Formulas exam physics II AE1204

Formula	Explanation
$F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$	Coulomb's law: Magnitude of the force F (in N) between two charges Q_1 and Q_2 (both in C), with r (in m) the distance between the two charges.
$\vec{E} = \frac{\vec{F}}{q}$	The electric field vector at any point due to one or more charges is defined as the force per unit charge that would act on a positive test charge placed at that point.
$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$	Magnitude of the electric field (in N/C) at a distance r (in m) from a point charge Q (in C).
$E = \frac{\sigma}{2\varepsilon_0}$	Electric field (in N/C) above or below an 'infinite' plane of any shape holding a charge density σ (in C/m^2).
$\Phi_E = \vec{E}.\vec{A}$	Electric flux (in Nm^2/C) through a flat area A for a uniform electric field $\vec{E}$ (direction of $\vec{A}$ is chosen perpendicular to the surface whose area is A).
$\Phi_E = \int \vec{E}.d\vec{A}$	Electric flux in case the field is not uniform.
$\oint \vec{E}.d\vec{A} = \frac{Q_{\text{encl}}}{\varepsilon_0}$	Gauss's law: Net flux passing through any closed surface (left-hand side of equation) equals the net charge Q_{encl} (in C) enclosed by that surface divided by ε_0.
$V_b - V_a = -\int_a^b \vec{E}.\vec{dl}$	Potential difference (in V or J/C) between two points, a and b, given the electric field $\vec{E}$ (in N/C or V/m).
$V_b - V_a = -Ed$	Potential difference (in V or J/C) between two points, a and b, in the case the electric field is uniform (with magnitude E). d (in m) is the distance between the two points.
$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$	Electric potential V (in V) due to a single point charge Q at a distance r (in m) from this point charge.
$E_x = -\frac{\partial V}{\partial x}, E_y = -\frac{\partial V}{\partial y}, E_z = -\frac{\partial V}{\partial z}$	Components of the electric field vector $\vec{E} = (E_x, E_y, E_z)$ given the known potential $V(x, y, z)$.
$C = \frac{Q}{V}$	Definition of capacitance C (in F): ratio of the charge Q (in C) to potential difference V (in V) between the two conductors of a capacitor (the two conductors of a capacitor hold equal and opposite charges of magnitude Q).
$C = \varepsilon_0 \frac{A}{d}$	Capacitance C (in F) of a parallel-plate capacitor with plate area A (in m^2) and separation d (in m).
$C_{eq} = C_1 + C_2 + \ldots$	Equivalent capacitance when capacitors are connected in parallel.

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$	Equivalent capacitance when capacitors are connected in series.
$U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$	A charged capacitor stores an amount of energy U as a function of C, Q, or V
$u = \frac{1}{2}\varepsilon_0 E^2$	In any electric field $\vec{E}$ in free space the energy density u (energy per unit volume)
$C = K\varepsilon_0 \frac{A}{d} = \varepsilon \frac{A}{d}$	Capacitance in dielectrics. K is the dielectric constant.
$\varepsilon = K\varepsilon_0$	Permittivity for a dielectric material
$u = \frac{1}{2}K\varepsilon_0 E^2 = \frac{1}{2}\varepsilon E^2$	The energy density for a dielectric material
$V = IR$	Relation between resistance R (in Ω) of a device and the current I (in A) in the device and the potential difference V (in V) applied across it. Ohm's law: R is a constant independent of V.
$R = \frac{\rho l}{A}$	Resistance R (in Ω) of a wire with cross-sectional area A (in m^2), length l (in m) and resistivity ρ (in Ω m).
$P = IV = I^2R = \frac{V^2}{R}$	Power P (in W) transformed in a resistance R (in Ω) with I (in A) the current in the resistor and V (in V) the potential difference applied across it.
$I_{rms} = \frac{I_0}{\sqrt{2}}, \quad V_{rms} = \frac{V_0}{\sqrt{2}}$	The rms values of sinusoidally alternating currents and voltages.
$\vec{j} = nq\vec{v}_d$	Relation between the current density $\vec{j}$ and the number of charge carriers n per unit volume, the charge q per particle and the drift velocity $\vec{v}_d$.
$\vec{j} = \sigma\vec{E}$	Relation between the current density, the electric field and the conductivity σ.
$\sigma = \frac{1}{\rho}$	The conductivity is one over the resistivity.
$\rho_T = \rho_0\left[1 + \alpha(T - T_0)\right]$	Resistivity ρ_T at temperature T expressed in terms of the resistivity ρ_0 at temperature T_0. The coefficient α is the temperature coefficient of resistivity (in $1/C^\circ$)
$R_{eq} = R_1 + R_2 + \ldots$	Equivalent resistance when resistors are connected in series.
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$	Equivalent resistance when resistors are connected in parallel.
$\tau = RC$	The time constant τ of an RC circuit is the resistance multiplied by the capacitance.
$\vec{F} = I\vec{l}\times\vec{B}$	Force (in N) exerted by a uniform magnetic field $\vec{B}$ (in T) on a wire of length $\vec{l}$ (in m) that carries a current I (in A).
$\vec{F} = q\vec{E} + q\vec{v}\times\vec{B}$	Force on a charge q moving with velocity $\vec{v}$ in an electric field $\vec{E}$ (in N/C) and magnetic field $\vec{B}$.

$\vec{\tau} = \vec{\mu} \times \vec{B}$	The torque $\vec{\tau}$ on a current loop in a magnetic field $\vec{B}$.
$\vec{\mu} = NI\vec{A}$	The magnetic dipole moment $\vec{\mu}$ as a function of the number of coils, N, the current, I, and oriented area of the loop $\vec{A}$.
$B = \frac{\mu_0}{2\pi} \frac{I}{r}$	Magnetic field B (in T) at a distance r (in m) from a long straight wire that carries a current I (in A).
$\oint \vec{B}.\vec{dl} = \mu_0 I_{\text{encl}} + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$	Ampère's law: line integral of the magnetic field $\vec{B}$ around any closed loop equals μ_0 times the total net current I_{encl} enclosed by the loop.
$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{\vec{dl} \times \hat{r}}{r^2}$	Biot-Savart Law: $d\vec{B}$ is the contribution to the magnetic field at some point P due to the current in the infinitesimal oriented line segment $\vec{dl}$ located at a distance r from P.
$\Phi_B = \vec{B}.\vec{A}$	Magnetic flux (in Wb or Tm^2) passing through a loop equals the product of the area of the loop times the perpendicular component of the uniform magnetic field $\vec{B}$ (direction of $\vec{A}$ is chosen perpendicular to the surface whose area is A).
$\Phi_B = \int \vec{B}.d\vec{A}$	Magnetic flux in case the field is not uniform.
$\varepsilon = -N \frac{d\Phi_B}{dt}$	Faraday's law of induction: The magnitude of the emf ε (in V) induced in a coil equals the time rate of change of the magnetic flux Φ_B (in Wb) through the loop times the number N of loops in the coil.
$\oint \vec{E}.\vec{dl} = -\frac{d\Phi_B}{dt}$	General law of Faraday's law: line integral of the electric field $\vec{E}$ is taken around the (closed) loop through which the magnetic flux Φ_B is changing.
$\varepsilon = -L \frac{dI}{dt}$ with $L = N \frac{\Phi_B}{I}$	Definition of self-inductance L (in H): Within a single coil (with N loops) a changing current I (in A) induces an opposing emf ε (in V), with L the coefficient of self-inductance (in H) of the coil and Φ_B the magnetic flux (in Wb) through the coil.
$U = \frac{1}{2} L I^2$	Energy stored in the inductor with inductance L when the current is given by I.
$u = \frac{1}{2} \frac{B^2}{\mu_0}$	Energy density in any magnetic field $\vec{B}$.
$\tau = \frac{L}{R}$	Time constant τ for LR-circuit.
$X_L = \omega L$	The reactance of an inductor X_L is the frequency ω multiplied by the inductance L, with $\omega = 2\pi f$.
$X_C = \frac{1}{\omega C}$	The reactance of a capacitor X_C is one over the frequency ω multiplied by the capacitance C, where $\omega = 2\pi f$.

$Z=\sqrt{R^2+(X_L-X_C)^2}$	The impedance Z in as LRC-circuit as a function of the resistance R and the reactance of an inductor and a capacitor.
$\oint \vec{B}\cdot d\vec{A}=0$	Gauss' Law for magnetism. 'No isolated magnetic monopoles exist'.
$\vec{S}=\frac{1}{\mu_0}\vec{E}\times\vec{B}$	Poynting vector.
$\overline{S}=\frac{1}{2}\varepsilon_0 cE_0^2=\frac{1}{2}\frac{c}{\mu_0}B_0^2=\frac{E_0B_0}{2\mu_0}$	Average magnitude of Poynting vector in terms of the maximum values E_0 and B_0.
$\overline{S}=\frac{E_{rms}B_{rms}}{\mu_0}$	Average magnitude of the Poynting vector in terms of the root mean square values E_{rms} and B_{rms}.
$P=\frac{F}{A}=\frac{1}{A}\frac{dp}{dt}=\frac{1}{Ac}\frac{dU}{dt}=\frac{\overline{S}}{c}$	Radiation pressure for fully absorbing material
$P=\frac{2\overline{S}}{c}$	Radiation pressure for fully reflecting material
$c=\lambda f$	The wavelength λ and the frequency f of EM waves are related to the speed of light c.
$Q(t)=Q_0\cos\omega t$ with $\omega=\frac{1}{\sqrt{LC}}$	Time evolution of the charge Q (in C) on the positive plate of the capacitor in an LC circuit (without resistance), with C the capacitance (in F) and L the inductance (in H).

$v = \frac{c}{n}$	Speed of light *v* (in m/s) in a material with index of refraction *n*, *c* being the speed of light (in m/s) in vacuum.
$f = \frac{r}{2}$	The focal length *f* of a curved mirror with radius of curvature *r*.
$\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f}$	Mirror equation and thin lens equation Relation between image and object distances, d_i and d_0, and the focal length *f* (all in m). (account for the sign conventions for all quantities involved)
$\lambda_n = \frac{\lambda}{n}$	The wavelength in a medium with refraction index *n* related to the wavelength in vacuum.
$m = \frac{h_i}{h_0} = -\frac{d_i}{d_0}$	Lateral magnification *m* of a mirror or lens, defined as the height of the image h_i divided by the height of the object h_0. (account for the sign conventions for all quantities involved)
$P = \frac{1}{f}$	The power *P* of a lens as a function of the focal length *f*.
$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$	Lensmaker's equation. *F* is the focal distance, *n* is the refraction index of the medium of the lens and R_1 and R_2 are the radii of curvature at both sides of the lens.
$M = \frac{N}{f}$	Angular magnification when viewed by a relaxed normal eye. *F* is the focal length and *N* is the near point of the eye. For normal eyes N=25 cm.
$\sin\theta = m\frac{\lambda}{d}$	Constructive interference of a double slit experiment where *d* is the distance between the slits, *m* is an integer and λ is the wavelength of the light.
$\sin\theta = \left(m + \frac{1}{2}\right)\frac{\lambda}{d}$	Destructive interference of a double slit experiment where *d* is the distance between the slits, *m* is an integer and λ is the wavelength of the light.
$I_\theta = I_0 \cos^2\frac{\delta}{2}, \quad \delta = \frac{2\pi d}{\lambda}\sin\theta$	Light intensity relative to the intensity at $\theta = 0$ as a function of the angle θ, the distance between the slits and the wave number λ of the light in the experiment.
$\sin\theta = \frac{\lambda}{D} \approx \theta$	Light passing through a narrow slit of width *D* (on the order of the wavelength λ) will produce a pattern with a bright central maximum of half-width θ.
$\theta = \frac{1.22\lambda}{D}$	For circular apertures with diameter *D* the central maximum has an angular half width θ
$n_1 \sin\theta_1 = n_2 \sin\theta_2$	When light passes from one transparent medium into another, the rays refract according to Snell's law of refraction, where n_1 and θ_1 are the index of refraction and angle with the normal to the surface for the incident ray, and n_2 and θ_2 are for the refracted ray.

Fundamental constants

Quantity	Symbol	Value
Speed of light in vacuum	c	3.00×10^{8} m s^{-1}
Charge on electron	e	1.60×10^{-19} C
Permittivity of free space	ε_0	8.85×10^{-12} C^2/N.m^2
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ T.m/A
Acceleration due to gravity (average value at Earth's surface)	g	9.80 m/s^2
Refractive index vacuum	n	1
Refractive index air	n_a	1
Refractive index water	n_w	1.33
Refractive index glass	n_g	1.50