

First, A General Note

For every Science Olympiad event, and especially Road Scholar, it is important to have your answers in the correct format as well as having the correct numbers. Any numeric answer needs to have the proper units included or correctly identify what the number is. For example, a 2 all by itself is at least incomplete and partially incorrect. Is it feet, meters, a US highway, a sector? For computations, numbers need units, such as 2 miles. For a highway number, it needs the type of highway, such as state highway 2. There are also standard abbreviations for most of the units and types. Miles is mi, state highway is SH 2 or SR 2 or M-2 in Michigan or WI-2 in Wisconsin. Latitude/longitude have very specific formats they need to be written with. For example, a latitude needs to be in the format of 43° 27' 39" N. Just getting it correctly computed is the major part of the answer, but expressing it correctly is a requirement. This general rule applies to all rectangular coordinate systems (Lat/Long, PLSS, UTM, SRS) and most other answers. The formats for the rectangular coordinate systems can be found in the Road Scholar Notes on the same soinc.org event page as this document.

Place names should be complete enough to identify exactly what is being identified. For example, Rouge River is a river. Rouge River Park is a different feature, a park. Counties almost always have to have County added to them to distinguish them from towns or other natural features like lakes.

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The required math skills for Road Scholar are pretty basic: the four arithmetic operations and the use of proportions. In addition, some basic measurements and conversions into distances are needed. Road Scholar math problems can be as simple as adding distances from information on a map. Many Road Scholar math problems involve setting up a simple proportion and finding the missing value. This first part of the paper will focus on these proportion problems. Road Scholar uses three main proportions: latitude/longitude, distance/scale, and slope/gradient.

Latitude/Longitude

$$\frac{\text{measured mm to an object}}{\text{measured mm to a known distance (e.g., 150")}} = \frac{\text{seconds to an object}}{\text{seconds of a known distance (e.g., 150)}}$$

Distance/Scales

$$\frac{\text{measured mm of a distance}}{\text{measured mm to a known distance (scale, e.g., 2 mi)}} = \frac{\text{mi/ft/km/m}}{\text{known distance (scale, e.g., 2)}}$$

Slope/Gradient

$$\frac{\text{(end elevation – start elevation (ft/m))}}{\text{horizontal run distance (ft/m)}} = \frac{\text{elevation change (ft/m) per}}{\text{some standard distance (ft/m, e.g., 100)}}$$

In each case, the left side of the proportion is the data from the map. The right side is the unknown in the numerator and a comparison value is in the denominator. Each of these proportions has one unknown, usually the right hand numerator. It is solved by cross multiplication; i.e. multiply the left hand numerator by the right hand denominator. This will isolate the unknown value on the right.

Slope/gradient requires a couple additional pieces of information. Mathematically, slope is always vertical change divided by horizontal change. The mnemonic for this is "Rise Over Run". But in Road Scholar and in the many real world applications of slope, the value is computed over some longer distance. In Road Scholar, slope is usually per 100 feet and gradient per 1000 feet. That is why you have a comparison value in the right hand denominator. Although the 100'/1000' values are default values, look at the question carefully to see what the comparison

value being asked for is. In the real world, that comparison value can vary considerably depending on the application the slope is being used for.

It is important to make sure you have matched the units of measurement. This is especially the case with slope/gradient where the elevations are almost always in feet and distances are often in miles. In that case, make sure to convert the miles to feet first so that the units of measurement are correctly matched. Remember that slope is a signed value. Upslope is positive and downslope is negative. Stream gradients are always negative. Terrain slope can be positive or negative depending on where you are measuring from and to.

When you understand how these proportions are set up, then you can do the math to find an unknown value in any of the four positions. For example, if you are given a latitude and longitude and asked to find the location, then you can still use the proportion with the unknown in a different place. In this example, you have the seconds of the latitude and longitude and need to find the millimeters to measure on the map. Therefore, the unknown is in the left hand numerator instead of the right hand numerator. That means you will multiply the right hand numerator by the left hand denominator to isolate the unknown on the left.



Here is an example of this process using the Imlay City topographic map. Locate the large building on the southeast side of Imlay City on the actual map. Using the proportion above, it is easy to compute the latitude and longitude. You should determine that it is  $43^{\circ} 01' 28.5''$  N  $83^{\circ} 04' 23''$  W. But suppose the question on the test asked you to determine what object or feature is located at  $43^{\circ} 01' 28.5''$  N  $83^{\circ} 04' 23''$  W. Here's how you work through that question.

The first step is to roughly locate the point on the map. You can look at geographic coordinates on each corner of the map and quickly determine the coordinates are closest to the southwest corner. The coordinates at the southwest corner are  $43^{\circ} 00' 00''$  N and  $83^{\circ} 07' 30''$  W. We need to find the correct number of seconds to plug into the proportion. Subtract the minutes and seconds of the coordinates in the question from the appropriate value of the corner coordinates. You should obtain a value of  $1' 28.5''$  for the latitude value and  $3' 07''$  for the longitude value. These can be reduced to  $88.5''$  and  $187''$ . We are now ready to plug those numbers into the proportion and solving. In the proportion, the seconds are the right hand numerator. The right hand denominator is still  $150''$  for both the latitude and longitude values. We still measure the millimeters for  $2.5'$  or  $150''$ : they are  $191.5$  for the latitude and  $140.5$  for the longitude. Those values become the left hand denominator. The unknown is the millimeters to the unknown object on the map which is the left hand numerator. We cross multiply by multiplying  $88.5$  times  $191.5$  for latitude or  $187$  times  $140.5$  for longitude. We take the result and divide by  $150$  in each case. The final result should be  $113$  mm for latitude and  $175$  mm for longitude. We measure those on the map and determine the large building is the object or feature at the specified latitude and longitude. Ta dah! You did it!

The kind of question where you are given the coordinates and asked to describe what is at those coordinates is very rare in Road Scholar, although it has a huge number of real world applications. It is within the rules and may appear at very strong, competitive tournaments. In general, you want to understand the underlying principle for a formula and then you can use it when and how needed.

Another common math problem, especially on the highway map portion of a test, are questions involving distance, time and speed. They are usually questions asking you to compute a time or a speed. In Road Scholar, the time is usually in hours and minutes, distance is usually in miles or kilometers, and speed is usually miles or kilometers per hour.

The three variables are related by three equations.

**Speed = distance divided by time**

**Time = distance divided by speed**

**Distance = speed times time**

The computations are straight forward as long as you keep track of time correctly. Time can be expressed as minutes, hours and minutes or hours as a decimal or fraction. Examples of each are 53 min or 322 minutes; 0 h 53 min or 5 h 22 min; and 0.883 h or 5.367 h. The decimal conversion involves taking the minutes value and dividing by 60.  $53/60 = 0.883$  and  $22/60 = 0.367$ . Don't forget to add the decimal piece to the hours value. Conversely, to get the decimal value of an hour converted to minutes, multiply the decimal value by 60.

Fractional hours are hard to handle on a calculator. In general fractions should be converted to decimals to simplify the calculator operations. E.g.,  $\frac{1}{4}$  h converts to 0.25 h by doing the division of 1 divided by 4.

#### **Examples:**

If you drive 43 miles in 48 minutes, what is your average speed in miles per hour (mph)? If you use the equation above,  $43/48 = 0.896$ . But that value is in miles per minute. To convert to mph, multiply by 60 and get 53.75 mph.

Next, try 288 miles in 5 h 22 min. 5 h 22 min can be converted to minutes (322) or 5.367 h. Since we want an answer in mph, let's use the decimal hours form:  $288/5.367 = 53.66$  mph. If you use the total minutes (322) as the divisor, don't forget to multiply by 60 to get to mph ( $288/322 \times 60$ ).

Now, let's try to find a time to travel. If you travel 43 miles at 53.75 mph, how long will it take in hours and minutes?  $43/53.75 = 0.8$  h. The 0.8 is in hours. To get minutes, multiply by 60 (= 48). Therefore, the answer is 0 h 48 mins.

Similarly, if you travel 288 miles at an average speed of 53.66 mph, how many hours will it take? So,  $288/53.66 = 5.367$  h. When the question asks for just hours, use the decimal form. However, in most cases, you would be OK to convert to hours and minutes. To do that, take the decimal value (0.367) times 60 to get 22 mins. Thus, 5 h 22 mins.

#### **Helpful Hints:**

1. 60 mph is equal to 1 mile/min. This means that if the time in minutes is less than the miles, the speed is more than 60 mph. Conversely, if the time in minutes is more than the miles, the speed is less than 60 mph. The same principle applies to kilometers.

2. The most common mistake on a test where you have to add times is to forget the 60 minutes per hour. If you add 48 mins and 1 h 22 mins, the answer is 2 h 10 mins, not 1 h 70 mins.

#### 3. Conversions

One mile = 5280 feet or 63,360 inches or 1.609344 km or 1609.344 m

One kilometer = 3280.84 feet or 1000 meters

Miles to kilometers =  $\times 1.609344$

Kilometers to miles =  $\times 0.621371$

Feet to meters =  $\times 0.3048$

Meters to feet =  $\times 3.28084$