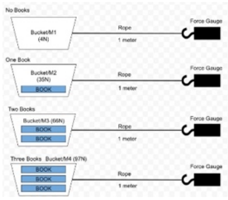
Question: How does adding weight to an object affect the kinetic coefficient of friction when it's being dragged?

Hypothesis: If the weight of the object increases, then the kinetic coefficient of friction will also increase. The increase in the weight of the object will have a positive and linear correlation to the coefficient of friction.



Strategy:

Figure 1: Diagram of Experiment

- To start off, the variables we had to account for were the different weights that we were adding to the object, how far we were going to pull the object, and what the pulling force of the object would be.
- Since we completed our tests on the carpet, we needed something that would slide across the carpet smoothly, so in this case, we chose to use a plastic box.
- For our weights, we used three different textbooks that were the same size and added one each time.
- We measured the weight of the box alone,
  which is what we used for our initial weight with no added-on objects. After this, each time we added a book, the weight had a constant increase.
- We decided to keep the distance the same for all of the tests.
- We did three trials for each weight: the plastic box alone, the plastic box and one book, the plastic box and two books, and the plastic box and three books. We then took the average of the three trials as our final pulling force for each of the weights.
- In order to measure the pulling force, we used a force gauge that we hooked up to a computer.
- Finally, in order to measure our data, we dragged the plastic box across the floor with a string that was attached to a pencil that sat in the crook of the box. We placed the books inside the box when increasing weight.

Data:

The last row is the average of the three trials so that we could get a singular force for each weight.
The weight of the box without any additional weight was 4 newtons, and each book had a weight of 31 newtons which is why as each book was added on, it increased at a constant rate. We kept the distance, 1 meter, the same for all trials.

no books	weight (kg)	pulling distance	pulling force (N)
trial 1	0.272	1 meter	0.560
trial 2	0.272	1 meter	0.747
trial 3	0.272	1 meter	0.930
Average	0.272	1 meter	0.746

1 book	weight (kg)	pulling distance	pulling force (N)
trial 1	1.587	1 meter	9.495
trial 2	1.587	1 meter	9.099
trial 3	1.587	1 meter	9.420
Average	1.587	1 meter	9.338

2 books	mass (kg)	pulling distance	pulling force (N)
trial 1	2.902	1 meter	17.525
trial 2	2.902	1 meter	17.062
trial 3	2.902	1 meter	17.149
Average	2.902	1 meter	17.245

3 books	mass (kg)	pulling distance	pulling force (N)
trial 1	4.217	1 meter	25.330
trial 2	4.217	1 meter	24.062
trial 3	4.217	1 meter	25.681
Average	4.217	1 meter	25.024

Figure 2: Data Table

Analysis:

The free body diagrams in Figure 2 show the forces on the weight s in the modified Atwood's machine.

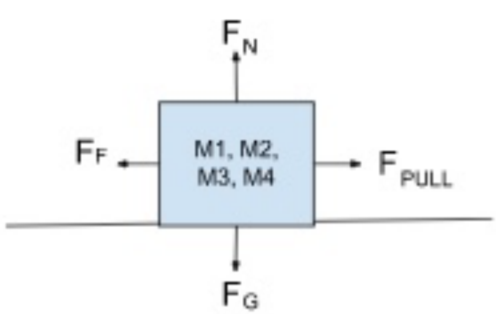


Figure 3: Free Body Diagram

$$F_{PULL} - F_F = m \bullet a$$
$$F_F = F_N \bullet \mu k$$
$$F_N - F_G = m \bullet a$$
$$F_G = m \bullet g$$

$$F_{PULL} = F_N \bullet \mu k$$
$$\frac{F_{PULL}}{F_N} = \mu k$$

Through the free-body diagram in Figure 3, we can see the various forces that are acting on the box.
When looking at this diagram, we start off by considering the first equation shown below. Since the drag had a constant velocity, this means that the pulling force equals the force of friction. The equation for the force of friction is displayed in the second equation, but we can replace the force of friction with the pulling force. The next equation we can consider is the third one shown below. Again, since acceleration is equal to 0, we can set the normal force and force of gravity equal to each other. Since the force of gravity equals weight times gravity, we can say that the normal force equals weight times gravity. Finally, we know that in order to find the coefficient of friction, we can do the force of friction divided by the normal force. We can substitute for everything we know and say that the coefficient of friction equals the pulling force divided by the normal force, which is where the weight comes in. Since we know that gravity is 9.8, we now have all of our information.

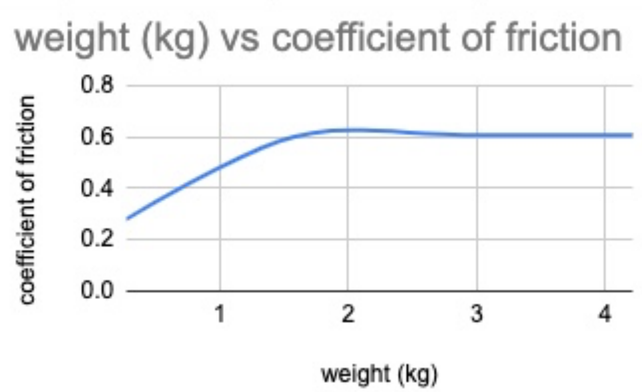


Figure 5: Weight vs. Coefficient Graph
Our prediction was that the kinetic coefficient would increase as the weight increased since the frictional force was increasing which is the denominator. However, as seen from the data, it actually increased at the beginning but then decreased. If it were to have a positive and linear increase, then it would've been going up and to the right in a straight line. The reason our hypothesis was not correct is that, in actuality, weight does not affect the coefficient of friction. The reason behind this is that no matter how much weight you add, it's still one surface rubbing against another, meaning that the weight doesn't actually have an effect. Along with this, if the weight is increasing, then it means the pulling force will also increase, which, in turn, cancels out and will keep the coefficient constant. It is likely that there may have been human errors in measurements, but either way, our data allowed us to prove that our hypothesis was incorrect; however, the human errors were not the reason why our hypothesis was incorrect. Although weight affects the frictional force, it only indirectly affects the coefficient of friction. If the weight is extremely large, then it could affect the surface, which might change the coefficient but other than that, it does not have a direct correlation.

	No Additional Weight	One Book	Two Books	Three Books
Pull Force	0.7457	9.338	17.2453	25.0243
Kinetic Coefficient of Friction	0.2797	0.6004	0.6064	0.6055

Figure 4: The calculated kinetic coefficient of friction