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Continuing Education Course #411
External Ballistics Primer for Engineers
Part II: Test Equipment

1. Fourth grade students in I.M. Mensa Elementary School's engineering course designed a marshmallow gun meant to shoot marshmallows supersonically (never mind what would happen to a marshmallow well before going supersonic). Rather than purchasing a doppler radar to measure initial velocity they create their own, which only outputs the doppler shift because outputting the velocity would be much too simple for these guys. They are transmitting a 100MHz, VHF signal, and measuring a 200Hz shift. Assuming the marshmallow is moving in a straight line away from their transceiver signal what is the calculated speed of the marshmallow in miles per hour?

- a. 221 mph
- b. Mach 1 mph
- c. 670.6 mph
- d. 922.3 mph

2. An amateur ballistician builds a small make-shift railgun which launches 15mm diameter projectiles. She wants to know the projectile velocity near the end of the railgun, but is low on funds. She also wants to get pretty good accuracy on the velocity and is looking at purchasing any one of the following: ballistic pendulum, doppler radar, or optical sensor ballistic chronometer. What is the likely the best option for the ballistician?

- a. The optical sensor ballistic chronometer because it provides good accuracy with low cost
- b. The ballistic pendulum because it has the best accuracy
- c. The doppler radar because they are generally the least expensive
- d. The acoustic chronometer

3. An anemometer *can* be used to measure what?

- a. How fast a projectile is moving relative to air
- b. How fast air is moving relative to a projectile
- c. A tool used to find clownfish with foreshortened fins in the ocean.
- d. Both A & B

4. A small hole in the fuselage of an airplane (A), and a pitot tube (B) on that same airplane are used to measure what? Answer in an A, B format respectively.

- a. Total pressure, Static pressure
- b. Stagnation pressure, Total pressure
- c. Static pressure, Stagnation pressure
- d. Pitot pressure and Stagnation pressure

5. The speed of sound through pure hydrogen gas with R=4124.18 J/kg·K, and γ=1.405, is measured at 4327 ft/s (1319 m/s). What is the estimated temperature of the hydrogen? The spreadsheet may be used iteratively to obtain this answer.

- a. 180°C (180°F)
- b. 27.1°C (80.8°F)
- c. 10K (-441.67°F)
- d. 100 $N \cdot s^2/kg \cdot m$ (217 °F/°R)

6. If an SR-71 is flying at Mach 3.1 in air with a *speed of sound* of 1046 ft/s using equations from the course, what is the plane's estimated speed in mph? (1ft/s=.682 mph)

- a. 22,100mph
- b. 22.1 mph
- c. 2,211 mph
- d. 2.21 mph

7. A ballistician is performing extreme temperature drag comparisons on projectiles in a specially designed wind tunnel. At the test chamber inlet the static temperature of the AIR is measured as -56°C (217K) and the Mach number is 2.0. She knows from several other parameters she can use the following equation to calculate the approximate stagnation temperature, T_{total}, at that point in the flow: $T_{\text{total}} = T_{\text{static}}\left(1 + \frac{\gamma - 1}{2} M^2\right)$. What is the approximate stagnation/total temperature?

- a. 391K
- b. 304K
- c. 101K
- d. 450K

8. Near flight apogee (highest point in its flight) a particular amateur rocket is expected to deploy its parachute. This particular rocket is fitted with pressure measuring equipment to calculate its velocity comprised of a pitot-static probe. The charge failed to deploy the chute in this flight so the rocket turns its nose toward the ground and heads back on a collision course. Just before impact the data recorder measured a pressure difference between total and static pressures ($p_{\text{total}} - p_{\text{static}}$) of: 1.45 kPa (1450 N/m²). Using the pressure data and assuming this is in a low-subsonic flight regime what is the terminal velocity of the rocket when the air density is 1.2041 kg/m³? Use equation 4 or the spreadsheet to easily answer this question.

- a. 4900 m/s (11,000 mph)
- b. 490 m/s (1,100 mph)
- c. 49 m/s (110 mph)
- d. 4.9 m/s (11.0 mph)

9. Referring back to question 8, if the rocket's terminal velocity were calculated at 200 mph and the speed of sound calculated at 700 mph, would it be appropriate to use equation 4?

- a. No
- b. Yes
- c. 15
- d. Not enough information is given to answer this question.

10. Why is equation 5 more appropriate for 0.3<M<0.8 than equation 4?

- a. Equation 4 does not take into consideration the effects of drag on a projectile at higher Mach numbers.
- b. Equation 5 considers the effects of compressibility of the gas (when the flow is isentropic)
- c. Equation 4 takes into consideration high Reynolds number flows
- d. Equation 5 accommodates low Reynold's number flows

11. While at an airport waiting for a flight you look out on the field and notice a windsock which is about 2/5 inflated. What is your estimate of the windspeed on the field?

- a. About 12 knots
- b. About 16 mph
- c. About 6 knots
- d. Not enough information is given to determine

12. Of the anemometer types below, which generally has the BEST high and low speed accuracy for determining a wind speed (high-speed, in this instance would be no more than maybe 60 knots and low-speed could be as low as 1-2

knots)?

- a. Pitot-Static
- b. Cup
- c. Ultrasonic
- d. Mercury Tube Barometer

13. Why is it that a straight water column is not used for measuring barometric pressure?

- a. The biggest reason is because of water's density the column would need to be excessively tall
- b. Water is clear and would make reading pressure difficult
- c. Mercury is non-toxic
- d. Water is too expensive

14. What is the difference between Station Pressure and Mean Sea Level Pressure (MSLP)?

- a. Station pressure is the actual barometric pressure at a given location and MSLP is the "uncorrected" pressure when measured at sea level.
- b. Station pressure is the corrected pressure and MSLP is the uncorrected pressure
- c. Station pressure and MSLP are names for the same pressure
- d. Station pressure is the actual barometric pressure at a given location and MSLP is station pressure "corrected" to a sea level standard.

15. Using equation 7 or the spreadsheet, what is the pressure CF (correction factor) for an altitude of 4,393 ft?

- a. .08497
- b. -.8497
- c. 2.11
- d. 0.8497

16. A weather station near the peak of Mount Mansfield in Vermont sits at an altitude of 4,393 ft. The current MSLP corrected atmospheric pressure reading taken from the station is 101.400 kPa, and the temperature 20°C. Using the given values and equation 8 or the spreadsheet what is the uncorrected air pressure?

- a. 86.545 kPa
- b. 14.71 psi
- c. 59.171 kPa
- d. 85.161 kPa

17. If the previous two problems used the same location (altitude of 4,393 ft.), and If the correction factor of question 15 is used with the corrected pressure from question 16 (101.400 kPa), what is the calculated uncorrected pressure using the CF, i.e. $CF*P_{MSLP}$? And, what is the difference in pressure between this value and the calculated value in question 16?

- a. 106.160 kPa, 385.420 kPa
- b. 106.160 kPa, 35 Pa
- c. 86.160 kPa, 385.42 Pa
- d. 106.160 kPa, 385.42 Pa

18. When calculating a ballistic coefficient in the US what atmospheric conditions should be used?

- a. 59°F, 14.696 psi, air density of 0.075126 lb/ft³ and 78% relative humidity
- b. Whatever feels right.
- c. 69°F, 15.696 psi, air density of 1.075126 lb/ft³ and 79% relative humidity
- d. 700°F, 100 psi, air density of 6 lb/ft³ and 100% relative humidity

19. Per the NASA standard temperature and pressure model in figure 13 of the course what is their standard temperature at an altitude of 26 km?

- a. -53.5°C
- b. 53.1°C
- c. -13.3°C
- d. 103.7°C

20. What is a psychrometer?
- a. A unit of measure used for scaling humidity
- b. A piece of equipment that can measure wet-bulb and dry-bulb temperatures, which are then used to get dew point and/or relative humidity.
- c. A transducer used to measure thermal convection patterns in a controlled volume of air
- d. A tool used to measure the strength of various types of psychoses

21. What is dew point?
- a. The air pressure at which dew will form on grass
- b. The temperature at which the water vapor in air will begin to condense
- c. The point from which dew droplets nucleate
- d. The USDA recommended limit of caffeine allowed in carbonated drinks per kg of body mass

22. While watching the news you hear the weather forecaster say the current temperature in your area is 82°F, and the relative humidity is 80%. The barometric pressure just happens to be pretty close to sea-level standard so you pull out your trusty sea-level *psychrometric chart* from the course to find out what the approximate dew point is. What is your determination?
- a. 75°F
- b. 175°F
- c. 65°C
- d. 55°F

23. The *vertical* component of earth's magnetic field lines is called what?
- a. Aggravation
- b. Declination
- c. Inclination
- d. Grivation

24. Congratulations, on building your first ballistic pendulum! In its inaugural run you shoot a 165gr bullet at it. You've borrowed a ballistic chronometer from a friend and measured the bullet velocity at 1131 ft/s just before impact. The pendulum has a rotational radius of 3 ft (dimension "L"), and swings 48.2° giving a height difference of 1 foot (dimension "h"). Assuming there are no losses in the pendulum nor energy losses on impact what is the velocity of the pendulum/bullet combination (use: g=32.174 ft/s² or 9.807 m/s²)?
- a. 8.02 ft/s
- b. 18.02 m/s
- c. 12.04 km/s
- d. 20.56 mph

25. As a double check to your calculations you decide to calculate the mass of the pendulum and compare it to what you measured on a scale. What is the mass of the pendulum? Use the following conversion: 1 grain = .0001429 lb_m.
- a. 30.0 lb
- b. 3.00 lb
- c. 0.30 lb
- d. 300 lb

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