $\hat{\mathbf{R}}\bullet\hat{\boldsymbol{\theta}} = \hat{\boldsymbol{\theta}}\bullet\hat{\boldsymbol{\phi}} = \hat{\boldsymbol{\phi}}\bullet\hat{\mathbf{R}} = 0$ $\hat{\mathbf{R}}\times\hat{\boldsymbol{\theta}} = \hat{\boldsymbol{\phi}}$ $\hat{\boldsymbol{\theta}}\times\hat{\boldsymbol{\phi}} = \hat{\mathbf{R}}$ $\hat{\boldsymbol{\phi}}\times\hat{\mathbf{R}} = \hat{\boldsymbol{\theta}}$
Dot product $\vec{A}\bullet\vec{B}$	$A_xB_x + A_yB_y + A_zB_z$	$A_rB_r + A_\phi B_\phi + A_zB_z$	$A_RB_R + A_\theta B_\theta + A_\phi B_\phi$
Cross product $\vec{A}\times\vec{B}$	$\begin{vmatrix} \hat{\mathbf{x}} & \hat{\mathbf{y}} & \hat{\mathbf{z}} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$	$\begin{vmatrix} \hat{\mathbf{r}} & \hat{\boldsymbol{\phi}} & \hat{\mathbf{z}} \\ A_r & A_\phi & A_z \\ B_r & B_\phi & B_z \end{vmatrix}$	$\begin{vmatrix} \hat{\mathbf{R}} & \hat{\boldsymbol{\theta}} & \hat{\boldsymbol{\phi}} \\ A_R & A_\theta & A_\phi \\ B_R & B_\theta & B_\phi \end{vmatrix}$
Differential length, $\overrightarrow{d\ell}$	$dx\,\hat{\mathbf{x}} + dy\,\hat{\mathbf{y}} + dz\,\hat{\mathbf{z}}$	$dr\,\hat{\mathbf{r}} + rd\phi\,\hat{\boldsymbol{\phi}} + dz\,\hat{\mathbf{z}}$	$dR\,\hat{\mathbf{R}} + Rd\theta\,\hat{\boldsymbol{\theta}} + R\sin\theta\,d\phi\hat{\boldsymbol{\phi}}$
Differential surface, $\overrightarrow{ds}$	$\overrightarrow{ds}_x = dy\,dz\,\hat{\mathbf{x}}$ $\overrightarrow{ds}_y = dx\,dz\,\hat{\mathbf{y}}$ $\overrightarrow{ds}_z = dx\,dy\,\hat{\mathbf{z}}$	$\overrightarrow{ds}_r = rd\phi\,dz\,\hat{\mathbf{r}}$ $\overrightarrow{ds}_\phi = dr\,dz\,\hat{\boldsymbol{\phi}}$ $\overrightarrow{ds}_z = rdr\,d\phi\,\hat{\mathbf{z}}$	$\overrightarrow{ds}_R = R^2\sin\theta\,d\theta\,d\phi\,\hat{\mathbf{R}}$ $\overrightarrow{ds}_\theta = R\sin\theta\,dR\,d\phi\,\hat{\boldsymbol{\theta}}$ $\overrightarrow{ds}_\phi = R\,dR\,d\theta\,\hat{\boldsymbol{\phi}}$
Differential volume, $\overrightarrow{dv}$	$dx\,dy\,\,dz$	$r\,dr\,d\phi\,dz$	$R^2\sin\theta\,dR\,d\theta\,d\phi$

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$$Q=\int \rho_\ell d\ell,$$
$$Q=\int \rho_s dS,$$
$$Q=\int \rho_v dv$$
$$\bar{F}_{12}=\frac{Q_1Q_2}{4\pi\varepsilon_0 R^2}\hat{a}_{R_{12}}$$
$$\bar{E}=\frac{\bar{F}}{Q},$$
$$\bar{E}=\frac{Q}{4\pi\varepsilon_0 R^2}\hat{a}_R$$
$$\bar{E}=\int\frac{\rho_\ell d\ell}{4\pi\varepsilon_0 R^2}\hat{a}_R$$
$$\bar{E}=\int\frac{\rho_s dS}{4\pi\varepsilon_0 R^2}\hat{a}_R$$
$$\bar{E}=\int\frac{\rho_v dv}{4\pi\varepsilon_0 R^2}\hat{a}_R$$
$$\bar{D}=\varepsilon\bar{E}$$
$$\psi_e=\int\bar{D}\bullet d\bar{S}$$
$$Q_{enc}=\oint_S\bar{D}\bullet d\bar{S}$$
$$\rho_v=\nabla\bullet\bar{D}$$
$$V_{AB}=-\int_A^B\bar{E}\bullet d\bar{\ell}=\frac{W}{Q}$$
$$V=\frac{Q}{4\pi\varepsilon r}$$
$$V=\int\frac{\rho_\ell d\ell}{4\pi\varepsilon r}$$
$$\oint\bar{E}\bullet d\bar{\ell}=0$$
$$\nabla\times\bar{E}=0$$
$$\bar{E}=-\nabla V$$
$$\nabla^2 V=0$$
$$R=\frac{\ell}{\sigma S}$$
$$I=\int\bar{J}\bullet dS$$

$$d\bar{H}=\frac{Id\bar{\ell}\times\bar{R}}{4\pi R^3}$$
$$Id\bar{\ell}\equiv\bar{J}_s dS\equiv\bar{J}dv$$
$$\oint\bar{H}\bullet d\bar{\ell}=I_{enc}=\int\bar{J}_s dS$$
$$\nabla\times\bar{H}=\bar{J}$$
$$\psi_m=\int_s\bar{B}\bullet d\bar{S}$$
$$\psi_m=\oint\bar{B}\bullet d\bar{S}=0$$
$$\psi_m=\oint\bar{A}\bullet d\bar{\ell}$$
$$\nabla\bullet\bar{B}=0$$
$$\bar{B}=\mu\bar{H}$$
$$\bar{B}=\nabla\times\bar{A}$$
$$\bar{A}=\int\frac{\mu_0 Id\bar{\ell}}{4\pi R}$$
$$\nabla^2\bar{A}=-\mu_0\bar{J}$$
$$\bar{F}=Q(\bar{E}+\bar{u}\times\bar{B})=m\frac{d\bar{u}}{dt}$$
$$d\bar{F}=Id\bar{\ell}\times\bar{B}$$
$$\bar{T}=\bar{r}\times\bar{F}=\bar{m}\times\bar{B}$$
$$\bar{m}=IS\hat{a}_n$$
$$V_{emf}=-\frac{\partial\psi}{\partial t}$$
$$V_{emf}=-\int\frac{\partial\bar{B}}{\partial t}\bullet d\bar{S}$$
$$V_{emf}=\int(\bar{u}\times\bar{B})\bullet d\bar{\ell}$$
$$I_d=\int J_d.d\bar{S}, J_d=\frac{\partial\bar{D}}{\partial t}$$
$$\gamma=\alpha+j\beta$$
$$\alpha=\omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left[\frac{\sigma}{\omega\varepsilon}\right]^2}-1\right]}$$
$$\beta=\omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left[\frac{\sigma}{\omega\varepsilon}\right]^2}+1\right]}$$

$$\bar{F}_1=\frac{\mu I_1 I_2}{4\pi}\oint_{L1}\oint_{L2}\frac{d\bar{\ell}_1\times(d\bar{\ell}_2\times\hat{a}_{R_{21}})}{R_{21}^2}$$
$$|\eta|=\frac{\sqrt{\mu/\varepsilon}}{\left[1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2\right]^{\frac{1}{4}}}$$
$$\tan 2\theta_\eta=\frac{\sigma}{\omega\varepsilon}$$
$$\tan\theta=\frac{\sigma}{\omega\varepsilon}=\frac{\bar{J}_s}{\bar{J}_{ds}}$$
$$\delta=\frac{1}{\alpha}$$
$$\varepsilon_0=8.854\times10^{-12}\ \text{Fm}^{-1}$$
$$\mu_0=4\pi\times10^{-7}\ \text{Hm}^{-1}$$

$$\int\frac{dx}{(x^2+c^2)^{3/2}}=\frac{x}{c^2(x^2+c^2)^{1/2}}$$
$$\int\frac{xdx}{(x^2+c^2)^{3/2}}=\frac{-1}{(x^2+c^2)^{1/2}}$$
$$\int\frac{dx}{(x^2\pm c^2)^{1/2}}=ln\left(x+\sqrt{x^2\pm c^2}\right)$$
$$\int\frac{dx}{(x^2+c^2)}=\frac{1}{c}tan^{-1}\left(\frac{x}{c}\right)$$
$$\int\frac{xdx}{(x^2+c^2)}=\frac{1}{2}ln(x^2+c^2)$$
$$\int\frac{xdx}{(x^2+c^2)^{1/2}}=\sqrt{x^2+c^2}$$

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