Black Widow says, “It’ll be fun – like Budapest all over again.”

1. In testing the Polio vaccine in 1954, researchers compared subjects who had the vaccine with subjects who did not, but both groups were observed at the same time. Would it be worse to simply treat everyone with the vaccine and see if there was less polio than in years prior to 1954? After all, this would save a lot of trouble compared to the study that gave a placebo to a large number of subjects.

2. An observational, international study finds that women who consume more fat in their diet tend to have higher rates of death due to breast cancer.

   (a) What relation to diet and breast cancer mortality would something have to have to be a confounding variable in this study?

   (b) Explain to someone, who does not understand experimental design, how the possibility of a confounding variable in this study shows that we cannot infer that fat in the diet causes higher breast cancer mortality.
3. Loki says: “Reality is boring. Let’s have some fun.”
In their youth, Loki and Thor would play a dice game with a 7-sided Asgardian die, with sides numbered 1,2,3,...,7. As on Midgard (Earth), a “1” is also called an “ace.” Knowing Loki’s ways, Thor had Heimdahl confirm that the die was, in fact, a fair die. In their game, they would roll the die 6 times. What is the chance that, in those 6 rolls, the outcomes are/have:

(a) All aces?

(b) No aces?

(c) At least one ace?

(d) Exactly two aces?

4. Below is a histogram for the number of shield-throws Captain America makes in various battles. Heights of blocks are as marked. Give the most precise estimate that you can of the median number of throws, explaining and/or showing work below. Explain very briefly.

5. The histogram below is for the number of hammer-throws Thor makes in his many battles, though one of the blocks is missing. Block heights are labeled for your convenience. In none of the battles did Thor throw his hammer more than 50 times. Fill in the missing block, and label its height, showing some work. [Note carefully the block widths.]
6. The number of arrows Hawkeye fires in a battle ranges from 18 to 91, and the numbers are fairly evenly spread in this range. Estimate the SD of the number of arrows fired in the battles, and explain your reasoning for each.

7. Having no iconic weapon to use, the Hulk throws Chitauri warriors. The distances vary from one throw to the next. The distances of the throws average 48 feet, with an SD of 15 feet. The histogram of these distances follows a normal curve.

(a) What percentage of these throws will go over 40 feet?

(b) What is the 90th percentile of the throw distances?

8. Back on earth, the Black Widow has been captured by the Mad Dr. X (or is it the other way around?), who is obsessed with probability. He proposes to roll an (ordinary, six-sided) fair die repeatedly. He will release the Widow if she can predict the number of \( \cdot \cdot \)’s within five. If given a choice, should she predict for 60 rolls or 600 rolls? Explain.

9. Tony Stark goes to a strange intergalactic casino on Knowhere, where the following game is played: An (ordinary, six-sided) fair die is rolled. If it comes up \( \cdot \cdot \), \( \cdot \), \( \cdot \cdot \), or \( \cdot \cdot \cdot \), Tony must pay $1 Million dollars per spot showing (e.g. for a \( \cdot \cdot \), he must pay $3 Million.) If the die comes up with any other number, the Casino pays $1 Million per spot showing. Is it a fair game? If so, why, if not, who does it favor?
10. When Iron Man goes on a mission, there is a 20% chance that a piece of his armor is torn off in the ensuing battle. He goes on 60 missions.

(a) Give an explicit box model for counting the number of missions that involve torn-off armor.

(b) Then in 60 missions, the number of those missions that involve torn-off armor will be __________, give or take ________ or so. (Show work)

(c) What is the chance that he has armor torn off in more than 15 of these missions? (Show work)

11. After the Chitauri invasion of New York, Faux TV News announces a survey on their evening news program, which shows only in NYC: “Call us and tell us if you like Super Heroes.” Will the survey results be a reliable measure of support for Super Heroes in NYC? Explain using concepts about surveys that we have studied in this class.
12. A different survey takes a simple random sample of 625 New York City residents after the Chitauri invasion. Of the 625 polled, 139 saw the battle with their own eyes. This may seem small, but NYC is a big place. Give a 95% confidence interval for the percentage of all NYC residents who saw the battle.

13. J. Jonah Jameson, editor of NYC’s Daily Bugle newspaper, says “the common man on the street doesn’t understand this ‘confidence interval’ mumbo-jumbo. I mean, ninety-five percent of what? We need a side article that explains this stuff as clearly as possible for Joe Doakes, the taxi driver in Queens. And the article has to get it right.” Write up your submission for Mr. Jameson, assuming you want him to print your “article.” Maximum four sentences, newspaper space is expensive.

14. Dr. Erik Selvig measures the power output of The Tesseract 16 times. His measurements average 3.4 GW, with SD of 0.13 GW. Assuming no bias in the good Dr. Selvig’s measurements,

(a) What is our best estimate for the power output?

(b) What is the likely error in our estimate? Show some work.
15. Thanos’ fleet has about a thousand leviathans - those giant, armored flying-whale things that carry invading Chitauri to earth. Captain America says “Those leviathans carry, on average, 100 Chitauri warriors.” However, Thanos obligingly allows us to survey a simple random sample of 90 of the leviathans and we find an average of only 85 warriors on each, with an SD of 50. Could this just be chance variation, or is Captain America’s average really too high?

(a) Give a detailed null hypothesis and box model.

(b) Find $p$, showing work.

(c) What is your conclusion? Include some explanation.

(d) J. Jonah Jameson of The Bugle is back, asking you to write up an explanation of what that $p$ means. Use the same standards of clarity as his last problem, but this time you have two sentences at most.
16. By one year after its release, entertainment industry magazines estimated that of people who saw the first Avengers movie, they saw it an average of 1.85 times, with an SD of 0.79 times. Looking into the future (it’s a superhero thing), we see that one year after the release of the second Avengers movie, people who saw it in fact saw it an (estimated) average of 1.93 times, with an SD of 0.85 times. You may assume these estimates are each based on independent simple random samples of \([1000]\) viewers [each] in the U.S. Perform an appropriate test of significance to tell if the average number of times the movies were/will be viewed are actually different.

(a) Give a detailed null hypothesis and box model.

(b) Find \(p\), showing work.

(c) What is your conclusion?

(d) Jameson is back again. Sigh. He says “What’s all this fancy statistical flim-flam? 1.93 is more than 1.85, period. I can tell the average went up.” Is J. Jonah right, or has he misunderstood the question? Explain for him. Remember, he’s a simple guy. Two sentences max, or you’ll lose his attention.
17. The Norns roll the mystical three-sided die of destiny 90 times. It should be a fair die, so 30 of each face should come up. (The faces have strange names listed below.) Odin would like to make sure the Norns aren’t cheating. We get this data:

<table>
<thead>
<tr>
<th>face</th>
<th>expected #</th>
<th>observed #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urðr</td>
<td>30</td>
<td>42</td>
</tr>
<tr>
<td>Verðandi</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Skuld</td>
<td>30</td>
<td>23</td>
</tr>
</tbody>
</table>

Compute Chi-squared for this data, AND give the number of degrees of freedom. Then you can stop, Odin can do the rest for himself.

18. Much research has shown that in superhero movies, the strength of the hero has a considerable negative correlation with the number of minutes remaining in the movie. This means that when there are fewer minutes left in the movie, the strength of the hero tends to be ___________ (fill in the blank, and explain, possibly with a diagram. Careful, this one is tricky.)

19. Hawkeye (the archer) finds that there is a strong negative correlation between the amount of time he takes to aim an arrow and the distance it lands from its intended target. Summary statistics are as follows, and the scatterplot is football-shaped.

<table>
<thead>
<tr>
<th>avg</th>
<th>SD</th>
<th>$r \approx -0.7$</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>2.0 sec</td>
<td>0.33 sec</td>
</tr>
<tr>
<td>distance</td>
<td>5.0 cm</td>
<td>2.0 cm</td>
</tr>
</tbody>
</table>

(a) Predict the distance-to-target of arrows fired with a 1.5-second aim.

(b) Put a give-or-take figure on your estimate in (A)