PHYS272: General Physics II: Electricity & Magnetism
Spring 2021: January 11–May 14
MWF 9:00–9:50 AM HST (lecture) & F 3:00–4:15 PM HST (recitation)
Zoom meeting: https://hawaii.zoom.us/j/99448332047
ID: 994 4833 2047 *Passcode:* 272enm

Version 6: April 16, 2021 (subject to change)

Professor: Dr. Kathy Cooksey; STB 220; kcooksey@hawaii.edu; 808-932-7195

Office Hours: M 2–3 PM HST; W 10 AM–12 PM HST; F 12–1 PM HST; and by appt.; in-person or Zoom

Zoom meeting: https://hawaii.zoom.us/j/93811629543

ID: 938 1162 9543 *Passcode:* 2665739 ("Cooksey")

Website: Laulima PHYS-272-001 (HIL.10338.SP21)

Textbook: *University Physics Volumes 2 & 3* from OpenStax (ISBN 1947172212 & 1947172220)
Available for free online, in web view or PDF format:
https://openstax.org/details/books/university-physics-volume-2.
Students are *strongly* encouraged to donate to OpenStax for their efforts to provide free, quality textbooks: https://openstax.org/give.

Course Description:
Introductory calculus-based physics designed for students majoring in physical sciences or engineering. Covers electric fields and potentials, magnetic fields, Maxwell's equations and basic optics. One class hour is dedicated to the development of problem-solving skills in small-group sessions.
Pre-requisites: MATH242 and C or better in PHYS170

Learning Objectives:

- Broad course goals:
  1. Extend fundamental principles from PHYS170—problem solving, vectors, dynamics (forces and torques), energy conservation—to electricity and magnetism (E&M). Notably, PHYS170 (mechanics) primarily focused on the macroscopic world and was challenging because of the abstraction; PHYS272 continues the abstraction into the microscopic world that is more challenging to visualize.
  2. Understand the principles of E&M upon which our modern society is based such as circuits, electromagnetic waves, and optics.
  3. Be able to derive many other useful equations from a set of fundamental equations.
  4. Practice and improve problem-solving skills, especially in how: (i) an approach is motivated; (ii) a solution is formatted; and (iii) the solution is verified to be reasonable.
  5. Communicating/presenting solutions to problems and solving problems in real time, in front of another.
  6. Learn/practice "reading" equations and figures for information so that even unfamiliar equations or figures can be assessed for their meaning.
- Specific content goals:
  1. Manipulating equations algebraically/symbolically makes the resulting equation applicable to all situations with the same boundary conditions.
  2. Dimensional analysis is a way of solving problems and "reverse engineering" equations.

3. Physical quantities have units that are used to understand the physical quantities, solve problems, and support intuition about the relative scales of physical quantities.
4. Fields, field lines, and equipotential curves are visual representations of how small test charges (particles) will move in the presence of charge, current distributions, and/or external magnetic fields.
5. Different charge or current distributions result in different scalings for E&M fields and understanding these general trends aids in assessing specific problems with similar geometry.

Email, Textbook, and Website:

- UHH considers email and Laulima an official form of communication; students are responsible for receiving and returning information in a timely manner.
- The professor will email students at their `hawaii.edu` accounts only.
- Students must have: reliable internet access;[1] a Zoom account and the necessary A/V equipment[2] to participate remotely; and a scanner or equivalent capability[3] to produce a PDF from hand-written work.
- The required textbook is *University Physics Volumes 2 & 3* from OpenStax (ISBN 1947172212 & 1947172220).
  - It is available for free online, in web view or PDF format: https://openstax.org/details/books/university-physics-volume-2.
  - Students are *strongly* encouraged to donate to OpenStax for their efforts to provide free, quality textbooks: https://openstax.org/give.
- The Laulima[4] course website PHYS-272-001 (HIL.10338.SP21) will be the hub for all course information.

Class Rules:

- Students are responsible for their own learning, which includes preparing for class, submitting work, asking questions, and seeking additional help.
  - College is the last time someone will ask you to do something hard and help you do it. The majority of college students use instructors' office hours.
  - Office hours are good times to get individualized help from the expert (i.e., the instructor), and office hours are part of the instructor's job.
- Students must respect and support their peers' learning, which means helping each other with difficult concepts but not just giving the answer.
- Students need to convey (either in person, by email, through an intermediary, or somehow) to the professor questions, comments, and concerns about the course.
- The professor will be receptive to and respectful of the students' needs and interests and must generally follow the class rules as detailed for the students (also see next section).
- Group work is encouraged in class and for homework assignments. However, all submitted work must be the original work of the student with reference to any homework partners.

[1] UH Hilo has increased Wi-Fi capacity to include all parking lots; see https://hilo.hawaii.edu/help/wifi/.

[2] Laptops are available for checkout at the UH Hilo library; see https://hilo.hawaii.edu/library/laptops.

[3] A smartphone and an app like CamScanner (https://www.camscanner.com/) can be used to produce legible PDFs.

[4] If you need Laulima help, click the Request Assistance link at any page on Laulima: http://www.hawaii.edu/simp/laulima-feedback.php. Or go to UH System Help Desk: https://www.hawaii.edu/its/help-desk/.

- All references (e.g., websites, books other than the official course textbook, etc.) used to complete assignments must be cited, including numbers, techniques, facts, etc.
- Solutions to problems must show sufficient supporting work to receive full points. A complete solution includes: proper problem setup (e.g., state assumptions, define knowns and unknowns as variables, draw and label a figure); sufficient work to follow substitutions and reductions (typically symbolically first, then numeric substitution); and assessment of solution (units but also order of magnitude). See the Problem-Solving Strategy section below.
- The professor will take attendance each class even though attendance is not part of the grade (see Grading below). Any student who misses a week of class without communicating with the professor will be made inactive on Laulima, meaning s/he cannot access course materials until meeting with the professor.
- An ABCD voting card is expected in every class; `ABCD_VotingCard.pdf` is available under Laulima:Resources.
- A non-smart-phone calculator is required for every class. Students should practice with the calculator they will use for quizzes, tests, and the final exam.
- *COVID-19 Online Instruction*—whole semester:
  - Lectures will be live via Zoom. Students must have reliable internet access,[1] a Zoom account, and the necessary A/V equipment[2] to participate remotely (i.e., webcam, mic, and speakers or headphones).
  - Lectures will not be recorded. Students are encouraged to learn how to take quick screen shots (the online equivalent of taking a picture of the whiteboard).
  - If a student misses lecture, s/he should, in the following order: review any posted material; get the notes from a peer; and ask the professor any follow-up questions. (In addition to contacting the professor, see Grading section below.)
  - The professor wants to see the students so webcams must be on and students visible the majority of the time.
  - Students will be participating during lecture. To facilitate explanations, students should have spare paper and a dark pen or a whiteboard and marker on hand, so they can hold up equations or sketches to their webcam.

Good-to-Know about the Professor:

- She enjoys teaching and wants to be better at it, and she really cares about helping students be better. These aspects combined mean she is on the students' side; trust in that and knowledge that she is receptive to feedback will smooth over rough patches.
- She chooses teaching techniques based on physics-education research to support student learning as best as possible. This means she has one or more reasons for nearly every component of and action in a course. She'll gladly motivate these choices whenever necessary or asked.
  - The COVID-19 pandemic has led to the professor teaching online. She still endeavors to use best practices, even given the new constraints.
- Her primary goal is to help students improve *how* they learn with the logic that if students learn how to learn, they can master any content. The related goal is to focus on transferrable skills so that time and effort spent for the class yield benefits beyond the course and semester.
- Generally, she does not answer questions directly. A student making connections and constructing a solution her- or himself will ingrain the answer more effectively, and the professor facilitates the process by asking leading questions. Since the motivation is to help the students, they should embrace and engage with this process. (It is also a transferrable skill to discuss ideas and answer questions on the fly.)
- She designs quizzes, tests, and exams so that no one gets 100% and no one gets 0% because either score would not be useful in assessing what the students understand and how to help. The percentage reflects what the student knows of what s/he could have learned; the letter grade reflects what the student learned and how much s/he has improved.
  The rule-of-thumb is to score above the median (see Grading below). She has no interest in failing students who make good-faith effort in the class (e.g., good attendance, submit completed work, ask questions in and out of class).
- She thinks no single resource is comprehensive, so the expectation is that the student will have to work with the professor, her materials, the textbook, and the wealth of material available on the internet.
- The expectation is that a course requires 2–3 hr outside-of-class time per credit per week. Hence a 15-cr semester equals 30–45 hr per week (i.e., a full-time job).
- She checks and responds to email twice each workday; thus people can expect a response within 24-to-48 hours. If the matter is urgent, the student should call (office voicemail is automatically emailed) or "stop by her office" (try office-hour Zoom); her general weekly schedule is on her homepage: http://www2.hawaii.edu/~kcooksey.

General Course Outline (subject to change)

Reading assignments must be read *before* the class in which they will be reviewed. A good-faith effort to understand the reading will improve learning during lecture. Lectures include active-learning strategies (e.g., think-pair-share conceptual questions). Names may be randomly drawn for students to share their thoughts on questions. The professor will strive to make the classroom a safe and collegial environment for students to share their understanding, which—since the purpose of the course is to learn—will often be incomplete.

> This course builds on PHYS170 principles and is an opportunity to reinforce understanding of its content. The professor will review as we go along. Students should also turn to their PHYS170 material (or OpenStax *University Physics Volume 1*, https://openstax.org/details/books/university-physics-volume-1) early and often.

Homework (HW) are due every two weeks, on Wednesday, at class time; they are typically three conceptual free-response questions and 12–17 quantitative problems total. They are distributed via Laulima:Resources and include recitation problems (see below). One problem will be graded in detail for half the points; the rest will be checked for completeness (e.g., attempt, "The Format") for the other half. Homework are to be uploaded to Laulima:Drop Box as one or a few clear, organized, and clearly labeled PDF(s); a scanner or equivalent[3] is necessary. Feedback will be given on the PDF(s); this includes about the quality of submission, which must be addressed before the next homework upload. The professor reserves the right to *not* grade unclear, disorganized, poorly labeled, or non-PDF solutions. There is a 24-hr late deadline, at a 25% penalty; the professor will grade mixed on-time+late submissions to maximize the student's points. Complete solutions will be posted after the late deadline.

> Note: grading of homework is a compromise. The professor would normally have in-class quizzes on the homework (one problem given verbatim, only Equation Sheet allowed). However, given the likely difficulties with a online course and uncertainty induced by the pandemic, real-time professor-student interaction is precious, thus lecture will predominately be reserved for teaching—and, ideally, learning.

Recitations (Rec) are problem-solving sessions every Friday afternoon. Typically, the pattern will be: (i) the students will work in small groups to brainstorm solutions to a set of problems. (ii) Then, the professor will facilitate the whole section in solving as many of the problems as possible. The problem set will be more than can be finished in the allowed time and will be part of an upcoming homework.

There are three tests, on Wednesday, during non-homework weeks; all content from a cutoff and earlier are fair game, including problems. The cutoff is determined by what assignments have been submitted and have solutions posted (hence the assignment(s) named in the square brackets by the scheduled quiz below). This pattern is designed so that students have a chance to: (i) learn the material via lecture and assignments; (ii) practice the content via assignments; and (iii) receive feedback via graded work and/or posted solutions. Thus, there is a lag between material being the focus of lecture and when the material will be on a quiz. The format of the tests and cumulative final exam are to be determined.

Detailed schedule: (subject to change)

Date	Topic	Activity
M Jan 11	L1. PHYS272 overview	Complete pre-quiz online
	Read "Secret to Raising Smart Kids" (Dweck) and complete Survey #1 (under Laulima:Assign., Tests & Surveys)	
W Jan 13	L2. PHYS170 Review (review §§1.3–1.4,1.7; Ch 2; §§3.4–3.6; §§4.3–4.4; Ch 5; §§6.1,6.3, OpenStax *Univ. Phys. Vol. 1*)	
F Jan 15	L3. Electricity I (§§5.1–5.3)	
F Jan 15	Rec#1: "PHYS170 Review"	
M Jan 18	*MLK Day (no class)*	
W Jan 20	L4. Electricity II (§5.4, §5.6)	
F Jan 22	L5. Electricity III (§5.5, §5.7)	
F Jan 22	Rec#2: "Electricity I"	
M Jan 25	L6. Electricity IV (§§6.1–6.2)	
W Jan 27	L7. Electricity V (§§6.3–6.4)	*HW#1: "Electricity I" (incl. Rec#1–2; dueW Feb 10)*
F Jan 29	L8. Electricity VI (§§7.1–7.2)	
F Jan 29	Rec#3: "Electricity II"	
M Feb 1	L9. Electricity VII (§7.3)	
W Feb 3	L10. Electricity VIII (§§7.4–7.6)	*Note: last day to w/d w/o 'W'*
F Feb 5	L11. dc Circuits I (§9.1, §§8.1–8.2)	
F Feb 5	Rec#4: "Electricity III"	
M Feb 8	L12. dc Circuits II (§§8.3–8.5)	
W Feb 10	L13. dc Circuits III (§§9.2–9.4)	HW#1 due (incl. Rec#1–2); *HW#2: "Electricity II" (incl. Rec#3–4; due W Feb 24)*
F Feb 12	L14. dc Circuits IV (§§9.5–9.6)	
F Feb 12	Rec#5: "dc Circuits I"	
M Feb 15	*President's Day (no class)*	
W Feb 17	L15. dc Circuits V (§§10.1-10.2)	
F Feb 19	L16. dc Circuits VI (§10.3)	
F Feb 19	Rec#6: "dc Circuits II"	
M Feb 22	L17. dc Circuits VII (§§10.4–10.6)	
W Feb 24	L18. dc Circuits VIII	HW#2 due (incl. Rec#3–4); *HW#3: "dc Circuits I" (incl. Rec#5–6; due W Mar 10)*
F Feb 26	L19. Magnetism I (§§11.1–11.2)	
F Feb 26	Rec#7: "dc Circuits III"	
M Mar 1	L20. Magnetism II (§11.3)	
W Mar 3	Test #1:"Electricity" [HW#1–2, Rec#1–4]	
F Mar 5	L21. Magnetism III (§11.4)	*Survey #2: Mid-course evaluation (due F Mar 12)*
F Mar 5	Rec#8: "Magnetism I"	
M Mar 8	L22. Magnetism IV (§11.5)	
W Mar 10	L23. Magnetism V (§§11.6–11.7)	HW#3 due (incl. Rec#5–6); *HW#4: "dc Circuits II & Magnetism I" (incl. Rec#7–8; due W Mar 24)*
F Mar 12	L24. Magnetism VI (§§12.1–12.2)	
F Mar 12	Rec#9: "Magnetism II"	
Mar 15–19	*Spring recess (no class)*	*Daylight savings time begins 2 AM Sun Mar 14; HST does not change*
M Mar 22	L25. Magnetism VII (§§12.3–12.4)	
W Mar 24	L26. Magnetism VIII (§§12.5–12.7)	HW#4 due (incl. Rec#7–8); *HW#5: "Magnetism II" (incl. Rec#9; due W Apr 7)*
F Mar 26	*Prince Kuhio Day (no class)*	
M Mar 29	L27. Magnetism IX	*Note: last day to w/d w/'W'*
W Mar 31	Test #2: "dc Circuits & Magnetism" [HW#3–4, Rec#5–8]	
F Apr 2	*Good Friday (no class)*	
M Apr 5	L28. Electromagnetism I (§§13.1–13.3)	
W Apr 7	L29. Electromagnetism II (§§13.4–13.7)	HW#5 due (incl. Rec#9); *HW#6: "Electromagnetism I" (incl. no Rec.; due W Apr 21)*
F Apr 9	L30. Electromagnetism III (§§14.1–14.3)	
F Apr 9	Rec#10: "Electromagnetism I"	
M Apr 12	L31. Electromagnetism IV (§14.4)	
W Apr 14	L32. Electromagnetism V (§§14.5–14.6)	
F Apr 16	L33. ac Circuits I (§§15.1–15.2)	
F Apr 16	Rec#11: "Electromagnetism II"	
M Apr 19	L34. ac Circuits II (§15.3)	
W Apr 21	L35. ac Circuits III (§§15.4–15.6)	HW#6 due (incl. no Rec.); *HW#7: 'EM II & ac Circuits" (incl. Rec#10–11; due W May 5)*
F Apr 23	L36. ac Circuits IV	
F Apr 23	Rec#12: ac Circuits	
M Apr 26	L37. EM Waves I (§§16.1–16.2)	
W Apr 28	Test #3: "Electromagnetism" [HW#5–6, Rec#9]	
F Apr 30	L38. EM Waves II (§§16.3–16.5)	
F Apr 30	Rec#13: "EM Waves"	
M May 3	L39. Course Synthesis	
W May 5	*(no lecture)*	HW#7 due (incl. Rec#10–11); complete course evaluations & post-quiz online
M May 10	Final Exam	7:30–9:30 AM (trust but verify)

Grading:

- The grade depends on the following categories: homework (35%); tests (40%); final exam (20%); and completing pre/post-quizzes (5%).
  - Homework is to be uploaded to Laulima:Drop Box as one or a few clear, organized, and clearly labeled PDF(s); a scanner or equivalent[3] is necessary. The professor reserves the right to *not* grade unclear, disorganized, poorly labeled, or non-PDF solutions.
  - The lowest homework grade will be dropped. There is a hard 24-hr late deadline, at a 25% penalty.
  - If a student notices an inconsistency in the professor's grading, s/he should ask; it might be a mistake or it might be a subtle point. Students are encouraged to ask questions about grading.
- Attendance is recorded but not part of the grade. Attendance is only required for tests and the final exam.
  - If a student must miss a class for a reasonable reason, s/he should email the professor before the start of class time.
  - If a student were unable to email in advance due to extreme circumstances, s/he should contact the professor as soon as possible. Such instances will be judged on a case-by-case basis.
    * In such (and similar) situations, the student is strongly encouraged to contact the Dean of Students Christopher Holland (cjh2020@hawaii.edu). He and Student Services (info below are liaisons between students and instructors, when Life adversely impacts Academics. If Student Services intervenes on a student's behalf, the professor will work to accommodate any missed content and points.
- If a student must miss test or the final exam for a reasonable reason, please discuss the options with the professor as soon as possible.
  - Homework is never excused because their deadlines are known in advance and there is a late deadline.
  - If a student were excused from an assignment, the graded work will not be included in her/his final grade.
  - If a student were excused from all points in a given category, the percentage of the other categories will be increased to fill the void.
- Cheating is not tolerated. Any question of cheating will be tested with an oral exam, to see whether the student(s) involved understand the material. Cheating will result in a zero for the item in question and a report to the University. It may result in immediate failure of the course.
- The final letter grade will be given based on the class statistics (e.g., the 25^{th}, 50^{th}/median, 75^{th} percentiles). The goal is to score higher than the median on all graded work. The expectation is that final grades higher than the median will pass with at least a C and that the 25^{th} to 50^{th} percentiles will likely earn something in the C range. A percentage grade of less than 50% is expected to receive no higher letter grade than a C−.
  - The instructor will give projected final letter grades after each test so the students know where they stand.

Problem-Solving Strategy (AKA "The Format"): This is the explicit format expected for solutions to all quantitative problems. It is not required for conceptual problems (though may be useful).

Student's Name
Collaborator(s):

PHYS272 Homework #X

1. Problem title or very brief description

   Physics Category
   - Identify the broad category under which the problem falls because this reduces the set of concepts and equations that will be useful.
   - The broadest categories reflect the course modules (e.g., "electric potential" or "magnetic field") but being more specific can be useful (e.g.,"electric potential (extended charge distribution)" or "magnetic field (current-carrying wire)").

   Definitions
   - Define the variables to represent the known/given quantities (with units) and the unknown/target quantities.
   - Use informative symbols for the variables; subscripts are useful.
   - Often a diagram is a useful way to define the known and unknown variables.

   Algebraic Derivation
   - Write the basic equations on which the solution is based, in terms of the defined variables. There should be as many equations as unknowns.
   - Algebraically manipulate the equations to reduce and simplify.

   Numeric Substitution
   - If the problem requires a numeric answer, substitute into the reduced equation (while tracking units explicitly) and compute the result.

   Assessment
   - Check the units come out correctly (even if it's a non-numeric answer).
   - If it's a numeric answer, check the order-of-magnitude, else justify the derived equation scales reasonably with each variable.
   - Clearly justify that the final answer is reasonable. Units and order-of-magnitude/scaling are two "sanity checks" but also demonstrate understanding of expectation based on physics.
     - If result is not expected, discuss whether this is the point (e.g., learning, new intuition) or if it seems incorrect.
     - If the latter, then attempt to explain what is wrong (and earn back points).

2. Problem title or very brief description

   Physics Category
   Definitions
   Algebraic Derivation
   Numeric Substitution
   Assessment

3. *...wash, rinse, repeat*

Content Not on Equation Sheet: Below are a combination of fundamental concepts in physics that must be learned (which is more than memorized) and relationships that can be derived from fundamental concepts and given equations. This is not a comprehensive list.

- This section (Content Not on Equation Sheet) of the PHYS170 Syllabus; see the latest version of PHYS170 Syllabus at: http://guavanator.uhh.hawaii.edu/~kcooksey/teaching/UHH/UHH.html.
- The following relevant content that was on the PHYS170 Equation Sheet (see link above) but not on PHYS272 Equation Sheet:
  - Gravitational acceleration at Earth's surface: $g = 9.806\,\mathrm{m\,s^{-2}}$
  - Kinematic equation:[5] $\vec{\mathbf{v}} = \vec{\mathbf{v}}_0 + \vec{\mathbf{a}}t$
  - Kinetic energy:[5] $K = \frac{1}{2}Mv^2$
  - Ideal gas law (gas pressure): $PV = \mathcal{N} k_\mathrm{B} T$, where $\mathcal{N}$ is number of particles. and k_B is Boltzmann constant.
  - Temperature: $T_{(^\circ\mathrm{C})} = T_{(\mathrm{K})} - 273$ and $T_{(^\circ\mathrm{C})} = \frac{5}{9}\left(T_{(^\circ\mathrm{F})} - 32\right)$
  - Impulse:[5] $\vec{\mathbf{J}} = \int\limits_{t_0}^{t_\mathrm{f}} \vec{\mathbf{F}}_\mathrm{net}dt = \vec{\mathbf{p}}_\mathrm{f} - \vec{\mathbf{p}}_0$
  - Power: $P = \frac{dW}{dt}$
  - Gravitational potential energy: $U(r) = -\frac{GM_1M_2}{r}$
  - Potential energy of particle near Earth's surface: $U(y) = Mgy + \text{constant}$
  - Period (T)-frequency (f) relation: $T = \frac{1}{f}$
  - Wavelength (λ)-frequency relation: $v = \lambda f$
  - **Calculus**
    * $\frac{d}{dx}f(x) \equiv \lim\limits_{\Delta x \to 0}\left(\frac{f(x+\Delta x) - f(x)}{\Delta x}\right)$
    * Chain rule: $\frac{d}{dx}f(y) = \frac{df(y)}{dy}\frac{dy}{dx}$
    * Product rule: $\frac{d}{dx}\big(f(x)g(x)\big) = f(x)\frac{dg(x)}{dx} + g(x)\frac{df(x)}{dx}$
    * $\int\limits_{x_0}^{x+\mathcal{N}\Delta x} f(x)dx \equiv \lim\limits_{\Delta x \to 0}\left(\sum_{n=1}^{\mathcal{N}} f(x_0 + n\Delta x)\Delta x\right)$
    * $\int\limits_{x_\mathrm{A}}^{x_\mathrm{B}} \frac{d}{dx}f(x) = f(x_\mathrm{B}) - f(x_\mathrm{A})$
    * $\frac{d}{dx}\left(x^n\right) = nx^{n-1}$

[5] Also applicable to fixed-axis rotating systems with appropriate substituions of $\vec{\boldsymbol{\theta}}$, $\vec{\boldsymbol{\omega}}$, $\vec{\boldsymbol{\alpha}}$, I, $\vec{\boldsymbol{\tau}}$, and/or $\vec{\mathbf{L}}$.

- **Geometry**
  - Radian: $2\pi\,\text{rad} = 360°$
  - Circumference of a circle: $s = 2\pi r$
  - Area of a circle: $A = \pi r^2$
  - Area of a triangle: $A = \frac{1}{2}bh$
  - Area of a trapezoid: $A = \frac{1}{2}(a+b)h$
  - Surface area of a cone: $A = \pi r\left(r + \sqrt{h^2 + r^2}\right)$
  - Volume of a cone: $V = \frac{1}{3}\pi r^2 h$
- **Trigonometry** (see figure on Equation Sheet)
  - Pythagorean theorem: $a^2 + b^2 = c^2$
  - $\angle A + \angle B + \angle C = 180° = \pi\,\text{rad}$

- **Normal unit vector:** $\hat{\mathbf{n}}$ points perpendicular to a surface: $d\vec{\mathbf{A}} = dA\,\hat{\mathbf{n}}$

- **Right-hand rule:** As in PHYS170 Content Not on Equation Sheet (finger curl rule, palm rule, and "gang sign") but also in application to determine magnetic field $\vec{\mathbf{B}}$ of current-carrying wire.
  - In most cases, place right thumb in direction of current and right fingers curl in direction of $\vec{\mathbf{B}}$.
  - For coils of wire, curl right-hand fingers in direction of current and thumb points in direction of $\vec{\mathbf{B}}$.

  For the induced current I_{ind}, place right thumb in the direction we want the induced magnetic field $\vec{\mathbf{B}}_{\text{ind}}$ from the loop, right fingers curl in direction of I_{ind}.

- ***Meaning* of Maxwell's Equations:**
  - Gauss's Law: Electric flux $\Phi_E = \underset{\substack{\text{closed}\\\text{surf}}}{\oiint} \vec{\mathbf{E}} \bullet d\vec{\mathbf{A}} = \dfrac{Q_{\text{free,encl}}}{\varepsilon_0}$

    means charges create *diverging* electric fields
  - Ampére-Maxwell Law: $\underset{\text{contour}}{\oint} \vec{\mathbf{B}} \bullet d\vec{\boldsymbol{\ell}} = \mu_0\left(I_{\text{encl}} + \varepsilon_0 \dfrac{d\Phi_E}{dt}\right)$

    means current and changing electric fields create *curling* magnetic fields
    - The definition of a displacement current is: $I_{\text{disp}} = \varepsilon_0 \dfrac{d\Phi_E}{dt}$
  - Magnetic Gauss's Law: $\underset{\substack{\text{closed}\\\text{surf}}}{\oiint} \vec{\mathbf{B}} \bullet d\vec{\mathbf{A}} = 0$

    means no *magnetic* monopoles
  - Faraday's Law: $\underset{\text{contour}}{\oint} \vec{\mathbf{E}} \bullet d\vec{\boldsymbol{\ell}} = -\dfrac{d\Phi_B}{dt} = -\dfrac{d}{dt}\left(\iint \vec{\mathbf{B}} \bullet d\vec{\mathbf{A}}\right)$

    means changing magnetic flux can induce *curling* electric fields

- **Electric Force, Field, & Potential**
  - Electric or **Coulomb force** of point charges (force on Q_1 due to Q_2):
    $\vec{\mathbf{F}}_{E,12}(r) = -\frac{k_e Q_1 Q_2}{r^2}\,\hat{\mathbf{r}}_{12}$
    And fundamentally understand that like-charges repel and opposites attract.
  - Continuous uniform charge distribution and how they relate to infinitesimal charge dq:

$$\begin{aligned} \text{Line: } \lambda &= \frac{Q}{\ell} \quad \rightarrow \quad dq = \lambda d\ell \\ \text{Area/Surface: } \sigma &= \frac{Q}{A} \quad \rightarrow \quad dq = \sigma dA \\ \text{Volume/Solid: } \rho &= \frac{Q}{V} \quad \rightarrow \quad dq = \rho dV \end{aligned}$$

    where ρ is volume charge density not resistivity in this context.
  - Electric field of infinitesimal charge: $d\vec{\mathbf{E}} = \frac{k_e dq}{r^2}\,\hat{\mathbf{r}}$ ($\hat{\mathbf{r}}$ points radial away from dq), where the electric force on a test charge q_0 experience is: $d\vec{\mathbf{F}}_{q_0} = q_0 d\vec{\mathbf{E}}$.
    * Electric field falls off as $1/r^2$ for a point charge, $1/r$ for an infinite line of charge, and is constant for an infinite plane of charge.
    * Electric field of an electric dipole $\vec{\mathbf{p}}$: $\vec{\mathbf{E}} \approx \frac{k_e \vec{\mathbf{p}}}{z^3}$ for $\ell \ll z \ll \infty$.
  - Electric potential: $V = \frac{U}{q_0}$, where U is potential energy (which only matter as differences, aka Δ's, "delta's") and q_0 is a test particle
  - Electric potential of infinitesimal charge: $dV = \frac{k_e dq}{r}$
  - Electric potential difference: $\Delta V_{\mathrm{AB}} = V_{\mathrm{B}} - V_{\mathrm{A}} = -\int_{r_{\mathrm{A}}}^{r_{\mathrm{B}}} \vec{\mathbf{E}} \bullet d\vec{\mathbf{r}}$ and its origin from the work-energy theorem: $\Delta U_{\mathrm{AB}} = -\int_{r_{\mathrm{A}}}^{r_{\mathrm{B}}} \vec{\mathbf{F}} \bullet d\vec{\mathbf{r}}$ and the definition of the electric field above.
- **Current & Resistors**
  - Current: $I = \frac{dq}{dt}$
  - **Ohm's Law**: $V = IR$
  - In series (share current): $R_{\mathrm{eq}} = \sum_n R_n$
  - In parallel (equal potential across): $\frac{1}{R_{\mathrm{eq}}} = \sum_n \frac{1}{R_n}$
  - Power: $P = I^2 R = \frac{V^2}{R}$
  - Resistance of a wire: $R = \frac{\rho \ell}{A}$, where ρ is resistivity and A is cross-section ($\perp I$).
  - Continuous uniform current density $\vec{\mathbf{J}}$ and how it relates to total current: $I = \iint_{\text{area}} \vec{\mathbf{J}} \bullet d\vec{\mathbf{A}}$

- **Capacitors**
  - Capacitance: $C = \dfrac{Q}{V}$
  - In series (share current): $\dfrac{1}{C_{\text{eq}}} = \sum_n \dfrac{1}{C_n}$
  - In parallel (charge equal because equal potential across): $C_{\text{eq}} = \sum_n C_n$
  - Stored potential energy: $U = \dfrac{1}{2}\dfrac{Q^2}{C} = \dfrac{1}{2}CV^2$
  - Charging: $Q(t) = Q_0\left(1 - e^{-t/\tau}\right)$
    Discharging: $Q(t) = Q_0 e^{-t/\tau}$
    where $Q_0 = CV_0$ and $I = dQ/dt$
- **Magnetic Fields**
  - **Lorentz force:** $\vec{\mathbf{F}} = q(\vec{\mathbf{E}} + \vec{\mathbf{v}} \times \vec{\mathbf{B}}_{\text{ext}})$
  - **Lenz's Law** relates to Faraday's Law: "the direction of the induced emf drives current around a wire loop to always *oppose* the change in magnetic flux that causes the emf" (OpenStax *University Physics Volume 2*, §13.2, p. 586). It is the reason for the negative sign in Faraday's Law.
  - Motional emf for conducting rod moving in uniform external magnetic field: $\varepsilon_{\text{ind}} = B_{\text{ext}} v \ell$
  - In limit of very far away, magnetic field of current-carrying wire: $\vec{\mathbf{B}} \approx \pm \dfrac{\mu_0 I}{2\pi r}\,\hat{\boldsymbol{\phi}}$
  - LC circuits oscillate with charge on the capacitor: $q(t) = q_0 \cos(\omega t + \phi_0)$.
- **ac Circuits**
  - ac source voltage: $V(t) = V_0 \sin(\omega t) = V_0 \sin(2\pi f t)$
  - ac current: $I(t) = I_0 \sin(\omega t - \phi)$, where ϕ is tthe phase, depending on load.
  - Ohm's Law for ac $V_0 = I_0 Z$ where V_0 and I_0 are the amplitudes of variable voltage and current, respectively, and Z is impedance (on Equation Sheet).
    * capacitor in ac circuit: $V_C(t) = X_C I_0 \sin(\omega t - \phi - \phi_C)$ (indir. on Equation Sheet) where $V_C(t)$ *lags* current ($\phi_C = +\pi/2$)
    * inductor in ac circuit: $V_L(t) = X_L I_0 \sin(\omega t - \phi - \phi_L)$ where $V_L(t)$ *leads* current ($\phi_L = -\pi/2$)

    where reactances X given on Equation Sheet.
  - Phasor diagram for voltages to determine phase and what dominates (leads).
  - Transformer equation: $\dfrac{V_{\text{S}}}{V_{\text{P}}} = \dfrac{\mathcal{N}_{\text{S}}}{\mathcal{N}_{\text{P}}}$, where P is primary and S is secondary coil; if "stepping up", $\mathcal{N}_{\text{S}} > \mathcal{N}_{\text{P}}$ to make voltage $V_{\text{S}} > V_{\text{P}}$.
- **E&M Units**
  - Electric field: $\text{N}\,\text{C}^{-1}$
  - Electric flux: $\text{N}\,\text{m}^2\,\text{C}^{-1}$

- Electric potential (volt): $1\,\mathrm{V} = 1\,\mathrm{J\,C^{-1}}$
- Capacitance (farad): $1\,\mathrm{F} = 1\,\mathrm{C\,V^{-1}}$
- Resistance (ohm): $1\,\Omega = 1\,\mathrm{V\,A^{-1}}$
- Resistivity: $\Omega\,\mathrm{m}$
- Magnetic field (tesla): $1\,\mathrm{T} = 1\,\mathrm{kg\,s^{-1}\,C^{-1}}$ (or $\mathrm{kg\,A^{-1}\,s^{-2}}$ or $1\,\mathrm{V\,s\,m^{-2}}$)
- Inductance (henry): $1\,\mathrm{H} = 1\,\mathrm{Wb\,A^{-1}} = 1\,\mathrm{T\,m^2\,A^{-1}} = 1\,\Omega\,\mathrm{s}$

- **Logarithm Rules**, where b is the base (e.g. base-10 is $\log_{10}()$, or often $\log()$; natural logarithm is base e, so $\log_e()$, often $\ln()$):
  * $\log_b(xy) = \log_b x + \log_b y$
  * $\log_b\left(\frac{x}{y}\right) = \log_b x - \log_b y$
  * $\log_b(x^y) = y \log_b x$
  * $b^{\log_b x} = x$

- Mathematical constant: $e \approx 2.71828$. (e is associated with natural logarithms, exponential decays, etc.)

Campus-wide Information

Disability Support: Any student with a documented disability who would like to request accommodation should contact the University Disability Services Office—Hale Kauanoe A Wing Lounge; 932-7623 (V), 932-7002 (TTY), uds@hawaii.edu—as early in the semester as possible.

Advising: Advising is a very important resource designed to help students complete the requirements of the University and their individual majors. Students should consult with their advisor at least once a semester to decide on courses, check progress towards graduation, and discuss career options and other educational opportunities provided by UH Hilo. Advising is a shared responsibility, but students have final responsibility for meeting degree requirements.

Kilohana Academic Success Center: The KASC provides a range of free academic services and resources to all currently enrolled UHH students. Current services include access to peer academic staff via Zoom from a range of academic majors and course-related tip sheet PDF handouts for various courses available on the Kilohana Math Center website and the Kilohana Science Center website, both linked through the main Kilohana website: http://hilo.hawaii.edu/kilohana/. Tutor availability is accessible via the academic subject Google calendars. Questions can be directed to Karla Hayashi, Director, at karlah@hawaii.edu or by phone at 932-7287 and Corin Kim, STEM Coordinator/Student Employee Supervisor at corink@hawaii.edu or 932-7294.

Human Rights: The University of Hawaiʻi at Hilo prohibits discrimination in its education programs based on race, national origin, color, creed, religion, sex, age, disability, veteran status, sexual orientation, gender identity or associational preference. If at any time during class you feel uncomfortable about what is being talked about, or feel that your human rights have been violated, please feel free to leave the room. However, the professor asks that you confer with her as soon as possible about what happened so that appropriate action can be taken if necessary to avoid future problems. If you are uncomfortable speaking with the professor about your concern, please contact Kalei Rapoza (kaleihii@hawaii.edu), Interim EEO/AA Director, at 932-7626.

UH Hilo Title IX Policy: The University of Hawaii is committed to providing a learning, working and living environment that promotes personal integrity, civility, and mutual respect and is free of all forms of sex discrimination and gender-based violence, including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence, and stalking. If you or someone you know is experiencing any of these, the University has staff and resources on your campus to support and assist you. Staff can also direct you to resources that are in the community. Here are some of your options:

> If you wish to remain anonymous, speak with someone confidentially, or would like to receive information and support in a confidential setting, contact: • UH Hilo Counseling Services: SSC, room E-203, 932-7465; • UH Hilo Medical Services: Campus Center, room 212, 932-7369; and/or • Hawaiʻi Island YWCA, 935-0677.
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> If you wish to report an incident of sex discrimination or gender-based violence including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence, or stalking as well as receive information and support,† contact: • Libby Bailey, Title IX Coordinator, 932-7818, libby.bailey@hawaii.edu; • Jennifer Stotter, Director of the Office of Equal Opportunity & Deputy Title IX Coordinator, 932-7641, jstotter@hawaii.edu; and/or • Kalei Rapoza, Interim Director of Human Resources, 932-7626, kaleihii@hawaii.edu.
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> †Please note that you do not have to file a report with the University to receive institutional support or assistance.

As a member of the University faculty, the professor is required to immediately report any incidence of sex discrimination or gender-based violence to the campus Title IX Coordinator. Although the Title IX Coordinator and professor cannot guarantee confidentiality, the student will still have options about how the case will be handled. The goal is to make sure the student is aware of the range of options available and has access to the necessary resources and support. For more information regarding sex discrimination and gender-based violence, the University's Title IX resources and the University's Policy, Interim EP 1.204, go to: http://www.hawaii.edu/titleix.

Student Conduct: Students are expected to follow the University of Hawaiʻi at Hilo Student Code of Conduct available at the following URL: http://www.uhh.hawaii.edu/catalog/student-conduct-code.html.