Lecture 1 Outline: Introduction – Energy in Transportation

I. Thoughts on the future of transportation
   a. Mass electrification vs. biofuels vs. fuel cells vs. nuclear fusion?
II. Energy use in the USA
   a. Thought exercise
      i. Typical energy use on a car
   b. Vehicle energy model
      i. Braking energy
      ii. Energy conversion losses
      iii. Aerodynamic drag
      iv. Rolling resistance
         1. Comparison to bicycle and train
   c. Transportation efficiency calculation
      i. Comparison to aircraft, trains, buses, rockets
III. Propulsion system efficiency
   a. Brief introduction
IV. Administrative issues
   a. Course objectives
   b. Grading/assignments/participation
   c. Topics covered
   d. Assignments

Lecture 2 Outline: Energy & Thermodynamics

I. 1st law of thermodynamics
   a. Conservation of energy
   b. Carnot cycle
   c. Heat engines
II. 2nd law of thermodynamics
   a. Entropy conservation
III. Example problem
   a. Piston-membrane-dual gas problem
IV. Example problem II
   a. Similar to problem 1
V. Example problem III
   a. Brayton cycle

Lecture 3 Outline: Internal Combustion Engines I

I. Introduction
   a. Otto vs. Diesel vs. Brayton
II. Otto Cycle specifics

a. Animation
b. PV diagram
c. Comparison to ideal Carnot efficiency

III. Diesel Cycle specifics
a. Animation
b. PV diagram
c. Comparison to ideal Carnot efficiency

IV. Otto vs. Diesel
a. Key differences
i. Mechanical components
ii. Efficiencies

V. Brayton Cycle specifics
a. Animation
b. PV diagram
c. Comparison to ideal Carnot efficiency

VI. Engine Applications: Gasoline
a. Light vehicles and machinery

VII. Engine Applications: Diesel
a. Heavy machinery

VIII. Engine Applications: Brayton
a. Aircraft
b. Stationary power generation
c. Some heavy machinery

Lecture 4 Outline: Internal Combustion Engines II

I. Piston engines
a. 2 stroke vs. 4-stroke
b. Improvements
i. Turbo and super-charging
ii. Direct Injection
1. HCCI
iii. Variable valve timing
c. Emissions
i. Emissions types
ii. On-board vehicle controls
1. Catalytic converters
2. Particulate traps
3. Gasoline vs. Diesel differences
iii. Government regulations

II. Vehicle improvements
a. Transmissions

        i. Introduction to DSG, CVT, 7 and 8 speed automatics
    b. Start/stop
III. Transition to hybrid/electric drivetrains

Lecture 5 Outline: Road Vehicle Engineering & Components I (Vehicle Dynamics, Powertrain & Components)

I. Model for vehicle power demand
    a. Thermodynamic efficiency
    b. Vehicle Mass
    c. Aerodynamic drag
    d. Rolling Resistance
II. Vehicle Dynamics
    a. Geometry
        i. Wheelbase and track width
        ii. Steering and suspension angles
    b. Mass Distribution
        i. Roll Centers
    c. Traction
        i. Center of traction
    d. Aerodynamics
        i. Center of pressure
    e. Vehicle Response
        i. Under/Oversteer
        ii. Weight transfer
        iii. Speed wobble
    f. Advanced control

Lecture 6 Outline: Road Vehicle Engineering & Components II

III. Powertrain components
    a. Manual transmission
    b. Automatic transmission
    c. CVT
IV. Materials
    a. Steel
    b. Aluminum
    c. Magnesium
    d. Composites
V. Manufacturing processes
    a. Stamping
    b. Welding

VI. Electronics / Communication
    a. CANbus

Lecture 7 Outline: Electric & Hybrid Vehicles I (Consumer Electric Vehicles)

I. Brief background
    a. Different types of electric vehicles
        i. Commercial applications, etc…
    b. History of the development of the electric car
        i. 1968 Great Electric Car Race
    c. "Who killed the electric car" – brief mention
II. Drivetrain comparison
    a. Conventional vs. Hybrid vs. Battery-Electric
    b. Efficiency comparison
III. Technical – efficiency ratings
    a. Terminology
IV. Benefits
    a. V2G possibility
    b. Night-time charging
V. New energy sources
    a. Power grid capacity
    b. Operating costs
    c. CO2 emissions

Lec 8 Outline: Electric & Hybrid Vehicles II

VI. Challenges
    a. Energy density
    b. Range
    c. Charge time
    d. Cost
    e. Battery life
    f. Consumer acceptance
    g. Operating cost
VII. EV research at MIT

Lecture 9 Outline: Rail Transport: Fossil Fuel, Electric, Urban & High-Speed (Fossil Fuel Rail)

I. Rail Transportation Overview
II. Technical Overview of Rail and Energy
    a. Aerodynamic Drag
    b. Hertz contact forces

c. Energy balance vs. automotive

III. Rail Operations
   a. Switches
   b. Track Gauge
   c. Study of train wear, standards or gauges

IV. Steam Engine History
   a. Pre steam engine rail
   b. Development of Steam Engine, James Watt (1794)
   c. 1830, first intercity rail opened (Liverpool – Manchester)
   d. 1869, first transcontinental railway completed in US
   e. Steam dominant in rail from early 1800's till about 1930

V. Steam Engine Components
   a. Boiler
   b. Steam Circuit
   c. Running Gear
   d. Couplings

VI. Steam Engine Fuel
   a. Wood (US early), Coal
   b. Water

VII. Dieselisation
   a. Compression ignition patented by Dr. Rudolf Diesel in 1892
   b. Advantages over steam
      i. Much less pollution / cleaner work environment
      ii. Can be operated by one engineer
      iii. Higher thermodynamic efficiency
      iv. High tractive load
   c. Diesel Cycle
   d. Mechanical Transmissions
      i. Usually fluid coupling between engine and epicyclic gearbox
      ii. Transmission can be limiting factor for power and torque output

Lecture 10 Outline: Rail Transport: Fossil Fuel, Electric, Urban & High-Speed (Electric Rail)

VIII. Diesel – Electric
   a. Classifications
      i. On-board generation (hybrid diesel electric, gas turbine)
      ii. On-board storage (battery electric)
      iii. Off-board generation (third rail, overhead lines)
   b. Currently almost all locomotives are diesel-electric
   c. Technical
      i. Diesel engine to electric generator to electric traction motors

ii. (power transmission) - DC Versions until 1960's
iii. AC made possible by high capacity silicon-carbide rectifiers

d. Throttling
i. Usually accomplished in discrete steps

IX. Electric Rail
a. Patent by Thomas Edison
b. Late 19th century
c. Advantages
i. >90% efficiency of traction motors
ii. Less pollution
iii. Efficiency gains from regenerative braking
d. DC vs AC
i. Allowable voltage ranges
ii. Regenerative braking / fail safe motor braking
iii. Transition from DC to AC
iv. Grids

Lecture 11 Outline: Rail Transport: Fossil Fuel, Electric, Urban & High-Speed (Urban & High Speed Rail)

X. Urban Rail
a. History
b. Presence in cities
i. United States
ii. World
c. Technologies
i. From coal / steam to electric early on

XI. Intercity / High Speed Rail
a. History
i. Japan – Shinkansen
ii. Europe
iii. China
iv. United States
b. Technology
i. High Speed
ii. Aerodynamics
iii. Safety
c. Mag Lev Trains

Lecture 12 Outline: Water Transport: History, Vessels, Port Operations (Water Transport History)

I. Energy efficiency:
    a. BTU per ton-mile:
        i. Rail: 341
        ii. Water: 510
        iii. Heavy Trucks: 3,357
        iv. Air freight: 9,600
II. Most are propelled by diesel
    a. 2-stroke turbo
        i. Largest run on heavy fuel oil (little distillation required)
    b. Nuclear is insignificant
        i. A few experiments in the '60's; Russia has a few nuclear ice-breakers, not much else
    c. Single engine, single-screw is generally preferred
        i. Reliability and economy
III. 3-year engine overhaul schedule

Lecture 13 Outline: Water Transport: History, Vessels, Port Operations (Water Transport: Vessels)

I. 7.4 billion tons of cargo carried in 2007, globally (Source: wiki)
    a. Vs.
II. Bulk
III. Passenger
IV. Tanker
    a. Oil
    b. LPG
    c. Chemicals
    d. Food
V. Reefer ships
    a. Temperature controlled
VI. RORO (roll on / roll off) ships
    a. Ferries, for automobiles, etc…
VII. Cruise ships
    a. Many have propulsion by azimuth thrusters – large electric motors in pods
    b. Diesel-electric
        i. Electrical losses: ~8%
            1. Vs. shaft/mechanical losses at 2%
VIII. Improvements currently considered: counter-rotating propellers at pods
IX. Energy use per item carried

a. Also per ton

X. Compared to other transportation methods

Lecture 14 Outline: Water Transport: History, Vessels, Port Operations (Port Operations)

I. Containerization
   a. TEU – twenty foot equivalent unit, 20*8.0*8.5 feet
   b. Most today are 40-foot containers (2 TEU containers)
   c. Since 1960's – containerization (also interface with rail and road)

II. Big organizational hurdle:
   a. Movement:
      i. Ships
      ii. Containers
      iii. Cargo
   b. Loading/unloading
   c. Smaller ships – tugs
   d. Storage – warehousese
   e. Cashflow + pricing
   f. Information management
   g. Customs
   h. Marketing and competition
   i. Safety+security
   j. Environment and sustainability

III. Example from 15.053 – operational research algorithms
   a. Maximum flows
      i. Math problems

IV. Stats:
   a. Port flows

Lecture 17 Outline: Aircraft Types

I. Intro to Chapter 1 - History
   a. Balloons/Dirigibles
   b. Heavier than air
   c. Commercial Air transport
   d. Helicopters
   e. Conquest of space
   f. Commercial use of space

II. Current uses of aircraft
   a. Manufacturers overview
      i. Equipment volume / market share

b. Transportation efficiency per given payload

III. Airport considerations
   a. Traffic and logistics
      i. Relationship to port operations

IV. Fuels
   a. Sources/volume
   b. Future possibilities
   c. Consumption increase / industry growth

V. Maintenance Intervals

Lectures 18 & 19 Outlines: Fixed-Wing Aircraft Aerodynamics I & II

I. Lift:
   a. Buoyancy lift
   b. Lift from fluid air motion

II. Sources of Drag:
   a. Profile Drag
   b. Induced Drag
   c. Effects on Drag

III. 2-D Aircraft model
   a. Equations of motion

IV. Steady Flight:
   a. Thrust-velocity curves
   b. The stalling speed of an aircraft
   c. Maximum lift-to-drag ratio
   d. Endurance and range of an aircraft
   e. Gliding flight
   f. Technical:
      i. Basic equations governing flight – applied with examples relating to different aircraft geometry
   g. How Helicopters Work

Lectures 20 Outline: Aircraft Engines

Goal: Understand the principles that guide their design for varying applications. Basic combustion process has already been covered).

I. Inlet
II. Compressor
III. Combustor
IV. Power Turbine
V. Nozzles
VI. Engine Types

a. Turbojet
b. Turbofan
c. Turboprop
d. Afterburning turbojets
e. Ramjets
f. Ultra high bypass engines / Future possibilities

Lectures 21 Outline: Helicopters

I. Basic mechanics
    a. Swashplate + blade pitch control
    b. Physics behind tail rotor and twin rotor helicopters
II. Power plants
III. Efficiencies – quick overview: homework problem
IV. Uses
V. Role in transportation

Lectures 22 Outline: Radar

I. History
II. Principle of operation
III. Configurations and types
IV. Role in transportation today

Lecture 24 Outline: Navigation Module (Navigation)

I. History
    a. Improvements leading up to the GPS era
        i. Celestial navigation
        ii. Original mapping techniques
            1. Compass invention
        iii. Piloting
        iv. Dead reckoning

Lecture 25 Outline: Navigation module (Global Positioning System GPS)

I. GPS History
    a. LORAN and Decca Navigator – WWII ground based nav
    b. Observation of Doppler effect on Sputnik (1957)
    c. First satellite nav system – Transit, US Navy, 1960
    d. GPS developed in response to nuclear age – SLBM fixing, etc
    e. 1973 – Navstar GPS program created, combining multiple military projects
    f. Pres Reagan made GPS available for civilians after 1983 Korean Air disaster

g. Satellites launched between 1989 and 1994
h. Pres Clinton disables selective availability in 2000

II. GPS Technology Basics
    a. System Architecture
        i. DOD operated
        ii. Space Segment
            1. 24 to 32 satellites in medium earth orbit (~20000 km)
            2. 6 planes of 4 satellites each
            3. >= 6 satellites always within line of sight from anywhere on earth
        iii. Control Segment – master control station and monitor stations
        iv. User segment – military and civilian users of GPS
        v. Atomic clocks, corrections for relativity
    b. Competition to GPS
        i. EU, China, Russia
    c. Message Transmission
        i. Time of Message
        ii. Precise Orbital Information (Ephemeris)
        iii. Almanac of all GPS satellites
    d. Position and Velocity Calculation
        i. Trilateration using propagation time of signal
        ii. Usually requires at least 4 satellites
        iii. Time delays create sphere's of possible location from each satellite. Intersection of spheres indicates position
    e. Accuracy
        i. After SA disabled, civilian accuracy improved from 300 meters to 20 meters
        ii. Receiver clock major source of error

III. Possibilities and Limitations

IV. GPS Applications
    a. Navigation, Map Making, Surveying
    b. Integration with cellular telephony
    c. Geofencing
    d. Geotagging
    e. Missile and projectile guidance
    f. Reconnaissance, Search and Rescue
    g. GPS Satellites – US Nuclear Detonation Detection System

Lecture 26 Outline: Navigation Module (Global Information System GIS)

V. GIS Overview
    a. Definition (data linked to locations)
    b. History
        i. 1854 John Snow – Cholera outbreak

ii. 1960's – computer mapping applications for nukes
iii. Roger Tomlinson – father of GIS – Canada GIS
iv. 1980's/1990's – consolidation of available platforms

VI. GIS Data Representation
  a. Spatio-temporal location is key index variable
  b. Two Abstractions
    i. Discrete Data (houses, etc)
    ii. Continuous Data (rainfall, elevations, etc)
  c. Raster Images
  d. Vectors
  e. Image processing, raster to vector translation
  f. Point Clouds (3D points with RGB information)

VII. Data Capture
  a. Digitizing Map and Survey Data
  b. Photography
  c. Satellite remote sensing
  d. Processing, error removal

VIII. Geocoding

IX. Reverse Geocoding

X. Advantages / Disadvantages
  a. Uncertainties come when combining data from many different sources
  b. Quick analysis and representation of complex data sets
  c. Visualization of nonhomogenous entities
  d. Crazy consumer apps

XI. Open Geospatial Consortium (OGC) Standards
  a. 384 companies, agencies, etc
  b. OpenGIS Specifications => geo-enable web apps, enable use of complex spatial information

XII. GIS Applications
  a. Web Maps (Google Maps, etc)
  b. Business planning (store locations, etc)
  c. Monitoring Climate Change (Polar ice caps – map overlay)
  d. Hydrological Modeling
  e. Automated Cartography
  f. Geostatistics

Lecture 27 Outline: Navigation Module (Modern Mapping Techniques)

I. History of cartography

II. Satellite ownage.

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