

AerE 411 – Study Guide

Note: this document is subject to change by the instructor during the semester.

Exam Format:

Midterm Exam:

The midterm exam will be closed book and notes.

Bring scratch paper and extra pencils (you will have to do calculations).

Calculators are not allowed, and any use of a calculator, cell phone or any other electronic device will result in the immediate termination of the exam and a zero on the exam.

There may be some numerical computation, but you will be allowed to liberally estimate mathematical computations (for example: $1.345 * 120.1 / 56 = 1 * 100 / 50 = 2$).

The test will have short answer (written or equation), short essay questions, or components of derivation/calculation questions that cover qualitative issues.

There will be derivation questions on the test.

The majority of the questions will involve doing calculations using known engine cycles or cycles that are close to known engine cycles.

* indicates where to stop for the midterm exam

Final Exam:

The final exam will be open book and closed notes (i.e. you are only allowed to use the textbook, you may add post-it notes to the text and write notes to yourself on those).

Bring scratch paper and extra pencils (you will have to do calculations).

Calculators are required, and numerical calculations must be done accurately on a calculator. (no cell phones or other electronic devices are permitted and any use of such a device will result in immediate termination of the exam and a zero on the exam).

The test will have short answer (written or equation), short essay questions, or components of derivation/calculation questions that cover qualitative issues.

There will be derivation questions on the test.

The majority of the questions will involve calculations and derivations which require a synthesis of knowledge from the course, i.e. the exam problems will be closer to the homework than to the quizzes.

You will have to build a cycle analysis model for a new engine, which includes at least one non-ideal component.

Course Topics:

overall engine structure (review engine hardware in Howe)

know engine component parts and names

speed of sound and Mach number

stagnation and isentropic relations

integral and 1D forms of (no derivations, usage only):

mass conservation

momentum conservation

- energy conservation
- enthalpy, total enthalpy and total temperature
- ability to solve thermodynamic problems in Oates
 - application of constant volume, isobaric, isothermal and isentropic processes
 - application of conservation laws
 - derivation and use of constant area heat addition (CAHA)
 - understand relationship of CAHA flow to cycle analysis
 - understand concept of thermal choking

π and τ relations

thrust equation for single streams

specific thrust and specific fuel consumption (S) definition and rationale
fuel to air ratio (f)

Turbojet (ideal cycle analysis):

- understand overall engine structure and components
- qualitative understanding of the Brayton cycle
- know station definitions and nomenclature
- understand basic derivation strategy
- specific thrust derivation
- turbine/compressor work balance
- specific fuel consumption derivation
- understand final equation structure and usage
- optimum compressor pressure ratio for maximum thrust
- fully understand all turbojet solutions given in Oates
- understand and be able to compute maximum thrust turbojet

Rockets:

- understand thrust equation applied to rockets
- understand definition of specific impulse and relation to S
- understand rocket thrust equation derivation and use
- understand specific impulse equation derivation and use
- qualitatively understand properties of a rocket:
 - thrust increase with altitude
 - optimum design for a given altitude
 - role of third critical in optimum design
 - relationship between 1st, 2nd and 3rd criticals

Off-Design Analysis:

- understand derivation and use of choked mass flux equation
- be able to compute choked mass flux
- understand engine area scheduling between turbine and nozzle
- understand which areas in a turbojet engine limit mass flux
- understand how to compute mass flux through an engine
- understand how an engine operating line is calculated
- be able to calculate engine performance at partial throttle
- understand and be able to explain the concepts of:

operating line
design point
rotating stall
surge
surge margin

Ramjet (ideal cycle analysis):

understand overall engine structure, components and operating principles
be able to get ramjet equations from turbojet
fully understand all ramjet solutions given in Oates

understand limiting Mach number as calculated from equations

understand reasons for temperature limitations and role in limiting Mach number

Afterburners (ideal cycle analysis):

understand afterburner structure, components and usage
specific thrust derivation
specific fuel consumption derivation
relation between burner exit temperature and afterburner exit temperature
fully understand all afterburner solutions given in Oates

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Turbofans (ideal cycle analysis):

understand turbofan structure, components and usage
definition of bypass ratio
understand difference between low and high bypass ratio turbofans
understand difference between separate and mixed stream turbofans
derivation and use of thrust equation for multiple streams
derivation of specific thrust, including power balance with fan
derivation of specific fuel consumption and role of bypass ratio
understand equation structure and usage
understand derivation of bypass ratio for minimum fuel consumption
understand minimum fuel consumption formulation and solution structure
qualitatively understand constant area mixing and role of conservation laws
understand structure and be able to use constant area mixer equations
derivations for mixed stream turbofans
understand solution properties and use of mixed stream turbofan equations
understand structure of turboprops

Calculations:

be able to calculate any of the above cases using supplied data
understand qualitative structure of solutions
understand solution properties, as given in Oates
understand the advantages and disadvantages of different engine types
be able to create a model and do calculations for new engine types

Non-ideal cycle and component analysis:

understand pressure loss models in different parts of the engine

be able to compute shock pressure losses
inlets and diffusers

- understand the role of shock pressure losses
- understand use of MilSpec pressure loss formula
- understand the need for oblique shock inlets
- qualitatively understand the role of spillage, intake doors,
and inlet mass flux control

compressors and turbines:

- understand and be able to use (for both compressor and turbine)
compressor/turbine efficiency
polytropic efficiency
stage efficiency
- understand the overall structure of the compressor and turbine
- understand mechanisms and role of turbine cooling
- understand qualitative reasons for overall compressor geometry
- understand the derivation and use of the Euler turbine equation

burner:

- understand burner structure and cooling mechanisms
- be able to compute fuel to air ratio at stoichiometric conditions
- understand reaction balances in pre-mixed combustion
- understand concepts of lean and rich combustion
- understand concept of equivalence ratio

nozzles

- understand role of nozzle in setting exit pressure
- understand shock losses in nozzle
- understand the structure of plug and ejector nozzles

be able to perform non-ideal derivations, including

- thermodynamic property changes with temperature
- pressure losses
- compressor and turbine efficiency models
- variations in mass flow rates
- combustion and shaft efficiency factors

understand how to interpret results obtained from a non-ideal cycle analysis

Recommendations:

You should have all the basic derivations down, and you should carefully review all the cycles we have done in class and that you have done for HW. You may be required (especially on the final exam) to use some “higher level” thinking skills before doing calculations, i.e. you may be required to make choices based on experience and knowledge before actually doing a calculation. Think about the “big picture” while you study! All exams are comprehensive from the beginning of the course.