RESEARCH METHODS IN ENGINEERING

PHYSICS: Understanding nature, basic principles (Physics includes chemistry, in principle)

MATHEMATICS: The language of physics

ENGINEERING: Apply scientific principles to practical problems

TOOLS OF AN ENGINEER

- PHYSICS (the basic tool) therefore MATHEMATICS
- OTHERS (non-important; economy, environmetal concerns, etc.)
- GREAT THING IS THAT THE BASIC PRINCIPLES OF PHYSICS ARE VERY COMPACT

HIGHLIGHTS

- Mechanics $F=d(mv)/dt$
- Thermodynamics (Energy conservation)
- Electrodynamics (Maxwell or Kirchoff laws)
- Relativistic mechanics $F=d(\gamma mv)/dt$
- Quantum mechanics (Schroedinger eqn.)
- Statistical mechanics (Canonical distribution eqn.)

RELATIONS

- Mechanics $\rightarrow$ high velocity $\rightarrow$ relativistic mechanics
- Mechanics $\rightarrow$ microscopic scale $\rightarrow$ quantum mechanics
- Electrodynamics: basically remains the same
- Statistical mechanics: mechanics applied to very large systems

MECHANICAL ENGINEERING

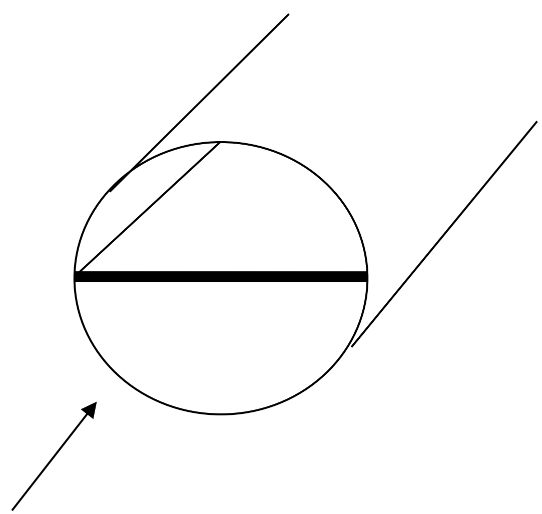
- Mechanics and Thermodynamics
- Electrodynamics: Electrical Engineering
- In the future: Quantum Engineering (MEMS, NEMS, Nanotechnology, Superconductivity, Superfluidity, quantum computers, quantum teleportation, atomic force microscopy, etc)
- Spooky quantum effects

MECHANICS AND THERMODYNAMICS APPLIED TO SPECIFIC PROBLEMS

- Fluids: Navier-Stokes equations
- Solids: Navier equations (elasticity)
- Vibrations of solids
- Vibrations of solids located within a moving fluid: AEROELASTICITY, FLOW-INDUCED VIBRATIONS
- SHOW CLIP

SPECIFIC AEROELASTIC PROBLEM

- Flutter of a plate located in a channel
- Air intake of some jet engines for example



HOW TO SOLVE THIS PROBLEM

- Given all dimensions, plate properties, etc., at what speed the plate will "flutter"
- Experiment; not very useful by itself
- Modelling: Go back to physics and pick equations

- FLUID: Linearized, inviscid, unsteady, potential equation
- PLATE: Plate vibration equation
- COUPLING: Fluid pressure on plate, fluid does not leave the plate surface
- BOUNDARY CONDITIONS

SOLUTION METHODS

- Expressed as a system of PARTIAL DIFFERENTIAL EQUATIONS
- Analytical solution
- Numerical solution (Finite difference, finite element, finite volume, boundary elements, so on)
- This problem can be solved analytically and an implicit expression for the flutter speed can be found.

- This could be useful
- But needs to be verified by experiment first

NONDESTRUCTIVE TESTING (NDT)
NONDESTRUCTIVE EVALUATION (NDE)
TAHRİBATSIZ MUAYENE

- Reason: Little cracks or flaws within a material causes the structure to fail in time
- Corrosion in aircraft lap joints
- Cracks in welds, in a nuclear power plant for ex.
- Cracks on gas turbine blades
- Inhomogeneities in solid-state integrated circuits

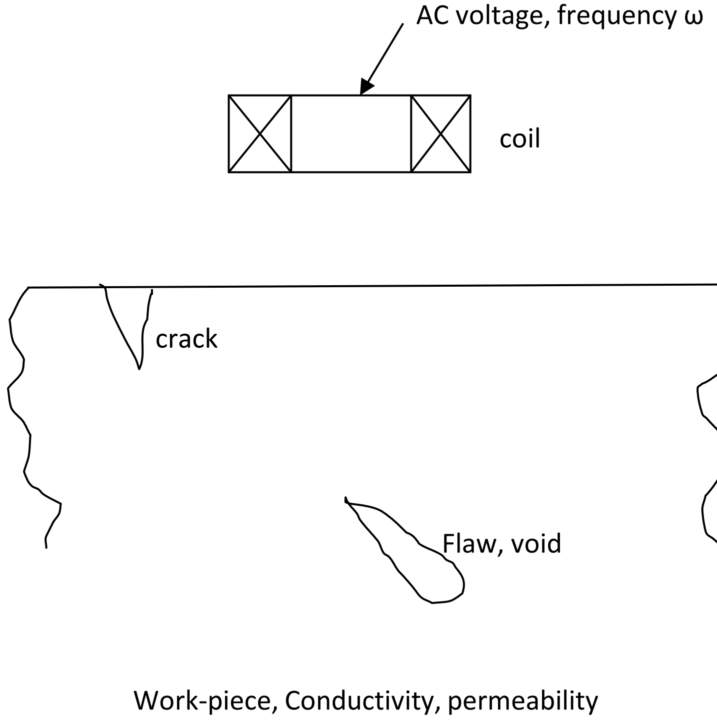
OTHER EXAMPLES

- Looking at internal organs (ultrasongraphy, X-ray, tomography, etc.)
- Metal ores or oil within the earth
- Sonar, Radar
- ALL USE SIMILAR TECHNIQUES
- SHOW CLIP

MAIN METHODS

- Ultrasonic
- Eddy current
- X-ray
- Magnetic particle
- Penetrant liquid (dye)
- Others (Barkhausen noise for ex.)

EDDY CURRENT NDE



- Impedance of simple coil (inductor) $Z = i\omega L$
- Coil with wire resistance $Z = R + i\omega L$
- Coil near work-piece:
- Eddy currents in work-piece
- No longer a simple inductance
- Use Maxwell equations to solve for electromagnetic fields within the work-piece and air.

- From this solution develop an expression for impedance
- (Numerical solution)
- Can be analytically solved for some geometries
- Practical use: measure impedance at several frequencies and infer the shape of crack or flaw (called an inverse problem)

- Measure the thickness of a layer on a work-piece
- Measure the properties of a heat-treated or modified layer
- THAT’S ALL