Learning objectives for PES 1120: Electricity and Magnetism

- **General objectives**
  - Understand how to do **vector** calculations including: vector addition, cross products, dot (scalar) products
  - Know how to **differentiate** and **integrate** functions such as polynomials, sine and cosine, 1/x, etc.
  - Use **significant figures** (they are significant!!)
  - Use correct SI **units** for all quantities studied
  - Demonstrate physical **understanding**, rather than regurgitating facts/formulas
  - Write **explanations** of physical phenomena in a clear manner. Sentences should have a logical flow, have good grammar, and correct spelling.
  - Apply knowledge from **Physics 1** (F=ma, mass on a spring, conservation of energy, Newton’s Laws, etc)

- **Chapter 21: Electric charge**
  - Define **electric charge** (q)
  - Know how objects become electrically charged
  - Understand the difference between **conductors and insulators**
  - Define **electric force** (F)
  - Use **Coulomb’s law** to calculate the electric force between charges (two or more point charges)
  - Understand the meaning of **quantized** and **conserved** charge
  - Explain phenomena like: hair standing on end when you go down a slide, shock when you turn on a light, van de Graaff generator, bees navigating to charged flowers, etc.

- **Chapter 22: Electric field**
  - Define **electric field** (E)
  - Know how to **draw electric field lines** and how to use them to interpret electric fields: point charge, dipole, three point charges, charged plate, etc
  - Define **charge density** (∑,σ,ρ)
  - Calculate the electric field due to a collection of charges: electric dipoles, line of charge, ring of charge, charged disk, infinite sheet of charge, etc
  - Calculate the **force** on (acceleration of) a particle in an electric field
  - Understand how a dipole feels a **torque** when placed in an electric field, eg. Water molecules in a microwave
• Chapter 23: Gauss’s law
  o Understand the concept of flux (\(\phi\))
  o Define and calculate the flux of an electric field
  o Define and understand the usefulness of Gauss’s law
  o Use Gauss’s law and choose appropriate Gaussian surfaces to
    calculate the electric field due to symmetrical charge distributions such as:
    point charge, spherical shell of charge, infinite line charge, infinite
    flat plane of charge, solid sphere of charge, etc
  o Understand the implications of Gauss’s law for conductors

• Chapter 24: Electric potential
  o Understand the difference between electric potential energy (U) and
    electric potential (V)
  o Know that electric potential decreases in the direction of the electric field
  o Calculate the electric potential from an electric field due to: a point
    charge, collection of charge, dipole, spherical shell, etc.
  o Draw equipotential surfaces
  o Calculate the work required to move a charge in an electric field
  o Use the electric potential to calculate the electric field
  o Understand electrostatic interactions of point charges in terms of electric
    force, electric field, electric potential, and electric potential energy
  o Explain phenomena such as: operation of a linear accelerator (“atom
    smashers”)

TEST 1

• Chapter 25: Capacitance
  o Understand how a capacitor works
  o Know how to relate charge on a capacitor to the potential of a capacitor
  o Define and calculate capacitance (C) for: a parallel plate capacitor, a
    spherical capacitor, cylindrical capacitor, etc
  o Calculate \(C_{\text{equivalent}}\) for capacitors in series and in parallel
  o Calculate the amount of energy stored in a capacitor
  o Understand dielectrics, dielectric breakdown, and how dielectrics make
    capacitors more effective
  o Explain phenomena such as: lightning, etc

• Chapter 26: Current and resistance
  o Define electric current (I)
  o Understand in which direction charge moves and current flows
  o Calculate electric current, current density, drift velocity
  o Know what happens when a current comes to a junction in a circuit
  o Define resistance (R) and know how it can be altered
  o Use Ohm’s law to design circuits
  o Calculate resistance from resistivity (conductivity)
  o Calculate power in electric circuits (both electrical energy transfer and
    energy lost through resistance)
Chapter 26 (continued): Current and resistance
- Describe several ways that power losses can be minimized in electricity transmission
- Understand how superconductivity is related to resistivity & explain possible applications including: power transmission, magnetic levitation, MRI, etc.

Chapter 27: Circuits
- Define electromotive force (EMF)
- Understand how batteries work
- Calculate $R_{\text{equivalent}}$ for resistors in series and in parallel
- Analyse multi-loop circuits using the junction rule and the loop rule (Kirchhoff’s rules)
- Understand how to use an ammeter, voltmeter, ohmmeter, and potentiometer in a circuit
- Analyse circuits that include both a resistor and capacitor (RC circuits)
- Calculate current and capacitor charge for a charging/discharging RC circuit.
- Understand the role of the capacitive time constant ($\tau$) in a charging/discharging RC circuit
- Draw the graphs of current and capacitor charge as a function of time for a charging/discharging RC circuit
- Explain phenomena such as: an electric eel does not cook itself while killing prey, electric signals in the body, the correct way to wire a house, etc.

Chapter 28: Magnetic fields
- Define magnetic field (B)
- Know what situations can create a magnetic field
- Draw magnetic field lines around: bar magnet, horseshoe magnet, Earth, etc
- Calculate the force felt by a charged particle moving in a magnetic field
- Know in which situations the charged particle’s motion is circular, helical or in a straight line
- Calculate the force on a current-carrying wire in a magnetic field
- Explain applications of this chapter’s theory including: discovery of the electron’s charge, mass spectrometers, EKG machines, electric motors, cathode ray tubes, etc

TEST 2
• Chapter 29: Magnetic fields due to currents
  o Draw magnetic field lines around a wire and through a solenoid
  o Use the Biot-Savart law to calculate the magnetic field at a point due to: infinite straight wire, circle of wire, finite straight wire, etc.
  o In cases with special symmetry, use Ampère’s Law instead to calculate the magnetic field: inside and outside a cylindrical wire, infinite straight wire, solenoid, etc.
  o Calculate the magnetic dipole moment of a loop or of a solenoid
  o Understand how a wire loop or solenoid feels a torque when placed in a magnetic field
  o Understand applications: how speakers work, electric motor, etc

• Chapter 30: Induction
  o Know that changing the magnetic flux through a wire or solenoid induces a current & EMF in the wire
  o Use Faraday’s law of induction to calculate the induced EMF
  o Use Lenz’s law to predict which way the current/EMF will be
  o Understand eddy currents and losses due to heat
  o Know what an inductor is
  o Define inductance (L) and know what it depends on
  o Explain how the following work: traffic light sensor, vibrating sample magnetometer, etc.

• Chapter 31: LC circuits & oscillations
  o Understand what happens in a circuit that has just a resistor (R) and an inductor (L) when it is first connected or disconnected
  o Understand what happens in a circuit that has an inductor (L) and a capacitor (C) when it is connected (energy oscillations)
  o Know what the natural frequency (ω) of the LC oscillation is
  o Understand the analogy of an LC circuit to a mass on a spring
  o Understand qualitatively how the oscillations change when a resistor is added into the circuit (RLC circuit)
  o Understand applications: alternating current, transformers, AC electricity generator, etc

• Chapter 32: Maxwell’s equations & permanent magnets
  o Understand that Maxwell’s four equations explain all of electromagnetic theory
  o Understand and do calculations using Gauss’s law for magnetic fields
  o Understand qualitatively the Ampère-Maxwell law
  o Describe the three types of magnetic materials
  o Define magnetization (M)
  o Explain possible applications of permanent magnets: computer hard drives, speakers, bio-medical nanoparticles, etc

FINAL (all chapters)