Department of Mechanical and Production Engineering

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Formula Sheet

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Contents

1 Constant Definitions

1.1 Coulomb Constant

$$k = \frac{1}{4\pi\epsilon_0} = 8{,}99 \cdot 10^9\,\mathrm{N\,m^2/C^2}.$$

Symbols

k	Coulomb constant	$8{,}99 \cdot 10^9\,\mathrm{N\,m^2/C^2}$
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$

Lecture 1: Electrostatics

26. Januar 2026

2.1 Coulomb's Law

$$\boldsymbol{F} = k\frac{q_1 q_2}{r^2}\,\hat{r}.$$

Assumptions

- Point charges

Symbols

$\boldsymbol{F}$	Electrostatic force	N
k	Coulomb constant	$8{,}99 \cdot 10^9\,\mathrm{N\,m^2/C^2}$
q_1, q_2	Charges	C
r	Distance	m
$\hat{r}$	Unit vector	—

2.1.1 Principle of Superposition

$$\boldsymbol{F}_{1,\mathrm{net}} = \sum_{i=1}^{n} \boldsymbol{F}_{1i}.$$

Symbols

$\boldsymbol{F}_{1,\mathrm{net}}$	Net force	N
$\boldsymbol{F}_{1i}$	Force contribution on particle 1 from particle i	N

2.2 Quantization of Charge

$$q = \pm n \cdot e.$$

Symbols

q	Charge	C
n	Integer number ($n \in \mathbb{Z}$)	—
e	Elementary charge	$1{,}6 \cdot 10^{-19}\,\mathrm{C}$

2.3 Electric Field at a point

$$\boldsymbol{E}(x,y,z) = \frac{\boldsymbol{F}(x,y,z)}{q_0}.$$

Symbols

$\boldsymbol{E}(x,y,z)$	Electric field at point (x,y,z)	$\frac{\mathrm{N}}{\mathrm{C}}$
$\boldsymbol{F}(x,y,z)$	Force on test particle at point (x,y,z)	N
q_0	Test charge	C

2.3.1 Electric Field Produced by Point Charge

$$\boldsymbol{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\hat{r}$$
$$E = \frac{1}{4\pi\epsilon_0}\frac{|q|}{r^2}.$$

Symbols

E	Electric field strength	$\frac{\mathrm{N}}{\mathrm{C}}$
ϵ_0	Permittivity constant	$8{,}85\cdot 10^{-12}\,\mathrm{C}^2/\mathrm{N\,m}^2$
q	Charge	C
r	Distance	m
$\hat{r}$	Unit vector	—

2.3.2 Electric Field due to a Dipole along dipole axis

$$E(z) = E_{(+)}(z) + E_{(-)}(z) = \frac{q}{4\pi\epsilon_0 z^2}\left(\frac{1}{1-\frac{d^2}{2z}} - \frac{1}{1+\frac{d^2}{2z}}\right) = \frac{q}{2\pi\epsilon_0 z^3}\left(\frac{d}{\left(1-\left(\frac{d}{2z}\right)^2\right)^2}\right).$$

Symbols

E	Electric field strength	$\frac{\mathrm{N}}{\mathrm{C}}$
$E_{(+)}, E_{(-)}$	Contribution to E from the positive and negative part of the dipole	$\frac{\mathrm{N}}{\mathrm{C}}$
ϵ_0	Permittivity constant	$8{,}85\cdot 10^{-12}\,\mathrm{C}^2/\mathrm{N\,m}^2$
z	Distance along axis	m
d	Separation distance	m
q	Charge	C

2.3.3 Electric Field due to a Dipole along Dipole axis at Long Distance

$$E = \frac{1}{2\pi\epsilon_0}\frac{qd}{z^3} = \frac{1}{2\pi\epsilon_0}\frac{p}{z^3}.$$

Assumptions

- $z \gg d$, i.e. the distance between charges is much smaller then the distance from the charges you are measuring ("normal" case)

Symbols

E	Electric field strength	$\frac{\mathrm{N}}{\mathrm{C}}$
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$
z	Distance along dipole axis	m
d	Separation distance	m
q	Charge	C
p	Electric dipole moment ($p = qd$)	C m

2.3.4 Electric Field of a Charged Ring at Large Distance

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{z^2}.$$

Assumptions

- $z \gg R$, i.e. distance from the ring is much grater than the radius of the ring

Symbols

E	Electric field strength	$\frac{\mathrm{N}}{\mathrm{C}}$
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$
q	Size of charge in the ring	C
z	Distance perpendicular to the radius of the ring	m

2.3.5 Electric Field of a Charged Disk

$$E = \frac{\sigma}{2\epsilon_0}\left(1 - \frac{z}{\sqrt{z^2 + R^2}}\right).$$

Assumptions

- Infinitesimally thin disk

Symbols

E	Electric field strength	$\frac{\mathrm{N}}{\mathrm{C}}$
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$
σ	Surface charge density	$\mathrm{C/m^2}$
z	Distance perpendicular to the disk	m
R	radius of disk	m

2.3.6 Electric field from an infinite sheet

$$E = \frac{\sigma}{2\epsilon_0}.$$

Assumptions

- Infinitesimally thin infinite sheet

Symbols

E	Electric field strength	$\frac{\mathrm{N}}{\mathrm{C}}$
σ	Surface charge density	$\mathrm{C/m^2}$
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$

2.3.7 Electric field of a Conducting Sphere

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} = k\frac{q}{r^2}.$$

Assumptions

- Positive electric charge Q distributed uniformly throughout the volume of a conducting sphere.
- Spherical symmetry
- No charge enclosed in conductor

Symbols

E	Electric field strength	$\frac{\mathrm{N}}{\mathrm{C}}$
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$
q	Charge	C
r	Distance	m
k	Coulomb constant	$8{,}99 \cdot 10^{9}\,\mathrm{N\,m^2/C^2}$

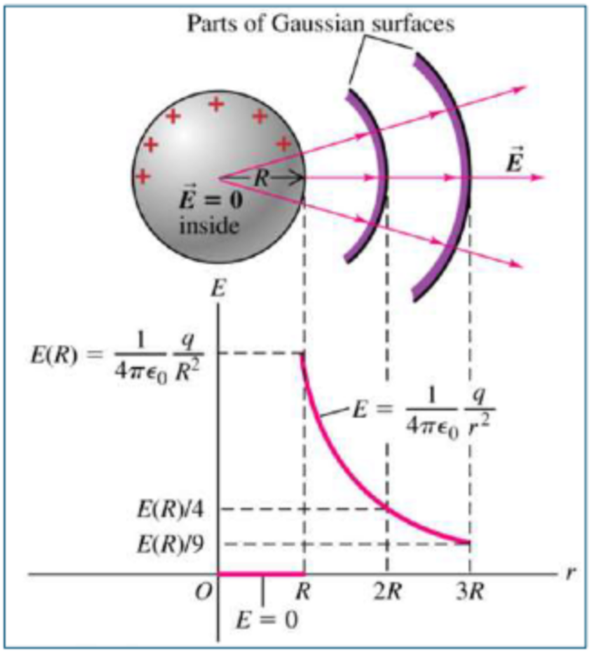

Figure 1: E-field propagation from a conducting sphere.

2.4 Electric Field of an Insulating Sphere

$$\text{Outside}: \quad E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$$

$$\text{Inside}: \quad E = \frac{q}{4\pi\epsilon_0 R^3} r.$$

Assumptions

- Positive electric charge Q distributed uniformly throughout the volume of an insulating sphere.
- Spherical symmetry

Symbols

E	Electric field strength	$\frac{\text{N}}{\text{C}}$
r	Distance	m
R	Radius	m
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\text{C}^2/\text{N}\,\text{m}^2$
q	Charge	C

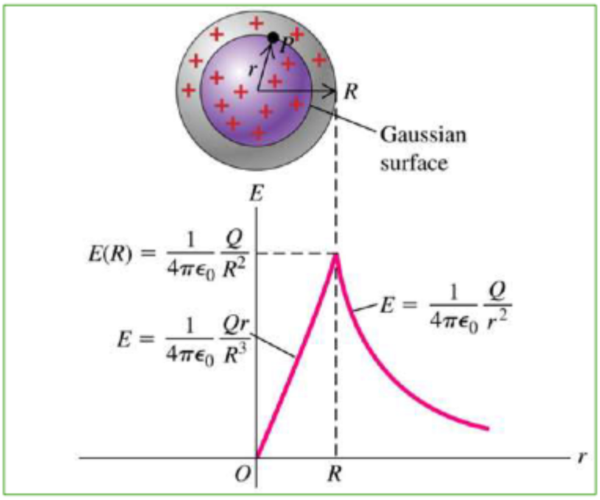

Figure 2: E-field propagation through an insulating sphere.

2.5 Gauss' Law

$$\Phi = \frac{q_{\text{enc}}}{\epsilon_0}.$$

Assumptions

- Vacuum (air)

Symbols

Φ	Electric flux	V m
q_{enc}	Enclosed charge	C
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\text{C}^2/\text{N}\,\text{m}^2$

2.5.1 Net electric flux through a surface caused by an electric field

$$\Phi = \oint \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{A}.$$

Symbols

Φ	Electric flux	V m
$\boldsymbol{E}$	Electric field vector	$\frac{\text{N}}{\text{C}}$
$\boldsymbol{A}$	Area vector	m^2

2.6 Electric Potential Energy

$$U_E = q_0 E \Delta d.$$

Symbols

U_E	Electric potential energy	J
q_0	Test charge	C
E	Electric field strength	$\frac{\text{N}}{\text{C}}$
d	Separation distance	m

2.6.1 Electrostatic Potential

$$V_E = \frac{U_E}{q_0}.$$

Symbols

V_E	Electrostatic potential	V
U_E	Electric potential energy	J
q_0	Test charge	C

2.6.2 Electrostatic Potential of a Plate Capacitor

$$V_E = Ed.$$

Symbols

V_E	Electrostatic potential	V
E	Electric field strength	$\frac{\text{N}}{\text{C}}$
d	Separation distance	m

Lecture 2: Fundamentals of Electric Circuits

28. Januar 2026

3.1 Current, Voltage, and Resistance

3.1.1 Electric Current

$$I = \frac{\mathrm{d}q}{\mathrm{d}t}.$$

Symbols

I	Current	A
q	Charge	C
t	Time	s

3.1.2 Electric Voltage

$$V = \frac{\mathrm{d}W}{\mathrm{d}Q}.$$

Symbols

V	Voltage	V
W	Work	J
Q	Total charge	C

3.1.3 Electric Resistance

$$R = \frac{V}{I}.$$

Symbols

R	Resistance	Ω
V	Voltage	V
I	Current	A

3.1.4 Current Density

$$J = \frac{I}{A}.$$

Symbols

J	Current density	$\mathrm{A/m^2}$
I	Current	A
A	Cross-sectional area	$\mathrm{m^2}$

3.1.5 Resistivity

$$\rho = \frac{E}{J}.$$

Symbols

ρ	Resistivity	$\Omega\,\mathrm{m}$
E	Electric field strength	$\frac{\mathrm{N}}{\mathrm{C}}$
J	Current density	$\mathrm{A/m^2}$

3.1.6 Conductivity

$$\sigma = \frac{1}{\rho}.$$

Symbols

σ	Conductivity	$\Omega^{-1}\,\mathrm{m}^{-1}$
ρ	Resistivity	$\Omega\,\mathrm{m}$

3.1.7 Resistance From Resistivity

$$R = \frac{\rho L}{A}.$$

Symbols

R	Resistance	Ω
ρ	Resistivity	$\Omega\,\mathrm{m}$
L	Length	m
A	Cross-sectional area	$\mathrm{m^2}$

3.1.8 Ohm's Law

$$I \propto V.$$

Symbols

I	Current	A
V	Voltage	V

3.1.9 Electric Power

$$P = VI = I^2 R = \frac{V^2}{R}.$$

Symbols

P	Electrical power	W
V	Voltage	V
I	Current	A
R	Resistance	Ω

3.2 Kirchoff's Circuit Laws

3.2.1 Kirchoff's Current Law (KCL)

$$\sum_{n=1}^{N} I_n = 0.$$

Symbols

I_n	Current at node n	A
N	Amount of nodes	—

3.2.2 Kirchoff's Voltage Law (KVL)

$$\sum_{n=1}^{N} V_n = 0.$$

Symbols

V_n	Voltage difference between two points	V
N	Amount of points	N

3.2.3 Resistors in Series

$$R_{\text{EQ}} = \sum_{n=1}^{N} R_n.$$

Symbols

R_{eq}	Equivalent resistance	Ω
R_n	Resistance of resistor n	Ω
N	Amount of resistors in series	—

3.2.4 Voltage Divider Rule

$$V_n = \frac{R_n}{\sum_{n=1}^{N} R_n} V_s.$$

Symbols

V_n	Voltage difference over resistor n	V
R_n	Resistance over resistor n	Ω
V_s	Source voltage	V

3.2.5 Resistors in Parallel

$$R_{\text{EQ}} = \frac{1}{\sum_{n=1}^{N} \frac{1}{R_n}}.$$

Symbols

R_{eq}	Equivalent resistance	Ω
R_n	Resistance of resistor n	Ω
N	Amount of resistors in parallel	—

3.2.6 Current Divider Rule

$$I_n = \frac{\frac{1}{R_n}}{\sum_{n=1}^{N} \frac{1}{R_n}} I_s.$$

Symbols

I_n	Current difference over resistor n	A
R_n	Resistance over resistor n	Ω
I_s	Source current	A

Lecture 3: Principles of Circuit Analysis — 2. Februar 2026

Lecture 4: Capacitors & Inductors — 9. Februar 2026

5.1 Capacitors

5.1.1 Capacitance

$$C = \frac{q}{V}.$$

Symbols

C	Capacitance	F
q	Charge	C
V	Voltage	V

5.1.2 Capacitance of a Parallel-Plate Capacitor

$$C = \epsilon_0 \frac{A}{d}.$$

Symbols

C	Capacitance	F
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$
A	Cross-sectional area	$\mathrm{m^2}$
d	Separation distance	m

5.1.3 I-V Relation for an Ideal Capacitor

$$I_C(t) = C\frac{\mathrm{d}V_C(t)}{\mathrm{d}t} \iff V_C(t) = \frac{1}{C}\int_{-\infty}^{t} I_C(t')\,\mathrm{d}t'.$$

Symbols

I_C	Current through capacitor	A
V_C	Voltage over capacitor	V
C	Capacitance	F
t	Time	s

5.1.4 Capacitance of a Cylindrical Capacitor

$$C = 2\pi\epsilon_0\frac{L}{\ln\frac{b}{a}}.$$

Symbols

C	Capacitance	F
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$
L	Length	m
a	Radius of the inner post	m
b	Radius of the outer post	m

5.1.5 Capacitance of a Cylindrical Capacitor

$$C = 4\pi\epsilon_0\frac{ab}{b-a}.$$

Symbols

C	Capacitance	F
ϵ_0	Permittivity constant	$8{,}85 \cdot 10^{-12}\,\mathrm{C^2/N\,m^2}$
a	Radius of the inner sphere	m
b	Radius of the outer sphere	m

5.1.6 Parallel Capacitance

$$C_{\mathrm{eq}} = \sum_{i=1}^{n} C_i.$$

Symbols

n	Number of capacitors	—
C_{eq}	Equivalent capacitance	F
C_i	Capacitance of capacitor i	F

5.1.7 Capacitors in Series

$$\frac{1}{C_{\mathrm{eq}}} = \sum_{i=1}^{n} \frac{1}{C_i}.$$

Symbols

n	Number of capacitors	—
C_{eq}	Equivalent capacitance	F
C_i	Capacitance of capacitor i	F

5.1.8 Potential Energy in a Capacitor

$$U_E = \frac{1}{2} C V^2.$$

Symbols

U_E	Electric potential energy	J
C	Capacitance	F
V	Voltage	V

5.2 Inductors

5.2.1 Inductance

$$L = n\frac{\Phi_B}{I}.$$

Symbols

L	Inductance	H
n	Number of windings	—
Φ_B	Magnetic flux	T
I	Current	A

5.2.2 I-V Relation for an Ideal Inductor

$$V_L(t) = L\frac{\mathrm{d}I_L(t)}{\mathrm{d}t} \iff I_L(t) = \frac{1}{L}\int_{t_0}^{t} V_L(t')\,\mathrm{d}t' + I_0.$$

Symbols

I_L	Current through inductor	A
V_L	Voltage over inductor	V
L	Inductance	H
t	Time	s

5.2.3 Magnetic Field of an Inductor

$$\boldsymbol{B} = \mu_0 I n.$$

Symbols

$\boldsymbol{B}$	Magnetic field vector	T

μ_0	Magnetic vacuum permeability	$1{,}26 \cdot 10^{-6}$ N/A^2
I	Current	A
n	Number of windings	—

5.2.4 Inductors in Series

$$L_{\mathrm{eq}} = \sum_{i=1}^{n} L_i.$$

Symbols

n	Number of inductors	—
L_{eq}	Equivalent Inductance	H
L_i	Inductance of inductor i	H

5.2.5 Parallel Inductors

$$\frac{1}{L_{\mathrm{eq}}} = \sum_{i=1}^{n} \frac{1}{L_i}.$$

Symbols

n	Number of inductors	—
L_{eq}	Equivalent Inductance	H
L_i	Inductance of inductor i	H

5.2.6 Energy Stored in an Inductor

$$U_L = \frac{1}{2} L I^2.$$

Symbols

U_L	Potential energy stored in inductor	J
L	Inductance	H
I	Current	A

5.2.7 Energy Density in an Inductor

$$u_L = \frac{\boldsymbol{B}}{2\mu_0}.$$

Symbols

u_L	Energy density of inductor	J/m^3
$\boldsymbol{B}$	Magnetic field vector	T
μ_0	Magnetic vacuum permeability	$1{,}26 \cdot 10^{-6}$ N/A^2

5.3 RC and RL Circuits in the DC Regime

5.3.1 Charge in a (Charging) Capacitor as a Function of Time

$$q(t) = CV_s\left(1 - e^{-\frac{t}{RC}}\right).$$

Symbols

q	Charge	C
C	Capacitance	F
V_s	Source voltage	V
t	Time	s
R	Resistance	Ω
C	Capacitance	F

5.3.2 Current in a (Charging) Capacitor as a Function of Time

$$I_C(t) = \frac{V_s}{R} e^{-\frac{t}{RC}}.$$

Symbols

I_C	Current through capacitor	A
C	Capacitance	F
V_s	Source voltage	V
t	Time	s
R	Resistance	Ω
C	Capacitance	F

5.3.3 Capacitive Time Constant

$$\tau_C = RC.$$

Symbols

τ_C	Capacitive Time Constant	s
R	Resistance	Ω
C	Capacitance	F

5.3.4 Inductive Time Constant

$$\tau_L = \frac{L}{R}.$$

Symbols

τ_L	Inductive Time Constant	s
L	Inductance	H
R	Resistance	Ω

5.3.5 Current in an Inductor

$$I = \frac{V_s}{R}\left(1 - e^{-\frac{t}{\tau_L}}\right).$$

Symbols

I	Current	A
V_s	Source voltage	V
R	Resistance	Ω

t	Time	s
τ_L	Inductive Time Constant	s

Lecture 5: AC Circuits

11. Februar 2026

6.1 AC Circuits

6.1.1 Periodic Signals

$$x(t) = x(t + nT), \quad n = 1, 2, 3, \ldots.$$

Symbols

$x(t)$	Periodic signal x of t	—
t	Time	s
T	Period	s

6.1.2 Average Value of a Signal Waveform

$$\langle x(t) \rangle = \frac{1}{T} \int_0^T x(t')\,\mathrm{d}t'.$$

Symbols

$x(t)$	Periodic signal x of t	—
$\langle x(t) \rangle$	Average value of $x(t)$	—
T	Period	s

6.1.3 RMS value

$$x_{\mathrm{rms}} = \sqrt{\frac{1}{T} \int_0^T x^2(t')\,\mathrm{d}t'}.$$

Symbols

x_{rms}	RMS of $x(t)$	—
$x(t)$	Periodic signal x of t	—
T	Period	s

6.2 Impedance

6.2.1 Impedance of a Resistor

$$Z(j\omega) = \frac{\boldsymbol{V}(j\omega)}{\boldsymbol{I}(j\omega)} = R.$$

Symbols

Z	Impedance	Ω
j	Imaginary unit	—
ω	Frequency	Hz
V	Voltage	V
I	Current	A

R	Resistance	Ω

6.2.2 Impedance of an Inductor

$$Z(j\omega) = \frac{\boldsymbol{V}(j\omega)}{\boldsymbol{I}(j\omega)} = \omega L \angle \frac{\pi}{2}.$$

Symbols

Z	Impedance	Ω
j	Imaginary unit	—
ω	Frequency	Hz
V	Voltage	V
I	Current	A
L	Inductance	H

6.2.3 Impedance of a Capacitor

$$Z(j\omega) = \frac{\boldsymbol{V}(j\omega)}{\boldsymbol{I}(j\omega)} = \frac{1}{\omega C} \angle - \frac{\pi}{2} = \frac{1}{j\omega C}.$$

Symbols

Z	Impedance	Ω
j	Imaginary unit	—
ω	Frequency	Hz
V	Voltage	V
I	Current	A
C	Capacitance	F

6.2.4 Total Impedance

$$Z(j\omega) = R(j\omega) + jX(j\omega).$$

Symbols

Z	Impedance	Ω
j	Imaginary unit	—
ω	Frequency	Hz
R	Resistance	Ω
X	Reactance	Ω

6.2.5 Admittance

$$Y = \frac{1}{Z}.$$

Symbols

Y	Admittance	§
Z	Impedance	Ω

6.3 Transient Analysis

6.3.1 1st Order Differential Equation for RC Circuits

$$\tau \frac{\mathrm{d}x(t)}{\mathrm{d}t} + x(t) = K_s f(t).$$

Symbols

τ	$\tau = a_1/a_0$ is a time constant	—
x	Voltage or current	—
t	Time	s
K_s	$K_s = b_0/a_0$ is DC gain	—

6.3.2 2nd Order Differential Equation for RLC Circuits

$$\frac{1}{\omega_n^2} \frac{\mathrm{d}x^2(t)}{\mathrm{d}t^2} + \frac{2\zeta}{\omega_n} \frac{\mathrm{d}x(t)}{\mathrm{d}t} = K_s f(t).$$

Symbols

ω_n	$\omega_n = \sqrt{a_0/a_2}$ is the natural frequency	Hz
ζ	$\zeta = a_1/2\sqrt{1/(a_0 a_2)}$ is the damping ratio	—
x	Voltage or current	—
t	Time	s
K_s	$K_s = b_0/a_0$ is DC gain	—

Lecture 6: Frequency Analysis

16. Februar 2026

7.1 Frequency Response Function

$$H_V(j\omega) = \frac{V_L(j\omega)}{V_S(j\omega)}.$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Frequency	Hz
V_L	Output voltage	V
V_s	Source voltage	V

7.1.1 Phase Shift due to the Frequency Response Function

$$V_L e^{j\phi_L} = |H_V| V_S e^{j(\angle H_V + \phi_S)}.$$

Symbols

V_L	Output voltage	V
j	Imaginary unit	—
ϕ_L	Output phase	—
ϕ_L	Output phase, $\phi_L = \angle H_V + \phi_s$	—
H_V	Frequency response function	—

V_s	Source voltage	V
ϕ_S	Source phase	—

7.2 Passive Filters

7.2.1 Cutoff Frequency

$$\omega_0 = \frac{1}{RC}.$$

Symbols

ω_0	Cutoff angular frequency	rad/s
R	Resistance	Ω
C	Capacitance	F

7.2.2 Low-Pass Filter

Frequency Response

$$H_V(j\omega) = \frac{1}{1 + j\omega CR} = \left|H_V(j\omega)\right| e^{j\angle H_V(j\omega)}.$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Frequency	Hz
C	Capacitance	F
R	Resistance	Ω

Magnitude of the Frequency Response

$$\left|H_V(j\omega)\right| = \frac{1}{\sqrt{1 + (\omega CR)^2}} = \frac{1}{\sqrt{1 + \left(\frac{\omega}{\omega_0}\right)^2}}.$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Angular frequency	rad/s
C	Capacitance	F
R	Resistance	Ω
ω_0	Cutoff angular frequency	rad/s

Phase of the Frequency Response

$$\angle H_V(j\omega) = -\tan^{-1}(\omega CR) = -\tan^{-1}\frac{\omega}{\omega_0}.$$

Symbols

H_V	Frequency response function	—

j	Imaginary unit	—
ω	Angular frequency	rad/s
C	Capacitance	F
R	Resistance	Ω
ω_0	Cutoff angular frequency	rad/s

7.2.3 High-Pass Filter

Frequency Response

$$H_V(j\omega) = \frac{j\omega CR}{1 + j\omega CR} = \left|H_V(j\omega)\right| e^{j\angle H_V(j\omega)}.$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Frequency	Hz
C	Capacitance	F
R	Resistance	Ω

Magnitude of the Frequency Response

$$\left|H_V(j\omega)\right| = \frac{\omega CR}{\sqrt{1 + (\omega CR)^2}}.$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Angular frequency	rad/s
C	Capacitance	F
R	Resistance	Ω

Phase of the Frequency Response

$$\angle H_V(j\omega) = 90^\circ - \tan^{-1}(\omega CR).$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Angular frequency	rad/s
C	Capacitance	F
R	Resistance	Ω

7.2.4 Bandpass Filter

Frequency Response

$$H_V(j\omega) = \frac{j\omega CR}{1 + j\omega CR + (j\omega)^2 LC} = \frac{jCR\omega}{\left(j\frac{\omega}{\omega_1} + 1\right)\left(j\frac{\omega}{\omega_2} + 1\right)}.$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Angular frequency	rad/s
C	Capacitance	F
R	Resistance	Ω
L	Inductance	H
ω_1	Lower angular cutoff frequency	rad/s
ω_2	Upper angular cutoff frequency	rad/s

Magnitude of the Frequency Response

$$\left|H_V(j\omega)\right| = \frac{CR\omega}{\sqrt{\left(1+\left(\frac{\omega}{\omega_1}\right)^2\right)\left(1+\left(\frac{\omega}{\omega_2}\right)^2\right)}}.$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Angular frequency	rad/s
C	Capacitance	F
R	Resistance	Ω
ω_1	Lower angular cutoff frequency	rad/s
ω_2	Upper angular cutoff frequency	rad/s

Phase of the Frequency Response

$$\angle H_V(j\omega) = \frac{\pi}{2} - \tan^{-1}\frac{\omega}{\omega_1} - \tan^{-1}\frac{\omega}{\omega_2}.$$

Symbols

H_V	Frequency response function	—
j	Imaginary unit	—
ω	Angular frequency	rad/s
ω_1	Lower angular cutoff frequency	rad/s
ω_2	Upper angular cutoff frequency	rad/s

Natural or Resonant Frequency

$$\omega_n = \sqrt{\frac{1}{LC}}.$$

Symbols

ω_0	Resonant or natural angular frequency	rad/s
L	Inductance	H
C	Capacitance	F

Quality Factor

$$Q = \frac{2}{\zeta} = \frac{1}{\omega_n CR} = \frac{1}{R}\sqrt{\frac{L}{C}}.$$

Symbols

Q	Quality	—
ζ	Damping Ratio	—
ω_0	Resonant or natural angular frequency	rad/s
C	Capacitance	F
R	Resistance	Ω
L	Inductance	H

Damping Ratio

$$\zeta = \frac{1}{2Q} = \frac{R}{2}\sqrt{\frac{C}{L}}.$$

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Symbols

ζ	Damping Ratio	—
Q	Quality	—
R	Resistance	Ω
C	Capacitance	F
L	Inductance	H

Bandwidth

$$B = \frac{\omega_n}{Q}.$$

Symbols

B	Bandwidth	rad/s
ω_0	Resonant or natural angular frequency	rad/s
Q	Quality	—

Lecture 7: Diodes

25. Februar 2026

8.1 Diodes

8.1.1 Net Diode Current in forward bias mode

$$I_D = I_0\left(e^{V_D \frac{q}{kT}} - 1\right).$$

Symbols

I_D	Current across diode	A
I_0	Leakage current at low voltage	A
q	Charge of an electron	$1{,}6 \cdot 10^{-19}$ C
V_D	Voltage across diode	V
k	Boltzman's constant	$1{,}3 \cdot 10^{-23}\ \frac{\mathrm{J}}{\mathrm{K}}$
T	Temperature	K