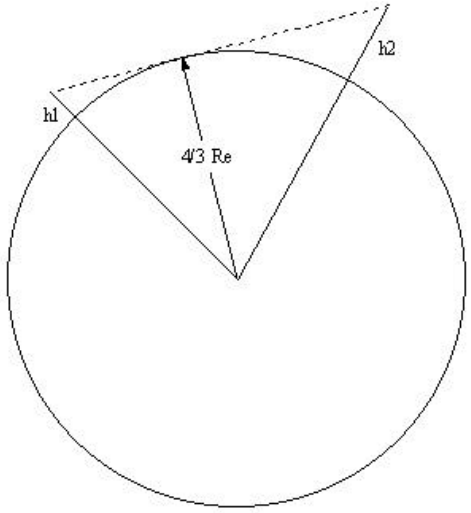
Air Defense

1. The detection of low altitude *anti-ship cruise missiles* (*ASCMs*) by surface ships is governed primarily by radio frequency (RF) propagation and earth curvature. It is commonly known that the *radio horizon* is further than the optical horizon. An estimate of the radio horizon can be determined using the *four-thirds earth* approximation, i.e. the radio horizon is the optical horizon for a sphere with radius equal to $4/3 \cdot$ earth radius. Show that the radio horizon (the range from the radar to the target (nm)) can be approximated by

   $$d = 1.23 \cdot \left(\sqrt{h_1} + \sqrt{h_2}\right)$$

   where

   h_1 is the height of the radar (ft), &
   h_2 is the height of the target (ft).



Units: 1 nautical mile (nm) ≅ 6076 ft
1 earth radius ≅ 2.09E+07 ft

2. Assuming *d* as defined in (1) is the *detection range* for the target, find the detection ranges for the following radar/target pairs:

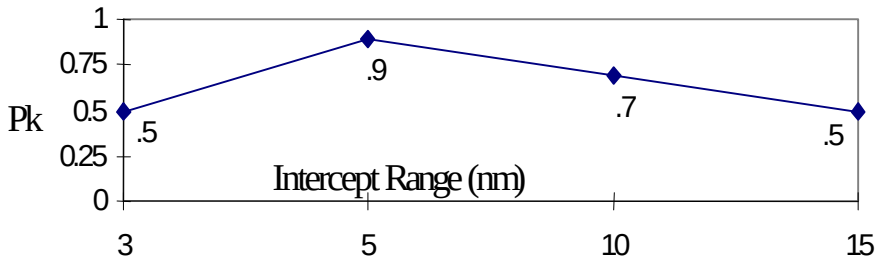
	Radar Altitude (ft)	**Target Altitude** (ft)
A	50	30
B	50	10
C	80	30
D	80	10

3. For a *Mach 1* (1125 ft/s) target, calculate the time from detection to *impact* for each of the radar/target pairs considered in (2). Do the same for a *Mach 2* target. Note the shortest time from detection to impact.

4. The *reaction time* is commonly considered the time from *firm track* (for simplicity assume detection) to *missile away*. For a defending missile or *interceptor* with an average speed of Mach 2, compute the *intercept range* for a Mach 1 target using the parameters from above and a 10 second reaction time.

5. Continuing with (4), if it takes 7 seconds to evaluate the outcome of an engagement (*kill assessment time*) and 3 seconds to fire another missile (*reengagement time*), at what range will a second intercept take place (assuming the first has failed)? If the minimum range of the missile is 3 nm, can a third intercept occur? [Note: the total number of intercepts or *engagements* on a target is referred to as the *depth of fire*.]

6. The probability that an interceptor can successfully engage and kill a target is known as the *probability of kill* or P_K. Assume that an interceptor has the following intercept range dependent P_K against low altitude ASCMs:



For each of the intercept points found above, compute the P_K. What is the probability that the threat will be successfully countered, often referred to as the *raid annihilation probability* P_{RA}? Hint: Consider 1 - Prob(both engagements fail). What is the average number of weapons that will be expended?

7. Now assume that the target is not engaged immediately. Instead, the first intercept occurs at 5 nm. Does the depth of fire change? What is the P_{RA}? What is the average number of weapons that will be expended? Comment on the advantages and disadvantages of not engaging the target immediately.