| **Due:**<br>In class, Friday<br>**December 9, 2022** | **Name(s)** (*Each* student must submit; list anyone you worked with) **PSU ID (abc123)**<br>Student submitting:<br>Worked with:<br>Worked with: |
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# ME 420
## Fall Semester, 2022
### Homework Set # 11

*Professor J. M. Cimbala*

| For instructor or TA use only: | | |
|---|---|---|
| **Problem** | **Score** | **Points** |
| 1 | | 25 |
| 2 | | 25 |
| 3 | | 40 |
| 4 | | 10 |
| **Total:** | | **100** |

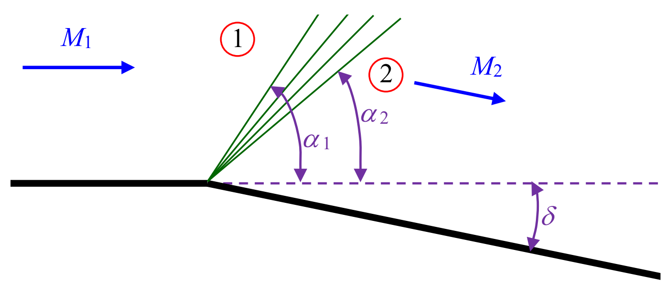
**1**. (25 pts) *Note*: This will be useful in the next problem as well. Many times in this course we have encountered equations that are explicit for one variable but implicit for another. Most of the time, the implicit form occurs when solving for Mach number. The Prandtl-Meyer expansion fan equation is another such example. This equation is explicit for P-M function $\nu$ when given $M$ and $\gamma$. But in a typical solution, we also need to solve for $M$ implicitly for a given $\nu$ and $\gamma$,

$$\nu(M)=\sqrt{\frac{\gamma+1}{\gamma-1}}\tan^{-1}\left[\sqrt{\frac{\gamma-1}{\gamma+1}\left(M^2-1\right)}\right]-\tan^{-1}\left[\sqrt{\left(M^2-1\right)}\right]$$

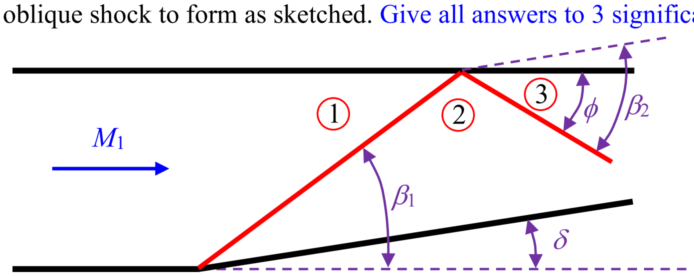
(**a**) Using software of your choice, generate an iteration scheme to solve for $M$ implicitly for a given $\nu$ and $\gamma$. Report the software you used and your iteration scheme (Newton's method, trial and error, false position method, …).

(**b**) Verify your scheme by setting $\nu(M)$ = 33.8° (for air) and calculate $M$. Attach a printout of your work with your answer boxed or somehow highlighted. Also verify your results using the online *Compressible Aerodynamics Calculator*.

**2**. (25 pts) Air flows supersonically along an insulated wall at Mach number $M_1$. The wall suddenly tilts down at angle $\delta$, and a stationary expansion fan is generated, as sketched. The Mach numbers are measured: $M_1$ = 2.032 and $M_2$ = 2.460. Calculate angles $\alpha_1$, $\alpha_2$, and $\delta$, as defined in the sketch. Give all answers to **4 significant digits** in *degrees*, not in radians.




**3**. (40 pts) Air flows at Mach number $M_1$ = 2.58 in a rectangular (2-D) duct. The pressure and temperature of the inflow (state 1) are 192.2 kPa and 331.3 K, respectively. At some $x$ location, the lower wall of the duct turns upward sharply at angle $\delta$ = 13.9°, causing an oblique shock to form as sketched. Give all answers to 3 significant digits.




(**a**) Calculate the oblique shock angle $\beta_1$, assuming a *weak* oblique shock. Also calculate the conditions at state 2 after the oblique shock: $M_2$, $T_2$, and $P_2$.

(**b**) Eventually, the oblique shock encounters the top wall of the duct and reflects from it. Calculate the oblique shock angle $\beta_2$, again assuming a weak oblique shock. Also calculate the conditions at state 3 after the reflected oblique shock: $M_3$, $T_3$, and $P_3$.

(**c**) Finally, calculate angle $\phi$ from the upper wall to the reflected oblique shock. Is this angle smaller, the same, or larger than shock angle $\beta_1$ of the incident oblique shock?

*Note*: There is another page. →

4. (10 pts) Since this is the last homework of the semester, I thought I would ask you to reflect on a few things about this course. You can discuss anything you want as long as it is related to our course and my method of teaching it this semester. My goal is to improve my teaching, so please be honest. **Your responses, even if negative, will have no impact on your course grade.** You don't have to answer all of the questions below – they are only ***suggestions***. For example:

- When I was sick at home I was forced to switch to video lectures instead of in-person lectures. Please compare these video lectures with the in-person lectures. Which did you like better? Why? Would you be in favor of running the entire semester in this video-lecture format? Why or why not?
- Did you like the Friday candy questions? Why or why not?
- Discuss briefly what you liked most and least about the course and why.
- If we had the opportunity to travel back in time to the beginning of the semester and start all over again, what could/should I have done differently to make this course a better learning experience for you? Explain.
- You may think of other things to discuss – please do.