Spring 2015

ME 257/357 – Midterm Examination

Write your name on this handout and on the notebook(s), and sign the honor code.
Name: . . . .

Honor Code: I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code:

Signature

CLOSED-BOOK PART – This part tests your conceptual understanding of gas turbine propulsion systems and your ability to perform elementary thermodynamic calculations. Show brief answers in the spaces provided or circle your answer below. At the end of the exam, return this part together with the open-book part of the examination. This section amounts to about 25 percent to the total grade of the exam. Therefore allocate your time and spend **not more than twenty (20) minutes** to complete this part of the exam; after finishing you are not allowed to return to this section.

1. [1 point] Define the *sectional* drag coefficient c_d.

2. [3 points] Sketch the required thrust T^* as a function of the dynamic pressure q_{∞}; show contributions of the zero-lift drag and the lift-induced drag.

3. [2 points] Write down the thrust equation for a *turbojet engine*. Explain all terms.

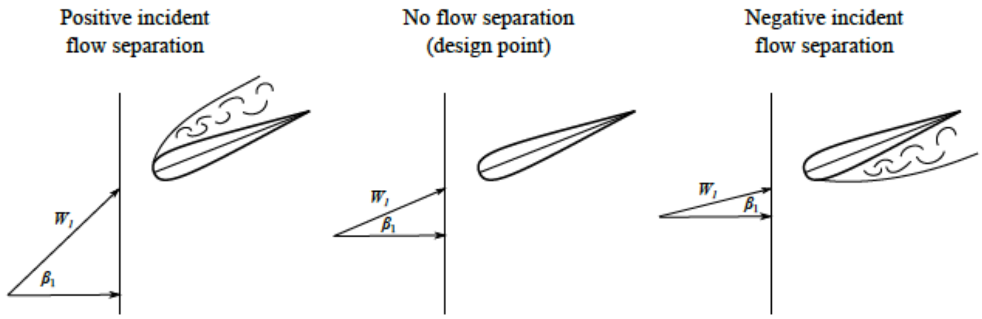
4. [4 points] Draw a *p-v* diagram and a *T-s* diagram of an *ideal Brayton cycle*, consisting of a diffusor, single-stage compressor, combustor, single-stage turbine, and nozzle. Clearly mark all stages and thermodynamic processes connecting each stage.
   In the same diagrams, show the thermodynamic cycle of a corresponding *real Brayton cycle,* having losses in the compressor and the combustor only.

5. [3 points] Name three advanced technologies that are currently considered for increasing the overall efficiency of gas-turbine engines.

6. [4 points] What is the definition of the propulsive efficiency? Write down the mathematical equation, and give a physical explanation. Plot the propulsive efficiency as a function of U_e/U_0, and approximately indicate conditions for (a) turboprop, (b) turbofan, (c) turbojet, and (d) ramjet.

7. [3 points] Consider the thrust equation for a turbofan engine:
$$T = \dot{m}_{Air,Core}\left[(1+f)U_e + \beta U_{1,e} - (1+\beta)U_0\right].$$
Keeping thrust, fuel-air ratio, air mass flow-rate through the core, and the propulsive efficiency constant, sketch the bypass ratio β as a function of the fan-to-core velocity ratio $U_{1,e}/U_e$.

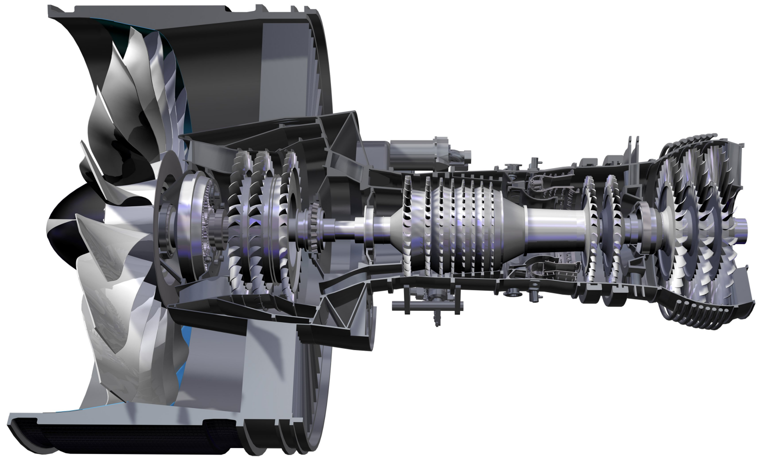
8. [2 points] Qualitatively explain compressor rotor stage efficiency and off-design operation in terms of blade angles, axial velocity u_x, and blade velocity U (or, the ratio u_x/U). Refer to the figure and comment on u_x and U in the three rotor blade scenarios shown.



9. [8 points] Using your understanding of engine development over the decades and knowledge of component matching, estimate parameters for the following four engines and explain your reasoning. (Some choices may be repeated or not used in each category except, as noted, bypass ratio – choose one of the β values for each engine)

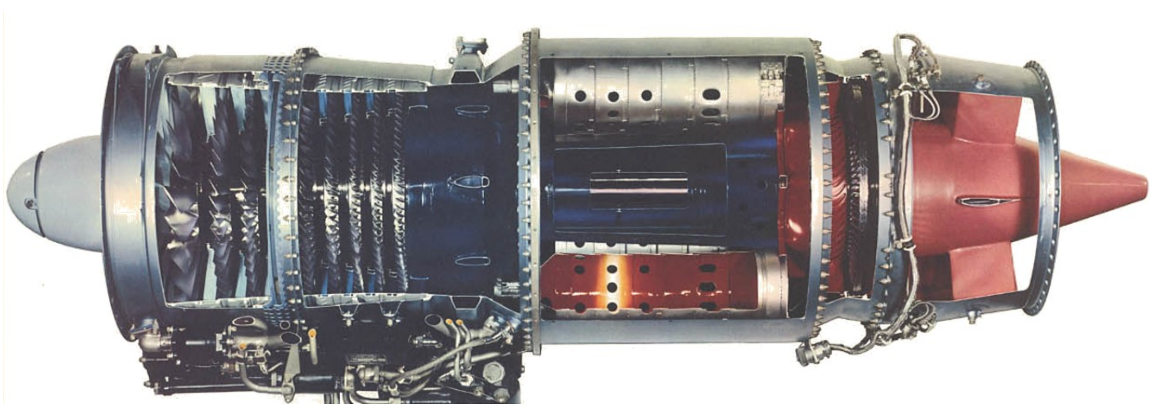
Engine Type	Turbojet, Low-BPR Turbofan, Mid-BPR Turbofan, High-BPR Turbofan, or Geared Turbofan
Number of Spools/Shafts	1, 2, or 3
Bypass Ratio, $\beta \approx$	0, 6, 10, 12 (one each)
Compression Pressure Ratio, $p_{03}/p_{02} \approx$	8, 25, or 45
Turbine Gas Temp, $T_{04} \approx$	1250, 1500, or 1900 K
Combustor Type	Can, Can-annular ("Cannular"), or Annular
Decade	1950's, 1980's, or 2000's

Engine a)



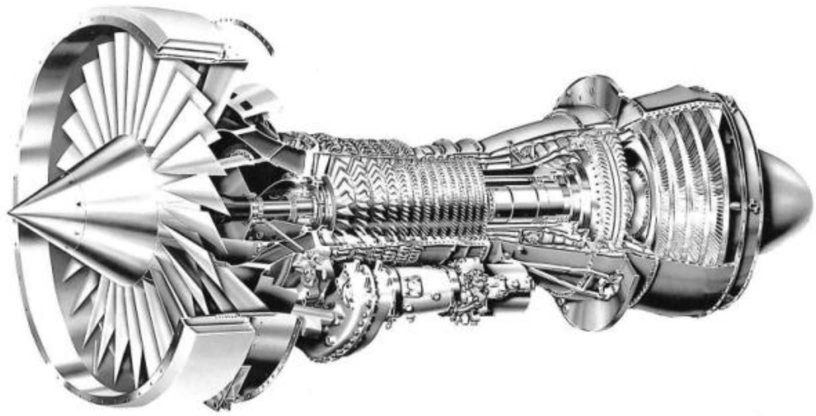
Engine Type	
Number of Spools/Shafts	
Bypass Ratio, $\beta \approx$	
Compression Pressure Ratio, $p_{03}/p_{02} \approx$	
Turbine Gas Temp, $T_{04} \approx$	
Combustor Type	
Decade	

Engine b)



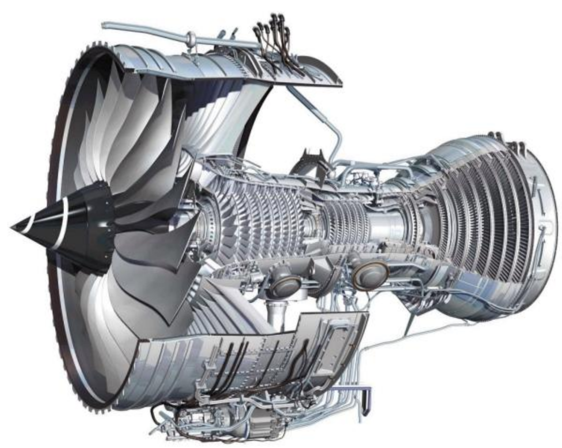
Engine Type	
Number of Spools/Shafts	
Bypass Ratio, $\beta \approx$	
Compression Pressure Ratio, $p_{03}/p_{02} \approx$	
Turbine Gas Temp, $T_{04} \approx$	
Combustor Type	
Decade	

Engine c)



Engine Type	
Number of Spools/Shafts	
Bypass Ratio, $\beta \approx$	
Compression Pressure Ratio, $p_{03}/p_{02} \approx$	
Turbine Gas Temp, $T_{04} \approx$	
Combustor Type	
Decade	

Engine d)



Engine Type	
Number of Spools/Shafts	
Bypass Ratio, $\beta \approx$	
Compression Pressure Ratio, $p_{03}/p_{02} \approx$	
Turbine Gas Temp, $T_{04} \approx$	
Combustor Type	
Decade	