

## Mechanics Activity: Track Records

### Student Worksheet

#### Objective

Determine how the speed of a runner depends on the distance of the race, and predict what the record would be for 2750 m.

#### Introduction

Now that you have begun studying motion, you have the tools necessary to analyze some real data from the real world. In this activity, your objective is to determine the relationship between the average speed in a competitive race and the distance covered by that race. To do this, you will use records from a track and field source of your choosing. Recall that average speed is the total distance covered divided by the total time. Recall also that 1 mile = 1609.3 meters.

#### Method

Find two sets of records (World, National, School, College) for the running events of Track & Field on the internet. You may select men's or women's records, or both. Copy them into Excel (using paste special... text... should help formatting). Put each set of records on its own tab in the Excel document. You may want to delete events that involve obstacles, such as hurdles and steeplechase. Make sure your data is formatted in a way that makes sense. Distances and times should be numbers only, and distances should all be in the same units (meters), with the units included only in the headers for the columns. If you have a record for the hour run, enter the distance in the distance column and one hour in the time column.

#### Data Analysis

1. For each record, calculate the average speed of the runner who set it, in meters per second.
2. Make a graph of average speed (y-axis) vs. race distance (x-axis) for each set of records.
3. What type of trend do the data exhibit? Choose an appropriate trendline and fit it to the data, replacing variables as appropriate.
4. If the 2750 m race were contested, what would the record be in each of the sets you have examined?

#### Discussion

Answer the following questions in complete sentences in paragraph form. Turn them in, along with your data table and graph.

1. What was your result for this experiment? Refer to the objective, and state, unambiguously and definitively, your findings.
2. How confident are you in your prediction for the 2750 m event? Assign an uncertainty to this measurement, and explain how you calculate it.
3. How confident are you in the relationship between distance and average speed? How similar was the relationship between the two sets of records? What might have affected this?
4. Look at the years the records were set. Do you notice any trends? Comment on the timing of the records, making reference to the graphs you created, as appropriate.
5. Make a prediction about the next record to be broken. Explain your reasoning, referring to your graph as appropriate.



## Mechanics Activity (World Records)

### Teacher Notes

This activity is intended to give students practice calculating average speed as well as experience drawing conclusions from a real set of data.

An example of possible data sets and conclusions are below.

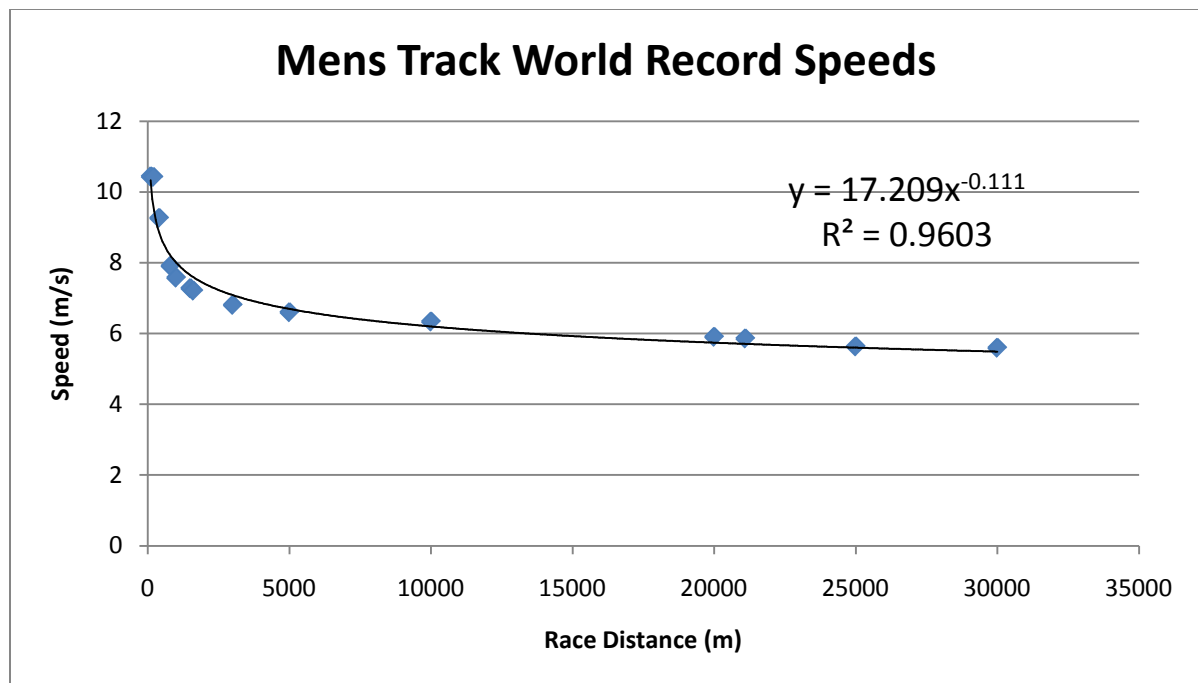
Example: World Records for Men

Track Event	Time	Time (s)	Avg. Speed (m/s)	Record Holder (Country)	Date Set
100	9.58	9.58	10.43841	Usain Bolt (Jamaica)	8/16/2009
200	19.19	19.19	10.42209	Usain Bolt (Jamaica)	8/20/2009
400	43.18	43.18	9.263548	Michael Johnson (US)	8/26/1999
800	0:01:41	101.11	7.912175	Wilson Kipketer (Denmark)	8/24/1997
1000	0:02:12	131.96	7.578054	Noah Ngeny (Kenya)	9/5/1999
1500	0:03:26	206	7.281553	Hicham El Guerrouj (Morocco)	7/14/1998
1609	0:03:43	223.13	7.211043	Hicham El Guerrouj (Morocco)	7/7/1999
3000	0:07:21	440.67	6.807815	Daniel Komen (Kenya)	9/1/1996
5000	0:12:37	757.35	6.601967	Kenenisa Bekele (Ethiopia)	5/31/2004
10,000	0:26:18	1577.53	6.339024	Kenenisa Bekele (Ethiopia)	8/26/2005
20,000	0:56:26	3385.98	5.906709	Haile Gebrselassie (Ethiopia)	6/27/2007
21101	1:00	3600	5.861389	Arturo Barrios (Mexico)	3/30/1991
25,000	13:55.8	4435.8	5.635962	Toshihiko Seko (Japan)	3/22/1981
30,000	29:18.8	5358.8	5.598268	Toshihiko Seko (Japan)	3/22/1981

In this spreadsheet, I have converted the times (given in mm:ss) to seconds in the third column. This is a little bit tricky in Excel, and it may be easier to just have your students compute it by hand. If you are interested, the formula to enter to convert is  $=(B5-INT(B5))*24*3600$  to convert the cell B5 (1:41) into seconds. You will then want to change the format of the cell to a decimal to have the seconds appear as above.

The graph of average speed versus distance is below. The function is decreasing, concave up, and non-linear. Students should know to fit a power-function in such a case, but may need reminding.

Once students have fit the trendline, they can interpolate to solve for the average speed associated with the 2750 m race, and then, solve for the time.



$$v = 17.209 (2750)^{-0.111} = 7.145 \text{ m/s}$$

$$v = d/t, \text{ so } t = d/v = 2750 \text{ m} / 7.145 \text{ m/s} = 384.9 \text{ seconds} = 6:24.9$$

This, of course, is only a fair prediction if the record setter in the 2750 m race is of comparable speed and fitness to the record holders determining the model.

If we look at the predicted value from the trendline, we can compute the residual and get a sense of the average uncertainty in a world record as compared to the prediction.

Track Events	Time (s)	Predict v	Predict t	residual	% error
100	9.58	10.261	9.75	-0.16542	-1.7%
200	19.19	9.501	21.05	-1.85966	-9.7%
400	43.18	8.798	45.47	-2.28628	-5.3%
800	101.11	8.146	98.21	2.90497	2.9%
1000	131.96	7.947	125.83	6.125201	4.6%
1500	206	7.597	197.44	8.558634	4.2%
1609	223.13	7.538	213.44	9.685719	4.3%
3000	440.67	7.035	426.46	14.20591	3.2%
5000	757.35	6.647	752.24	5.109982	0.7%
10,000	1577.53	6.155	1624.80	-47.2732	-3.0%
20,000	3385.98	5.699	3509.50	-123.519	-3.6%
21101	3600	5.665	3724.79	-124.787	-3.5%
25,000	4435.8	5.559	4496.89	-61.0884	-1.4%
30,000	5358.8	5.448	5506.59	-147.787	-2.8%

You see a hint of systematic error in this analysis—the model gives too slow a time for short and long races, and too fast a time for middle distance races. Still, looking at the race of error for the races near 2000 m, it might be reasonable to assume our prediction is off by 3-4 %, or 8-11 seconds. It's much more likely that our prediction is too fast than too slow.

The relationship between speed and distance is relatively consistent among the sets of records I checked, with a power of something in the -0.100 to -0.150 range usually providing the best fit.

In looking at the dates, students may notice that some records are much older than others. Things to encourage students to consider are whether all the records are of equal quality. For example, particularly for school or college records, it is quite likely that the school had a very good sprinter, middle-distance, or distance runner at some point in history that may have produced records that are much faster than the average top runner in the program. Another thing you may want students to consider is the role of performance enhancing drugs at different points in history, particularly for the professional records. This can be inferred by looking at the deviance of points from the trend on the graph (or by calculating residuals, as above).

In predicting the next record to be broken, you may want students to refer to the same kind of analysis as above, looking at the deviance of particular records from the trend. Students may also want to use their knowledge of track and field to make a prediction (for example, Usain Bolt already has the 100 m and 200 m records and is still actively running; students may conclude that he is likely to break his own record before too much more time passes).

Regardless of the specific answers to the questions provided in the discussion, students should be encouraged to think critically about the data and the trendline they fit to it. This is real data, so there are no right answers to be looked up or checked, and students should be encouraged to draw their own conclusions about what the data tell them.