THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL OF TANZANIA

ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

131/2 **PHYSICS 2**

(For Both School and Private Candidates)

Time: 2:30 Hours **ANSWERS** **Year: 2009**

Instructions

1. This paper consists of section A, B and C with total of nine questions.
2. Answer five questions, choosing at least one question from each section.
3. Each question carries twenty marks.

1. (a)(i) Define tensile stress.

Tensile stress is the force per unit cross-sectional area applied to a material in a direction that tends to stretch it, given by

$\sigma = F / A$

(ii) Define tensile strain.

Tensile strain is the relative elongation of a material due to applied tensile stress, given by

$\varepsilon = \Delta L / L$

(iii) Define Young's modulus.

Young's modulus (E) is the ratio of tensile stress to tensile strain, representing the stiffness of a material, given by

$E = \sigma / \varepsilon = (F / A) / (\Delta L / L)$

(b)(i) Derive the expression for the work done in stretching a wire of length L by a load W through an extension X.

The work done in stretching a wire is given by

$dW = F\,dx$

Since $F = kx$, where k is the stiffness of the wire, integrating from 0 to X:

$W = \int_0^x F\,dx$

$= \int_0^x kx\,dx$

$= (1/2)\,kX^2$

Since $k = EA / L$, substituting:

$W = (1/2)\,(EA / L)\,X^2$

(ii) A vertical wire made of steel of length 2.0 m and 1.0 mm diameter has a load of 5.0 kg applied to its lower end. What is the energy stored in the wire?

Given:

$L = 2.0$ m

$d = 1.0$ mm $= 1.0 \times 10^{-3}$ m

$A = \pi d^2 / 4 = \pi(1.0 \times 10^{-3})^2 / 4 = 7.85 \times 10^{-7}$ m²

$m = 5.0$ kg

$F = mg = 5.0 \times 9.81 = 49.05$ N

$E = 2 \times 10^{11}$ N/m²

Strain:

$\varepsilon = (F\,L) / (AE)$

$= (49.05 \times 2.0) / (7.85 \times 10^{-7} \times 2 \times 10^{11})$

$= 6.24 \times 10^{-5}$

Extension:

$X = \varepsilon L$

$= (6.24 \times 10^{-5}) \times (2.0)$

$= 1.25 \times 10^{-4}$ m

Work stored:
$W = (1/2)\ (F\ X)$
$= (1/2)\ (49.05 \times 1.25 \times 10^{-4})$
$= 3.07 \times 10^{-3}$ J

(c) A copper wire 2.0 m long and 1.22×10^{-3} m diameter is fixed horizontally to two rigid supports 2.0 m apart. Find the mass in kg of the load, which when suspended at the midpoint of the wire, produces a sag of 2.0×10^{-2} m at the point.

Using small deflection formula:
$m = (48\ Y\ d^4\ g) / (64\ L\ \Delta)$
where
$Y = 1.1 \times 10^{11}$ N/m² (Young's modulus of copper),
$L = 2.0$ m,
$d = 1.22 \times 10^{-3}$ m,
$\Delta = 2.0 \times 10^{-2}$ m,
$g = 9.81$ m/s²

Substituting values:
$m = (48 \times 1.1 \times 10^{11} \times (1.22 \times 10^{-3})^4 \times 9.81) / (64 \times 2.0 \times 2.0 \times 10^{-2})$
$m \approx 1.08$ kg

2. (a) Define angular momentum and give its dimensions.
Angular momentum (L) is the rotational equivalent of linear momentum, given by
$L = I\omega = mvr$
Its dimensions are $[ML^2T^{-1}]$.

(b) A grinding wheel in a form of solid cylinder of 0.2 m diameter and 3 kg mass is rotated at 3600 rev./minute.

(i) What is its kinetic energy?
Angular velocity:
$\omega = (2\pi \times 3600) / 60$
$= 377$ rad/s

Moment of inertia:
$I = (1/2)\ MR^2$
$= (1/2) \times 3 \times (0.1)^2$
$= 0.015$ kg m²

Kinetic energy:

$KE = (1/2) I \omega^2$
$= (1/2) \times 0.015 \times (377)^2$
$= 1064.7$ J

(ii) Find how far it would have to fall to acquire the same kinetic energy.
Using conservation of energy:
$mgh = KE$
$h = KE / (mg)$
$= 1064.7 / (3 \times 9.81)$
$= 36.2$ m

(c) A uniform solid cylinder of mass M and radius R rotates about a vertical axis on a frictionless bearing. A mass less cord wrapped with many turns round the cylinder passes over a pulley of rotational inertia I and radius r and then attached to a small mass m that is otherwise free to fall under the influence of gravity.

Using energy conservation:
$mgh = (1/2) I\omega^2 + (1/2)Mv^2 + (1/2)m v^2$
Express ω in terms of v:
$\omega = v/r$
$mgh = (1/2) I (v^2/r^2) + (1/2) M v^2 + (1/2) m v^2$
Solve for v.

3. (a)(i) What is the difference between isothermal and adiabatic processes?
Isothermal process occurs at constant temperature ($\Delta T = 0$), whereas adiabatic process occurs without heat exchange ($Q = 0$).

(ii) Write down the equation of state obeyed by each process in 3(a)(i) above.
Isothermal: PV = constant
Adiabatic: PV^γ = constant

(iii) Using the same graph and under the same conditions, sketch the isotherms and the adiabatics.
(Sketch shows isothermal curves decreasing slower than adiabatic curves.)

(b) Derive the expression for the work done by the gas when it expands from volume V_1 to volume V_2 during an

(i) Isothermal process
$dW = PdV$
Since PV = constant, $P = nRT/V$,
$W = \int PdV$
$= \int (nRT / V) dV$
$W = nRT \ln(V_2 / V_1)$

(ii) Adiabatic process
Using PV^γ = constant,
$dW = PdV$
$P = (\text{constant}) V^{(-\gamma)}$
$W = \int (\text{constant}) V^{(-\gamma)} dV$
$W = (1/(\gamma - 1)) (P_1V_1 - P_2V_2)$

(c) When water is boiled under a pressure of 2 atmospheres the boiling point is 120°C. At this pressure one kg of water has a volume of 10^{-3} m³ and two kg of steam have a volume of 1.648 m³. Compute the

(i) work done when one kg of steam is formed at this temperature.
$W = P \Delta V$
$= (2 \times 1.013 \times 10^5) \times (1.648 - 10^{-3})$
$= (2.026 \times 10^5) \times (1.647)$
$W \approx 3.34 \times 10^5$ J

(ii) increase in the internal energy.
Using
$\Delta U = Q - W$
$Q = mL$,
where latent heat $L = 2.26 \times 10^6$ J/kg,
$Q = 1 \times 2.26 \times 10^6$
$= 2.26 \times 10^6$ J

$\Delta U = (2.26 \times 10^6) - (3.34 \times 10^5)$
$\Delta U \approx 1.93 \times 10^6$ J

4. (a)(i) State Kepler's laws of planetary motion.
- The orbit of a planet is an ellipse with the Sun at one of its foci.
- A line joining a planet and the Sun sweeps out equal areas in equal time intervals.
- The square of the orbital period of a planet is proportional to the cube of its semi-major axis.

(ii) Explain the variation of acceleration due to gravity, g, inside and outside the earth.
Inside the earth: g decreases linearly with depth according to
$g' = g(1 - d/R)$
where d is the depth and R is the radius of the Earth.

Outside the earth: g decreases with altitude according to
$g' = g (R^2 / (R+h)^2)$
where h is the height above the surface.

(b) Derive the formulae for mass and density of the earth.
Gravitational force provides the centripetal force:

$GMm / R^2 = mg$
Canceling m,
$GM / R^2 = g$
Rearrange for M:
$M = gR^2 / G$

Density:
$\rho = M / V$
Since $V = (4/3)\pi R^3$,
$\rho = (gR^2 / G) \times (3 / 4\pi R^3)$
$= (3g / 4\pi GR)$

(c)(i) What do you understand by the term satellite?
A satellite is an object that orbits around a planet or a star due to the gravitational force of attraction.

(ii) A satellite of mass 100 kg moves in a circular orbit of radius 7000 km around the earth, assumed to be a sphere of radius 6400 km. Calculate the total energy needed to place the satellite in orbit from the earth, assuming $g = 10\ Nkg^{-1}$ at the earth's surface.

Potential energy at Earth's surface:
$U_1 = - GMm / R$
$= - (10 \times 6400^2 \times 100)$

Potential energy in orbit:
$U_2 = - GMm / r$
$= - (10 \times 7000^2 \times 100)$

Total energy in orbit:
$E = (1/2)U_2$
$E = - (1/2) \times (10 \times 7000^2 \times 100)$

Total energy required:
$\Delta E = E - U_1$
$\Delta E = - (1/2) \times (10 \times 7000^2 \times 100) - (- 10 \times 6400^2 \times 100)$
$\Delta E \approx 4.8 \times 10^8\ J$

5. (a)(i) What is interference? Explain the term path difference with reference to the interference of two wave-trains.
Interference is the superposition of two or more waves leading to a resultant wave of greater, lower, or same amplitude. Path difference is the difference in distances traveled by two waves arriving at the same point, determining constructive or destructive interference.

(ii) Why is it not possible to see interference when the light beams from headlamps of a car overlap?

Light from car headlamps is incoherent, meaning there is no constant phase difference, so no stable interference pattern is formed.

(iii) Discuss whether it is possible to observe an interference pattern when white light is shone on a Young's double slit experiment.
It is possible, but instead of a uniform pattern, fringes of different colors appear due to different wavelengths interfering differently, with central white fringe and colored side fringes.

(b) A grating has 500 lines per millimeter and is illuminated normally with monochromatic light of wavelength 5.89×10^{-7} m.

(i) How many diffraction maxima may be observed?
Grating equation:
$n\lambda = d \sin\theta$
where
$d = 1 / (500 \times 10^3) = 2 \times 10^{-6}$ m
Maximum order:
$n = d / \lambda$
$= (2 \times 10^{-6}) / (5.89 \times 10^{-7})$
$= 3.39$

Since n must be an integer, maximum observable order is 3.

(ii) Calculate the angular separation.
Using $\sin\theta = n\lambda / d$, for first order (n=1):
$\sin\theta = (1 \times 5.89 \times 10^{-7}) / (2 \times 10^{-6})$
$\theta = \sin^{-1}(0.2945)$
$\theta \approx 17.1°$

(c) In figure 2 below, S_1 and S_2 are two coherent light sources in a Young's two slit experiment separated by a distance 0.5 mm and O is a point equidistant from S_1 and S_2 at a distance 0.8 m from the slits. When a thin parallel sided piece of glass (G) of thickness 3.6×10^{-6} m is placed near S_1 as shown, the central fringe system moves from O to a point P. Calculate OP. (The wavelength of light used = 6.0×10^{-7} m).

Path difference due to glass:
$\Delta x = (n - 1)t$
where
$n \approx 1.5$ (refractive index of glass),
$t = 3.6 \times 10^{-6}$ m

$\Delta x = (1.5 - 1) \times (3.6 \times 10^{-6})$
$= 1.8 \times 10^{-6}$ m

Fringe shift formula:
$OP = \Delta x \times (D/d)$
$= (1.8 \times 10^{-6}) \times (0.8 / 0.5 \times 10^{-3})$
$= (1.8 \times 10^{-6}) \times (1600)$
$= 2.88 \times 10^{-3}$ m
= 2.88 mm

6. (a) Explain the mechanism of electric conduction in:

(i) gases.
Electric conduction in gases occurs when a sufficient voltage is applied across a gas-filled space, causing ionization of gas molecules. The free electrons and positive ions generated in the process move towards the respective electrodes, allowing current to flow. In normal conditions, gases are insulators, but at high voltages, ionization breakdown occurs, leading to electrical discharge, as seen in neon lights and plasma arcs.

(ii) electrolytes.
Electric conduction in electrolytes occurs due to the movement of positive and negative ions in solution. When an external voltage is applied, positive ions migrate towards the cathode while negative ions move towards the anode. The continuous movement of these charged particles allows current to flow through the solution. This principle is utilized in electrolysis, batteries, and electroplating.

(b)(i) State the laws of electromagnetic induction.

- Faraday's Law: The induced electromotive force (emf) in a coil is directly proportional to the rate of change of magnetic flux through the coil.
  emf = $-\, d\Phi/dt$
- Lenz's Law. The direction of the induced current is such that it opposes the change in magnetic flux that produced it.

(ii) Outline four applications of eddy currents.

- Electromagnetic braking. Used in trains and roller coasters to slow down motion using induced eddy currents.
- Induction heating. Used in cooking and metal processing, where eddy currents generate heat in a conductor.
- Metal detectors. Detects metallic objects by inducing eddy currents and sensing their effects.
- Energy meters: Used in watt-hour meters where eddy currents help in damping moving coils for accurate measurement.

(c) A coil of 100 turns is rotated at 1500 revolutions per minute in a magnetic field of uniform density 0.05 T. If the axis of rotation is at right angles to the direction of the flux and the area per turn is 4000 mm², calculate the:

(i) frequency.

Frequency is given by
$f = (RPM) / 60$
$= 1500 / 60$
$= 25$ Hz

(ii) period.
Period is the reciprocal of frequency
$T = 1 / f$
$= 1 / 25$
$= 0.04$ s

(iii) maximum induced e.m.f.
Maximum emf is given by
$E_0 = N B A \omega$
where
N = 100 turns
B = 0.05 T
$A = 4000 \text{ mm}^2 = 4 \times 10^{-3} \text{ m}^2$
$\omega = 2\pi f = 2\pi \times 25$

$E_0 = (100) \times (0.05) \times (4 \times 10^{-3}) \times (2\pi \times 25)$
$E_0 = (100 \times 0.05 \times 4 \times 10^{-3} \times 157.08)$
$E_0 \approx 3.14$ V

(iv) maximum value of the induced e.m.f when the coil has rotated through 30° from the position of zero e.m.f.
Instantaneous emf is given by
$E = E_0 \sin\theta$
$E = 3.14 \sin 30°$
$E = 3.14 \times 0.5$
$E = 1.57$ V

7. (a) The diagram below (fig. 3) shows a wire of length l carrying a current I and placed in a magnetic field B such that its length is perpendicular to B. Derive an expression for the force exerted on the wire.

The force on a current-carrying conductor in a magnetic field is given by Lorentz force law. Consider a small segment of the wire carrying current I in a magnetic field B. The force on a charge q moving with drift velocity v in a magnetic field is
$F = q(v \times B)$

For a conductor of length l, the number of charge carriers moving is proportional to the total current, given by
$F = (q\, n\, A\, l\, v) \times B$

Since current $I = nqAv$,
$F = (nqAv\, l) \times B$

Since $v \times B$ gives $\sin\theta$ of the angle between them, and for a perpendicular field $\theta = 90°$,
$F = I\, l\, B \sin 90°$
$F = I\, l\, B$

(b)(i) Give a general form expressing the force exerted on the wire carrying current I if its length l is inclined at an angle θ to the magnetic field B.

The force when the wire is inclined at an angle θ is given by
$F = I\, l\, B \sin\theta$

(ii) A wire carrying a current of 2A has a length 100 mm in a uniform magnetic field of 0.8 Wbm^{-2}. Find the force acting on the wire when the field is at 60° to the wire.

Given:
$I = 2$ A
$l = 100$ mm $= 0.1$ m
$B = 0.8$ T
$\theta = 60°$

Using the equation
$F = I\, l\, B \sin\theta$
$F = (2) \times (0.1) \times (0.8) \times \sin(60°)$
$F = (0.16) \times (0.866)$
$F = 0.13856$ N

(c) A wire carrying a current of 25 A and 8 m long is placed in a magnetic field of flux density 0.42 T. What is the force on the wire if it is placed:

(i) at right angles to the field?
Given:
$I = 25$ A
$l = 8$ m
$B = 0.42$ T
$\theta = 90°$

$F = I\, l\, B \sin\theta$
$F = (25) \times (8) \times (0.42) \times \sin(90°)$
$F = (200) \times (0.42)$
$F = 84$ N

(ii) at 45° to the field?

$F = I\,l\,B\sin\theta$
$F = (25) \times (8) \times (0.42) \times \sin(45°)$
$F = (200) \times (0.42) \times (0.707)$
$F = 59.39$ N

(iii) along the field?
For $\theta = 0°$,
$F = I\,l\,B\sin(0°)$
$F = (25) \times (8) \times (0.42) \times 0$
$F = 0$ N

(d)(i) Develop an equation for the torque acting on a current carrying coil of dimensions $l \times b$ placed in a magnetic field. How is this effect applied in a moving coil galvanometer?

A rectangular coil carrying a current I and placed in a uniform magnetic field B experiences a torque due to the force exerted on each side of the coil. The force on a length l of the wire is given by
$F = I\,l\,B\sin\theta$

For a rectangular coil of width b and length l, the torque on each side is
Torque = Force × perpendicular distance
$\tau = (I\,l\,B\sin\theta) \times b$

For N turns of the coil, the total torque is
$\tau = N\,I\,A\,B\sin\theta$

For a moving coil galvanometer, the coil is suspended by a suspension wire with a torsion constant k. The restoring torque is
$\tau = k\theta$

At equilibrium, the two torques balance
$N\,I\,A\,B = k\theta$

This principle is used in a moving coil galvanometer, where the deflection θ is proportional to the current I, allowing it to measure small currents.

(ii) A galvanometer coil has 50 turns, each with an area of 1.0 cm². If the coil is in a radial field of 10^{-2} T and suspended by a suspension of torsion constant 2×10^{-9} Nm per degree, what current is needed to give a deflection of 30°?

Given:
N = 50 turns

$A = 1.0\ cm^2 = 1.0 \times 10^{-4}\ m^2$
$B = 10^{-2}\ T$
$k = 2 \times 10^{-9}$ Nm/degree
$\theta = 30°$

Using
$N I A B = k\theta$

Rearrange for I:
$I = (k\theta) / (N A B)$

Substituting values:
$I = (2 \times 10^{-9} \times 30) / (50 \times 1.0 \times 10^{-4} \times 10^{-2})$
$I = (6 \times 10^{-9}) / (5 \times 10^{-5})$
$I = 1.2 \times 10^{-4}$ A or 120 μA

8. (a)(i) Forward bias
Forward bias occurs when a positive voltage is applied to the p-side and a negative voltage to the n-side of a p-n junction, allowing current to flow.

(ii) Reverse bias
Reverse bias occurs when a negative voltage is applied to the p-side and a positive voltage to the n-side of a p-n junction, preventing current flow except for a small leakage current.

(iii) Inverting and non-inverting amplifier
An inverting amplifier has its input applied to the inverting terminal of an operational amplifier, producing an output that is 180° out of phase with the input.
A non-inverting amplifier has its input applied to the non-inverting terminal, producing an output that is in phase with the input.

(b)(i) Logic gate
A logic gate is an electronic circuit that performs a Boolean function, processing binary inputs to produce a specific binary output.

(ii) Integrated circuit
An integrated circuit (IC) is a miniature electronic circuit consisting of transistors, resistors, and capacitors fabricated onto a single semiconductor chip.

(iii) Modulation
Modulation is the process of varying a carrier signal's amplitude, frequency, or phase according to a message signal to facilitate communication over a medium.

(c) An operational amplifier is to have a voltage gain of 100. Calculate the required values for the external resistances R_1 and R_2 when the following gains are required:

(i) non-inverting
For a non-inverting amplifier, the voltage gain is given by
$A = 1 + (R_2 / R_1)$

Setting A = 100:
$100 = 1 + (R_2 / R_1)$
$99 = R_2 / R_1$
$R_2 = 99 R_1$

Choosing $R_1 = 1$ kΩ:
$R_2 = 99 \times 1$ kΩ
$R_2 = 99$ kΩ

(ii) inverting
For an inverting amplifier, the voltage gain is given by
$A = - R_2 / R_1$

Setting A = 100:
$100 = R_2 / R_1$
$R_2 = 100 R_1$

Choosing $R_1 = 1$ kΩ:
$R_2 = 100 \times 1$ kΩ
$R_2 = 100$ kΩ

(d) Given the circuit in figure 4 below, describe what happens to Vo when Vi is raised suddenly from 0 to 1V and remains at that voltage.

The given circuit is an integrator using an operational amplifier with a feedback capacitor of 2 μF and an input resistor of 1 MΩ. The response of the circuit depends on the sudden change in input voltage from 0V to 1V.

The output voltage of an integrator is given by:
$V_o = -(1/RC) \int V_{in}\, dt$

Given:
$R = 1\ \text{M}\Omega = 1 \times 10^6\ \Omega$
$C = 2\ \mu\text{F} = 2 \times 10^{-6}$ F
Vin = 1V (step input)

Since the input voltage jumps from 0V to 1V and remains constant, integration of a constant value results in a linear ramp:
$Vo = -(1 / (1 \times 10^6 \times 2 \times 10^{-6})) \times \int 1\, dt$
$Vo = - (1 / 2) \times t$
$Vo = -0.5t$ V

This means that Vo will decrease linearly at a rate of 0.5 V per second. Initially, Vo is 0V, and then it starts decreasing negatively as time increases.

9. (a) Write down Bragg's equation for the study of the atomic structure of crystals by X-rays.

Bragg's equation is given by
$n\lambda = 2d \sin\theta$
where
n = order of diffraction,
λ = wavelength of X-ray,
d = interplanar spacing,
θ = angle of incidence.

(b) The radiation from an X-ray tube which operates at 50 kV is diffracted by a cubic KCl crystal of molecular mass 74.6 and density 1.99×10^3 kg/m³. Calculate:

(i) The shortest wavelength limit of the spectrum from the tube.

The shortest wavelength is given by
$\lambda = hc / eV$
where
$h = 6.626 \times 10^{-34}$ J·s,
$c = 3.0 \times 10^8$ m/s,
$e = 1.602 \times 10^{-19}$ C,
$V = 50 \times 10^3$ V.

$\lambda = (6.626 \times 10^{-34} \times 3.0 \times 10^8) / (1.602 \times 10^{-19} \times 50 \times 10^3)$
$\lambda = (1.9878 \times 10^{-25}) / (8.01 \times 10^{-15})$
$\lambda = 2.48 \times 10^{-11}$ m

(ii) The glancing angle for first order reflection from the planes of the crystal for that wavelength and angle of deviation of a diffracted beam.

Using Bragg's equation for first order (n = 1):
$\sin\theta = \lambda / (2d)$

Given the density and molecular mass, d can be found using crystal structure relations. Substituting d, solve for θ.

(c) The radiation emitted by an X-ray tube consists of continuous spectrum with a line spectrum superimposed on it. Explain how the continuous spectrum and the line spectrum are produced.

The continuous spectrum arises from the deceleration of high-energy electrons when they strike the target, emitting Bremsstrahlung radiation. The line spectrum appears due to the ejection of inner-shell electrons, causing outer electrons to fall into lower energy levels, emitting characteristic X-ray photons.

10. (a) Explain the following observations:

(i) A radioactive source is placed in front of a detector which can detect all forms of radioactive emissions. It is found that the activity registered is noticeably reduced when a thin sheet of paper is placed between the source and detector.

This indicates the presence of alpha particles, which have low penetration power and are stopped by a thin sheet of paper.

(ii) When a brass plate with a narrow vertical slit is placed in front of the radioactive source in 10.(a)(i) above and a horizontal magnetic field normal to the line joining the source and the detector is applied, it is found that the activity is further reduced.

This suggests the presence of beta particles, which are deflected by the magnetic field and prevented from reaching the detector.

(iii) The magnetic field in 10.(a)(ii) is removed and a sheet of aluminium is placed in front of the source. The activity recorded is similarly reduced.

Beta particles have higher penetration than alpha particles but can be stopped by a thin sheet of aluminium.

(b)(i) Define the terms laser and maser.

Laser (Light Amplification by Stimulated Emission of Radiation) is a device that emits coherent light through the process of optical amplification.

Maser (Microwave Amplification by Stimulated Emission of Radiation) is similar to a laser but operates in the microwave frequency range.

(ii) Give three applications of laser.

- Laser cutting and welding in industries.
- Optical fiber communication for high-speed data transmission.
- Medical applications such as laser surgery and eye treatments.

(c)(i) A laser beam has a power of 20×10^9 watts and a diameter of 2 mm. Calculate the peak values of electric field and magnetic fields.

Power per unit area (intensity):
$I = P / A$
$A = \pi(d/2)^2$
$A = \pi(0.002/2)^2$
$A = 3.14 \times 10^{-6}$ m²

$I = (20 \times 10^9) / (3.14 \times 10^{-6})$
$I = 6.37 \times 10^{15}$ W/m²

Peak electric field:
$E_0 = \sqrt{(2I / c\varepsilon_0)}$
where
$\varepsilon_0 = 8.85 \times 10^{-12}$ F/m,
$c = 3.0 \times 10^8$ m/s.

$E_0 = \sqrt{(2 \times 6.37 \times 10^{15}) / (3 \times 10^8 \times 8.85 \times 10^{-12})}$
$E_0 = 2.19 \times 10^9$ V/m

Peak magnetic field:
$B_0 = E_0 / c$
$B_0 = (2.19 \times 10^9) / (3.0 \times 10^8)$
$B_0 = 7.3$ T

(ii) A 2.71 g sample of KCl from the chemistry stock is found to be radioactive and decays at a constant rate of 4490 disintegrations per second. The decays are traced to the element potassium and in particular to the isotope ^{40}K which constitutes 1.17% of normal potassium. Calculate the half-life of the nuclide.

Given data:
Activity, A = 4490 disintegrations per second
Mass of KCl = 2.71 g
Percentage of ^{40}K in normal potassium = 1.17% = 1.17 / 100

Molar masses:
Molar mass of KCl, M_KCl = 74.6 g/mol

Molar mass of K, M_K = 39.1 g/mol

Avogadro's number:
Na = 6.022×10^{23} atoms/mol

Step 1: Find the mass of potassium (K) in the sample
Since KCl consists of potassium and chlorine, the proportion of potassium in KCl is:
Mass of K in KCl = (M_K / M_KCl) × Mass of KCl

Substituting values:
Mass of K = (39.1 / 74.6) × 2.71
Mass of K = 1.42 g

Step 2: Find the mass of ^{40}K in the sample
Mass of ^{40}K = (Percentage of ^{40}K) × (Mass of K)
Mass of ^{40}K = (1.17 / 100) × 1.42
Mass of ^{40}K = 0.0166 g

Step 3: Find the number of ^{40}K atoms in the sample
Number of ^{40}K atoms, N = (Mass of ^{40}K / Molar mass of K) × Avogadro's number

$N = (0.0166 / 39.1) \times (6.022 \times 10^{23})$
$N = (4.25 \times 10^{-4}) \times (6.022 \times 10^{23})$
$N = 2.56 \times 10^{20}$ atoms

Step 4: Find the decay constant (λ)
The decay equation is given by:
$A = \lambda N$
Rearranging for λ:
$\lambda = A / N$

$\lambda = 4490 / (2.56 \times 10^{20})$
$\lambda = 1.75 \times 10^{-17}\ s^{-1}$

Step 5: Calculate the half-life ($T_1/_2$)
The half-life formula is:
$T_1/_2 = \ln(2) / \lambda$

$T_1/_2 = (0.693) / (1.75 \times 10^{-17})$
$T_1/_2 = 3.96 \times 10^{16}$ seconds

Step 6: Convert to years
1 year = 60 × 60 × 24 × 365 = 3.154×10^{7} seconds

$T_{1/2}$ (years) = $(3.96 \times 10^{16}) / (3.154 \times 10^{7})$
$T_{1/2} = 1.25 \times 10^{9}$ years

Final Answer:
The half-life of the nuclide is 1.25 billion years (1.25×10^{9} years).