LaTeX Workshop

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What is LaTeX?

- A plain-text method of document preparation and typesetting
- *Compiled* into a document format (PDF, DVI, etc.)
- Started as an academic tool for mathematicians and computer scientists (Discrete, Algo!)
- Expansive set of packages on `CTAN`

Figure: The LaTeX Project Logo, CC BY 4.0

Comparison of LaTeX to Graphical Editors

WYSIWYG

- "Interpreted"
- Allows ambiguity
- More speed than control
- Platform-dependent
- Directly understood
- Combined composition and formatting

WYSIWYT

- Compiled
- Unambiguous (pedantic)
- More control than speed
- Portable
- Layer of Abstraction
- Seperated composition and formatting

4.2 Voltage Division

Using the series resistors construction from 4.1,

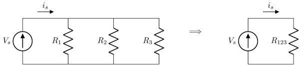
$$\frac{V_1}{V_s} = \frac{i_s R_1}{i_s R_{123}} = \frac{R_1}{R_{123}}$$

Voltage Division

For a resistor R_i where $1 \leq i \leq n$ in series with resistors R_1 ... R_n contributing to an equivalent resistance R_{eq}, the ratio of the total voltage across R_i,

$$\frac{V_i}{V_s} = \frac{R_i}{\sum_{j=1}^{n} R_j}$$

4.3 Resistors in Parallel



The three resistors R_1 R_2 and R_3 can be simplified into an equivalent resistor R_{123} just using Ohm's Law and KCL,

$$i_s = \frac{V_s}{R_1} + \frac{V_s}{R_2} + \frac{V_s}{R_3} = \frac{V_s}{R_{123}}$$

Resistors in Parallel

For resistors R_1 ... R_n, the equivalent resistance R_{eq},

$$\frac{1}{R_{eq}} = \sum_{i=1}^{n} \frac{1}{R_i}$$

Note that $R_{eq} < R_i \forall i$.

4.4 Current Division

Using the parallel resistors construction from 4.3,

$$\frac{i_1}{i_s} = \frac{\frac{V_s}{R_1}}{\frac{V_s}{R_{123}}}$$

Current Division

For a resistor R_i where $1 \leq i \leq n$ in parallel with resistors R_1 ... R_n contributing to an equivalent resistance R_{eq}, the ratio of the total current across R_i,

$$\frac{i_i}{i_s} = \frac{1}{R_1 \sum_{j=1}^{n} \frac{1}{R_j}}$$

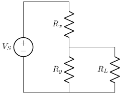
5 Lecture #5

5.1 Voltage Division and Loading

A voltage divider has already been covered in the context of resistors in series, but

Loading Resistor

What if an addition resistor (called the *Loading* resistor) is placed in parallel to a voltage divider?



To understand the behavior of this circuit, the three cases $R_L = 0$, $R_L = \infty$, and $R_L = l$ $(0 < l < \infty)$ show the general behaviour and the boundary cases. In the context of a voltage divider, the voltage across R_L shows the useful output voltage of the circuit.

Case 1: $R_L = 0$

$$\Delta V_L = 0$$

Here, there is a short across R_L, all of the current bypasses R_y and moves along the path of no resistance. R_L is functionally equivalent to a wire, which does not have any voltage drop.

Case 2: $R_L = \infty$

$$\Delta V_L = \frac{x}{x+y} V_S$$

With an extremely large resistance along the branch R_L, this reduced to the base case for a voltage divider, functionally only containing R_x and R_y.

Case 3: $R_L = l$

For the general case,

$$\Delta V_L = \frac{y \parallel l}{x + (y \parallel l)} V_S = \frac{\left(\frac{1}{y} + \frac{1}{l}\right)^{-1}}{x + \left(\frac{1}{y} + \frac{1}{l}\right)^{-1}} V_S$$

Math 2321 Final

Jack Leightcap

Chapter 1

Dot & Cross Product:

$$\vec{u}\cdot\vec{v} = \sum_{i=1}^{n} u_i v_i \qquad |\vec{u}\cdot\vec{v}| = |\vec{u}||\vec{v}|\cos(\theta)$$

$$\vec{u}\times\vec{v} = \begin{vmatrix} i & j & k \\ u_1 & u_2 & u_3 \\ v_1 & v_2 & v_3 \end{vmatrix} \qquad |\vec{u}\times\vec{v}| = |\vec{u}||\vec{v}|\sin(\theta)$$

Cross products returns normal vector

Area of parallelogram $|\vec{u}\times\vec{v}| \rightarrow$ Area of triangle $\frac{1}{2}|\vec{u}\times\vec{v}|$

Volume of parallelepiped $\begin{vmatrix} u_1 & u_2 & u_3 \\ v_1 & v_2 & v_3 \\ w_1 & w_2 & w_3 \end{vmatrix}$

Gradient Vector:

$$\vec{\nabla} f(x_1, x_2, \cdots, x_n) = (f_{x_1}, f_{x_2}, \cdots, f_{x_n})$$

Gradient vector returns normal vector

Chapter 2

Linearization:

In $\mathbb{R}^2$, $f(x)$ at a, $f(x) - f(a) = f'(a)(x-a)$. Using gradient,

$$\boxed{L(\underline{x}) - f(\underline{a}) = \vec{\nabla} f(\underline{a}) \cdot (\underline{x} - \underline{a})}$$

For a point $\underline{b}$ close to $\underline{a}$, $f(\underline{b}) \simeq L(\underline{b})$

Multivariable Chain Rule:

$$\frac{df}{dt} = \frac{\partial f}{\partial x}\frac{dx}{dt} + \frac{\partial f}{\partial y}\frac{dy}{dt} + \frac{\partial f}{\partial z}\frac{dz}{dt} = \vec{\nabla} f \cdot \left(\frac{dx}{dt}, \frac{dy}{dy}, \frac{dz}{dy}\right)$$

Evaluating at a point $t = t_0$, need to find corresponding point $t = t_0 \implies (x, y, z) = (a, b, c)$,

$$\boxed{\left.\frac{df}{dt}\right|_{t=t_0} = \vec{\nabla} f(a, b, c) \cdot \left(\left.\frac{dx}{dt}\right|_{t=t_0}, \left.\frac{dy}{dt}\right|_{t=t_0}, \left.\frac{dz}{dt}\right|_{t=t_0}\right)}$$

Directional Derivative:

Derivative in direction of unit vector $\vec{u}$ at point $\underline{p}$,

$$\boxed{D_{\vec{u}} f(\underline{p}) = \vec{\nabla} f(\underline{p}) \cdot \vec{u}}$$

Maximum:	direction $\vec{\nabla} f(\underline{p})$	magnitude $\lvert\vec{\nabla} f(\underline{p})\rvert$
Minimum:	direction $-\vec{\nabla} f(\underline{p})$	magnitude $-\lvert\vec{\nabla} f(\underline{p})\rvert$

Local Regular Parametrization:

For parametrization $\vec{r}(u, v)$ at point (u_o, v_0), local regular if

$$\vec{r}_u(u_0, v_0) \times \vec{r}_v(u_0, v_0) \neq \vec{0}$$

$z = f(x, y)$, $\quad \vec{r}(u, v) = (u, v, f(u, v))$ local regular.

Hessian Matrix:

$$\boxed{D(x, y) = \begin{vmatrix} f_{xx} & f_{xy} \\ f_{yx} & f_{yy} \end{vmatrix} = f_{xx} f_{yy} - f_{xy}^2}$$

At a point (a, b),

$D(a, b) > 0$	$f_{xx}(a, b)$ or $f_{yy}(a, b) > 0$	*local minimum*
$D(a, b) > 0$	$f_{xx}(a, b)$ or $f_{yy}(a, b) < 0$	*local maximum*
$D(a, b) < 0$		*saddle point*

Extrema:

Given a function f optimized over restriction function g, if restriction has interior,

Interior critical points: points (a, b) such that $\vec{\nabla} f(a, b) = \vec{0}$

Boundary critical points:

Traditional method: eliminate variable from f using g. Break up the boundary into sections parametrized by one variable. This reduces to finding extrema of one variable functions, where the endpoints must be considered.

Lagrange Multipliers: $\vec{\nabla} f = \lambda \vec{\nabla} g$, system in addition to g.

Chapter 3

Coordinate Conversions:

(x, y, z)	(r, θ, z)	(x, y, z)	(ρ, θ, ϕ)
x	$r\cos(\theta)$	x	$\rho\cos(\theta)\sin(\phi)$
y	$r\sin(\theta)$	y	$\rho\sin(\theta)\sin(\phi)$
z	z	z	$\rho\cos(\phi)$
$x^2 + y^2$	r^2	$x^2 + y^2 + z^2$	ρ^2
dV	$r dr dz d\theta$	dV	$\rho^2 \sin(\phi) d\rho d\phi d\theta$

Polar is cylindrical coordinates where $z = 0$ and without dz.

Iterated Integrals:

$$\text{Area} = \iint_D dA \qquad \text{Mass} = \iint_D \delta(x, y) dA$$

$$\text{Volume} = \iiint_E dV \qquad \text{Mass} = \iiint_E \delta(x, y, z) dV$$

where δ are density per unit area / unit volume.

Surface Area:

Surface parametrized by $\vec{r}(u, v)$, then at point (u_0, v_0) $\vec{r}_u(u_0, v_0)$ and $\vec{r}_v(u_0, v_0)$ linearly independent tangent vectors, so

$$dS = |\vec{r}_u(u_0, v_0) \times \vec{r}_v(u_0, v_0)| du dv$$

Integrating over surface D,

$$\boxed{\text{Surface Area} = \iint_D |\vec{r}_u(u_0, v_0) \times \vec{r}_v(u_0, v_0)| du dv}$$

If $z = f(x, y)$, then $\vec{r}(u, v) = (u, v, f(u, v))$,

$$\text{Surface Area} = \iint_D \sqrt{f_x^2 + f_y^2 + 1} dx dy$$

Chapter 4

Gradient Operator, Divergence, Curl:

$$\vec{\nabla} = \left(\frac{\partial}{\partial x_1}, \frac{\partial}{\partial x_2}, \cdots\right) \qquad \text{div}(\vec{F}) = \vec{\nabla} \cdot \vec{F} \qquad \text{curl}(\vec{F}) = \vec{\nabla} \times \vec{F}$$

2D curl: for $\vec{F} = (P, Q)$, then z component of curl is named

$$\text{curl}_{\mathbb{R}^2}(\vec{F}) = Q_x - P_y$$

Line Integrals:

In a force field $\vec{F} = (P, Q)$, a curve C parametrized by $\vec{r}(u)$ where $u_0 \leq u \leq u_1$, then the work is

$$W = \int_C \vec{F} \cdot d\vec{r} = \int_{u_0}^{u_1} \vec{F}(\vec{r}(u)) \cdot \vec{r}'(u) du$$

Green's Theorem:

For a closed curve ∂R that bounds the region R,

$$\boxed{\int_{\partial R} \vec{F} \cdot d\vec{r} = \iint_R Q_x - P_y dA}$$

If the curve C can be closed by a simple line segment L, then $C^* = C + L$ where C^* is the concatenation of C and L that encloses the region D. Then,

$$\int_C \vec{F} \cdot d\vec{r} = \int_{C^*} \vec{F} \cdot d\vec{r} - \int_L \vec{F} \cdot d\vec{r}$$

Green's Theorem can be applied to C^*, and L can be split,

$$\int_C \vec{F} \cdot d\vec{r} = \iint_D Q_x - P_y dA - \int_L P dx + Q dy$$

For simple line segments, dx or dy are 0, and x or y constants.

Flux Integral:

For a region D, parametrized by $\vec{r}(u, v)$ over the domain R,

$$\text{Flux} = \iint_D \vec{F} \cdot \vec{n} dS = \iint_R \vec{F}(\vec{r}(u, v)) \cdot (\vec{r}_u(u, v) \times \vec{r}_v(u, v)) du dv$$

Divergence Theorem:

For a closed surface ∂E that bounds the solid region E,

$$\boxed{\text{Flux} = \iint_{\partial E} \vec{F} \cdot \vec{n} dS = \iiint_E \vec{\nabla} \cdot \vec{F} dV}$$

Similarly to Green's Theorem, if D can be closed by a simple surface E, then $D^* = D \cup E$ is the union of D and E that encloses the solid region F. E must have a normal vector such that D^* is oriented outward.

$$\iint_D \vec{F} \cdot \vec{n} dS = \iint_{D^*} \vec{F} \cdot \vec{n} dS - \iint_E \vec{F} \cdot \vec{n} dS$$

The Divergence Theorem can be applied to D^*,

$$\iint_D \vec{F} \cdot \vec{n} dS = \iiint_F \vec{\nabla} \cdot \vec{F} dV - \iint_E \vec{F} \cdot \vec{n} dS$$

For a simple surface E, $\vec{n}$ points along an axis.

Stokes' Theorem:

$$\boxed{\int_{\partial R} \vec{F} \cdot d\vec{r} = \iint_R (\vec{\nabla} \times \vec{F}) \cdot \vec{n} dS}$$

Stokes' Theorem is a generalization of Green's Theorem where $\vec{n} \neq (0, 0, 1)$.

Stokes' Theorem simplifies problems where R shares a boundary with a simpler shape of a compatible orientation.

How to use LaTeX

Windows

- MiKTeX
- TeX Live

Mac OS

- MacTeX

Other

- Editors: vim and `vimtex`, emacs and `AUCTeX`
- IDE: VSCode and `LaTeX Workshop`
- Online: Overleaf (what we'll be using today)

Typesetting a Basic Document: Document Classes

- All documents must include a `\documentclass{CLASS}`.
- A set of defaults for specific use cases
- `\documentclass[12pt, letterpaper]{article}`, size 12 font article
- `report`, longer documents, dissertation
- `beamer`, what made these slides

Typesetting a Basic Document: Environments

- `\begin{FOO}` must be matched with `\end{FOO}`, and everything between is in the `FOO` *environment*.
- `document`: a. . . document!
- `itemize`: this kind of bullet point list
- `center`: horizontally centered
- `tabular`: tables
- can define custom environments

Time for a practical example, over to Overleaf!

Helpful Tools

General:

- Overleaf has extensive documentation
- Detexify – remembering LaTeX commands is hard

Packages:

- `siunitx`: anything with units
- `circuitikz`: circuit diagrams
- `minted`: syntax highlighted code blocks
- `amsmath`, `amssymb`: extended math support