The Battleship North Carolina's Fire Control

Objectives:

1. Students will see the application of trigonometry that the Mark 14 gun sight used with the 20mm guns aboard the NC Battleship. (Geometry SCOS: 1.01)
2. Students will learn about the history of general fire control in the Navy and the use of the Mark 14 gun sight on the NC Battleship. (US History SCOS: 10.05)

Overview:

In this lesson, students will not only learn about the Battleship North Carolina's artillery, but they will understand more of the geometry that goes into the technology of the ship. They will appreciate the history of the technology of the navy. Students will also have to solve trig functions the way that they did in the navy in the 1940's by using trig tables.

Teacher Directions:

This lesson was written to be taught in two ways, either as a self led lesson, or as a group activity. You can use direct instruction if you would like

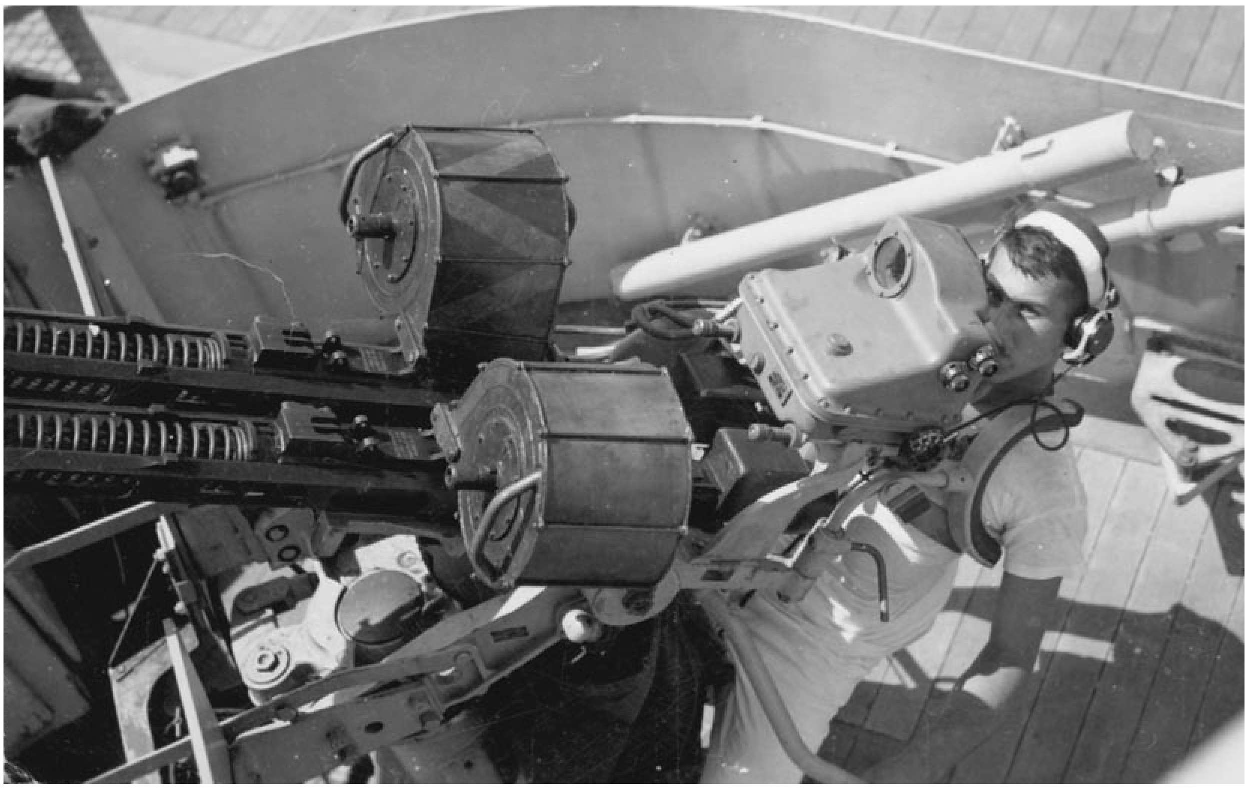
The Battleship North Carolina's Fire Control

Name: ____ Date: ___________

Group Members: ____

Fire control refers to the entire process of utilizing a ship's armament. It involves the material, personnel, methods, communications, and organization necessary to inflict upon the enemy maximum destruction in minimum time. There are several types of fire arms on the Battleship NC, including the 20mm, 40mm, 5in and 16in guns.

The 20mm is the smallest of the firearms on board the ship. Here is a picture of a sailor manning the 20mm.

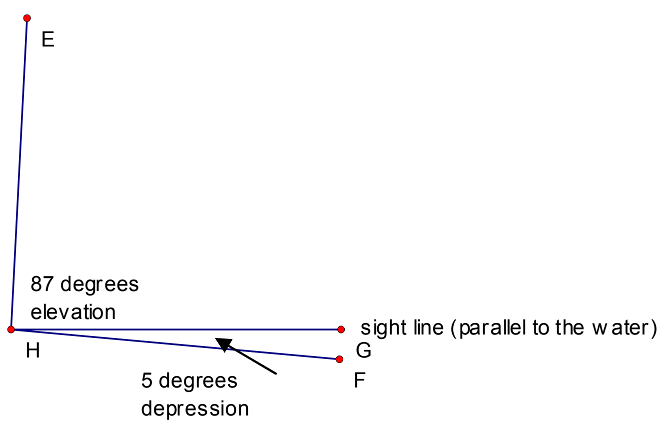


If you take a close look at the picture above, you will notice that the sailor is looking through a box instead of looking at the target. This box is the Mark 14 gun sight.

Here is an excerpt from a naval book about the 20mm gun.

7C19. General data.

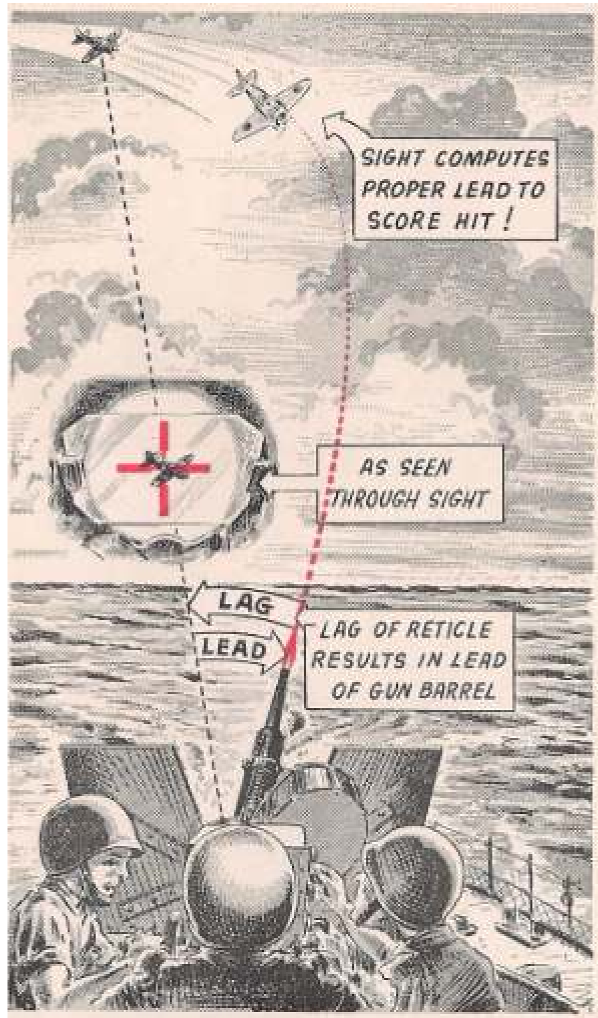
Caliber	20 mm. (.79 inch)
Length of barrel (calibers)	72 (approximately)
Limits on elevation (mechanical mount)	5° depression and 87° elevation
Arc of train	unlimited
Firing rate (assuming continuous ammunition supply)	450 rounds per minute
Firing rate (considering time to change magazines)	250-320 rounds per minute
Magazine capacity (rounds)	60 (100)
Muzzle velocity (f. s.)	2,725
Maximum range (36° elevation)	approximately 5,000 yards
Commence firing range (with Mark 14 sight)	
High elevation	1,000 yards
Horizontal	2,000 yards
Weights:	
Gun	141 pounds
Mount (mechanical)	1,578 pounds
Magazine—loaded	63 pounds
Magazine—unloaded	31 pounds
Round of ammunition	approximately 0.5 pound



Notice the limits on the elevation of the 20mm. Recall how to find the angles of elevation and depression. To the left is a sketch of these angles to help understand the limits on the gun's ability to shoot up and down.

It's also interesting to note that the optimal distance that the gun can fire is when its angle of elevation is at 36 degrees. Also, the gun can shoot 450 rounds per minute (if it is continuously loaded), which translates to 7.5 rounds per second. Now that's a fast gun!

The Mark 14 gun sight was also known as the “Lead Lag” sight. Lead Lag refers to how the sight basically works. To the right is a picture demonstrating the lead lag concept.

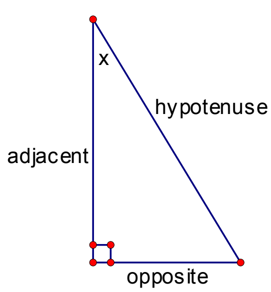


Notice how the lead and the lag are simply the angle at which you actually need to aim the gun, versus where you would point the gun directly at the target. The lag angle measure is the same as the lead angle measure. The only reason why they name it differently is because they have different initial and terminal rays.

The Mark 14 calculates the lead angle as you focus in on your target. The computer in the sight can calculate where the gun needs to be pointed based on your target continuing to move in the same direction at the same speed. As the plane’s speed and direction changes, the Mark 14 recalculates and lets the operator know where to move the gun to stay on target. The Mark 14 also calculates the affect gravity has on your projectile. Obviously your bullet cannot travel in a direct path. Wind is a factor. And remember, you are on a battleSHIP, so the motion of the ocean also comes into play.

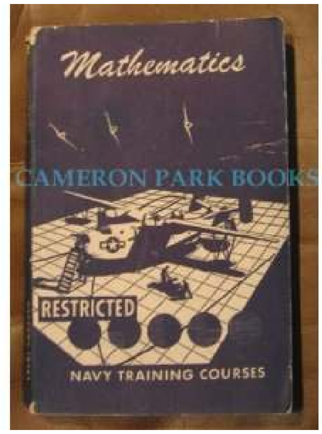
In our studies of the lead/lag angle, we are going to ignore the other factors that may skew our mathematics. After all, it is a computer that does the calculations!

Recall, formulas for sine, cosine, and tangent.



Trig Function	Formula
Sine	$\sin(x) = \frac{opposite}{hypotenuse}$
Cosine	$\cos(x) = \frac{adjacent}{hypotenuse}$
Tangent	$\tan(x) = \frac{opposite}{adjacent}$

The navy taught their sailors basic trigonometry through their Navy Training Course manual. There is a picture of this manual to the right. Remember, in the 1940s there were no calculators, so they found their trig functions by using trig tables.



We will be using the trig table from this book for this lesson, so there will be no calculators to calculate the trig functions!

Below is a copy of the trig table we will be using:

Table of Tangents, Cosines, and Sines

Angle	Tangent (opp./adj.)	Cosine (adj./hyp.)	Sine (opp./hyp.)	Angle	Tangent (opp./adj.)	Cosine (adj./hyp.)	Sine (opp./hyp.)
0°	.000	1.000	.000	45°	1.000	.707	.707
1	.017	1.000	.017	46	1.036	.695	.719
2	.035	.999	.035	47	1.072	.682	.731
3	.052	.999	.052	48	1.111	.669	.743
4	.070	.998	.070	49	1.150	.656	.755
5	.087	.996	.087	50	1.192	.643	.766
6	.105	.995	.105	51	1.235	.629	.777
7	.123	.993	.122	52	1.280	.616	.788
8	.141	.990	.139	53	1.327	.602	.799
9	.158	.988	.156	54	1.376	.588	.809
10	.176	.985	.174	55	1.428	.574	.819
11	.194	.982	.191	56	1.483	.559	.829
12	.213	.978	.208	57	1.540	.545	.839
13	.231	.974	.225	58	1.600	.530	.848
14	.249	.970	.242	59	1.664	.515	.857
15	.268	.966	.259	60	1.732	.500	.866
16	.287	.961	.276	61	1.804	.485	.875
17	.306	.956	.292	62	1.881	.469	.883
18	.325	.951	.309	63	1.963	.454	.891
19	.344	.946	.326	64	2.050	.438	.899
20	.364	.940	.342	65	2.145	.423	.906
21	.384	.934	.358	66	2.246	.407	.914
22	.404	.927	.375	67	2.356	.391	.921
23	.424	.921	.391	68	2.475	.375	.927
24	.445	.914	.407	69	2.605	.358	.934
25	.466	.906	.423	70	2.747	.342	.940
26	.488	.899	.438	71	2.904	.326	.946
27	.510	.891	.454	72	3.078	.309	.951
28	.532	.883	.469	73	3.271	.292	.956
29	.554	.875	.485	74	3.487	.276	.961
30	.577	.866	.500	75	3.732	.259	.966
31	.601	.857	.515	76	4.011	.242	.970
32	.625	.848	.530	77	4.331	.225	.974
33	.649	.839	.545	78	4.705	.208	.978
34	.675	.829	.559	79	5.145	.191	.982
35	.700	.819	.574	80	5.671	.174	.985
36	.727	.809	.588	81	6.314	.156	.988
37	.754	.799	.602	82	7.115	.139	.990
38	.781	.788	.616	83	8.144	.122	.993
39	.810	.777	.629	84	9.514	.105	.995
40	.839	.766	.643	85	11.430	.087	.996
41	.869	.755	.656	86	14.301	.070	.998
42	.900	.743	.669	87	19.081	.052	.999
43	.933	.731	.682	88	28.636	.035	.999
44	.966	.719	.695	89	57.290	.017	1.000
45	1.000	.707	.707	90		.000	1.000

To use this table, find the angle measure that you are working with, then follow over to the appropriate column that contains the trig function that you are looking for.

For example, if you were looking to find the value for cos(56), look down the angle column for 56, then follow over to the column for cosine. You will find, .559.

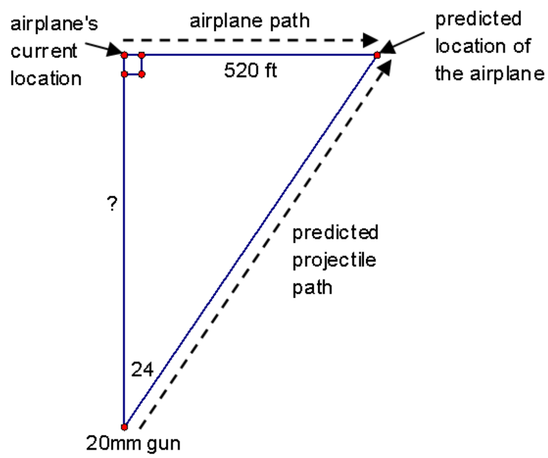
We will also be using the table to find the measures of the angles. Supposed you are trying to solve, $\tan(x) = \frac{18}{12}$. First you need to find the decimal value of 18 over 12, which is 1.5. Next, in the tangent column, find the value that is closest to 1.5, which you will find 1.483. Then following over to the associated angle measure, which is 56 degrees.

Next let's solve some practical scenarios that could have happened aboard the Battleship North Carolina.

Example 1:

Suppose you are manning a 20mm gun aboard the Battleship North Carolina. A Japanese zero is flying parallel to the ship. The Mark 14 gun sight has calculated that in order for you to hit the plane, you need to have a lead/lag angle of 24 degrees, and also to aim 520 feet in front of the plane. Assuming that the plane continues its route in the same speed and direction, approximately how far away, in feet is the plane from the ship?

First we have to sketch the situation,



Next, we need to decide which trig function we are using,

520 is opposite, and ? which we will denote as x is adjacent, so we will be using tangent.

Then we set up our problem,

$$\tan(24) = \frac{520}{x}$$

Use your trig table to find tan(24) = .445, then substitute it in your expression,

$$.445 = \frac{520}{x}$$

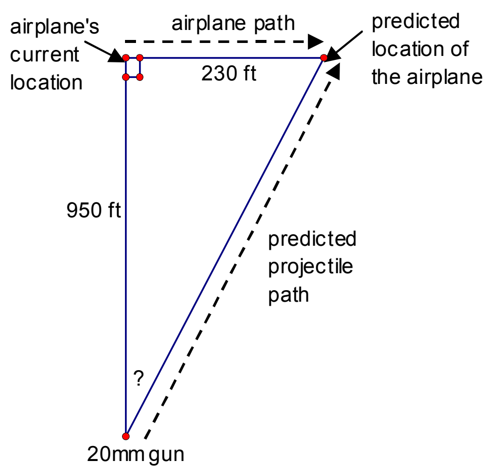
Then use algebra to solve, and we find that

x = 1,168.54 feet

Example 2:

The Mark 14 gun sight has calculated that in order for you to hit the plane, you must aim 230 feet in front of it. You know that the plane is 950 feet away from the ship. Assuming that the plane continues in the same direction at the same speed, what would the Mark 14 tell you was the lead/lag angle?

First we have to sketch the situation,



Next, we need to decide which trig function we are using,

230 is opposite, and 950 is adjacent, so we will use tangent.

Then we set up our problem,

$$\tan(x) = \frac{230}{950}$$

Next we need to find write 230 over 950 as a decimal, and we get .242, and substitute it into our expression,

$$\tan(x) = .242$$

Next, under the tangent column, find the number closest to .242, which we find, .249, which is associated with 14 degrees.

$$x = 14 \text{ degrees}$$

Here are some examples for you to try yourself:

1. The Mark 14 gun sight has calculated that in order for you to hit the plane, you need to have a lead/lag angle of 20 degrees, and also to aim 435 feet in front of the plane. Assuming that the plane continues its route in the same speed and direction, approximately how far away, in feet is the plane from the ship?

2. Suppose the Mark 14 gun sight has calculated that in order for you to hit the plane, you must aim 325 feet in front of it, and that the predicted projectile travel distance is 1,250 feet. Assuming that the plane continues in the same direction at the same speed, what would the Mark 14 tell you was the lead/lag angle?

3. There is a Japanese zero airplane located 2,750 feet away. The Mark 14 gun sight has calculated that you will have a lead/lag angle of 12 degrees. Approximately how far in feet would you need to aim your gun in front of the airplane?

4. Suppose you know that the Mark 14 has calculated that you to aim 345 feet in front of the airplane with a lead/lag angle of 22 degrees in order to hit your target. How far in feet will the projectile travel before hitting its target?

5. In two different scenarios we have identical planes that are both flying 1,115 feet away from the battleship. In the first case, the projectile will have to travel 1,530 feet to hit the target, and in the second case, the projectile will have to travel 1,772 feet to hit the target. What are the lead/lag angles in both cases? Why do you think the lead/lag angles are different even though these planes are identical and flying at the same distance away from the plane?

All sources courtesy of Battleship North Carolina Collections.

Answers:

1. 1,195.059 ft
2. 75 degrees
3. 585.75 ft
4. 920 ft.
5. 43 degrees, and 46 degrees
   Possible answers: planes are flying at different speeds, one plane may have changed its course, etc.