



Hit or Miss: How Large Is a Penny?

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Topic

Measurement



Time

1½ hours



Safety

Please click on the safety icon to view the safety precautions.

Materials

10 pennies

one metric ruler

one sheet plain white typing paper

scissors

one pen

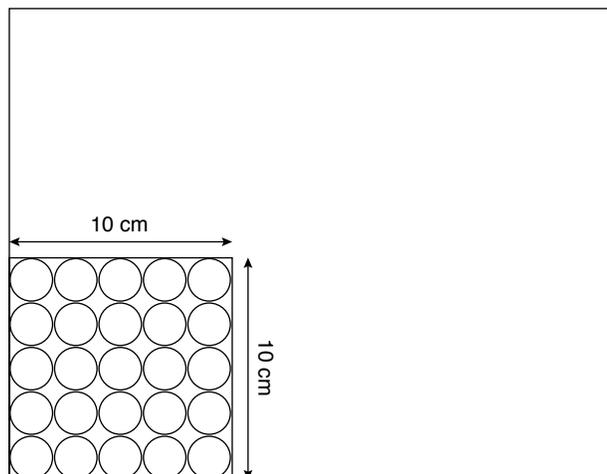
transparent tape

Procedure

METHOD A: INDIRECT MEASUREMENT

1. Use the ruler and pen to outline a box 10 cm \times 10 cm in the corner of the paper.
2. Trace a penny's outline as many times as you can inside the square without letting any of the outlines overlap. Be careful not to make any outlines larger than the penny (see figure 1).

Figure 1



3. Cut the 10-cm 2 10-cm square out of the paper sheet, place it on the floor, and tape it down.
4. Standing above the square, drop a pen, point down, on the paper. *Do Not Aim!*

DATA TABLE											
Drop no.	Hit	Miss	Drop no.	Hit	Miss	Drop no.	Hit	Miss	Drop no.	Hit	Miss
1			26			51			76		
2			27			52			77		
3			28			53			78		
4			29			54			79		
5			30			55			80		
6			31			56			81		
7			32			57			82		
8			33			58			83		
9			34			59			84		
10			35			60			85		
11			36			61			86		
12			37			62			87		
13			38			63			88		
14			39			64			89		
15			40			65			90		
16			41			66			91		
17			42			67			92		
18			43			68			93		
19			44			69			94		
20			45			70			95		
21			46			71			96		
22			47			72			97		
23			48			73			98		
24			49			74			99		
25			50			75			100		

- Record on the data table whether you got a “hit” (pen point landed inside a circle) or a “miss” (pen point landed in the area between circles). If the pen lands off the paper square altogether, do not record anything, and take the drop over again.
- Repeat this process until you have 100 good drops resulting in a hit or a miss.
- Calculate the size of a penny using the following ratio:

$$\frac{\text{hits}}{\text{drops}} = \frac{\text{pennies area}}{\text{paper area}}$$

$$\frac{\text{hits}}{\text{drops}} \times \text{paper area} = \text{pennies area} = \text{_____ cm}^2$$

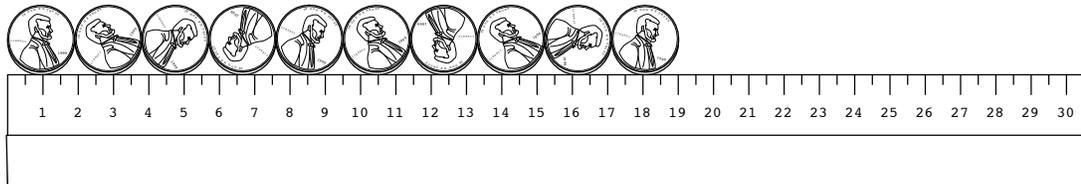
- Once you know the area of all the pennies, you can find the area of one penny. Count the number of penny outlines on the paper square, then use the following equation:

$$\text{Area of a single penny} = \frac{\text{area of all penny outlines}}{\text{no. of penny outlines}} = \text{_____ cm}^2$$

METHOD B: DIRECT MEASUREMENT

- Line up the 10 pennies along the ruler's edge. Make sure that the outside edge of the first penny reaches just to the ruler's edge and that all the pennies touch each other and the ruler. (See figure 2.)

Figure 2



- Record the length of the penny chain here: _____ cm.
- The diameter of a single penny is the total length of the chain of 10 pennies divided by 10:

$$d = \frac{\text{length of chain}}{10} = \text{_____ cm}$$

- The area of a circle is described by the following equation:

$$A = \pi r^2$$

where A = area, r = radius, and π = the constant 3.14. Since the radius of any circle is equal to half its diameter, divide the value of d in step 3 above by 2 to get r :

$$\frac{d}{2} = r = \text{_____ cm}$$

Now you can plug in the values of r and π and solve for the penny's area:

$$A = \pi r^2 = \text{_____ cm}^2$$

5. How different were the results of methods A and B for measuring the area of a penny? To calculate the percent difference, subtract the area found using method A from the area obtained with method B:

$$\text{area 2} - \text{area 1} = \underline{\hspace{2cm}}$$

Now divide the absolute value of this result by area 2 and multiply by 100 to put the answer in terms of percentage:

$$\frac{|\text{area 2} - \text{area 1}|}{\text{area 2}} \times 100 = \underline{\hspace{2cm}} \% \text{ difference}$$

6. Which method do you think is more accurate? Why?
 7. List two ways in which each method could be improved to yield better data.
 8. Why do you think it is important not to aim at the pennies in method A?

What's Going On

You can expect a difference of 10% to 20%. Assuming that you read your ruler carefully, method B should be more accurate. Direct observation of the penny's size can be expected to be reasonably correct. You could improve the accuracy of method A by doing more drops. The larger your sample, the more likely that the proportion of hits accurately reflects the proportion of space covered by the pennies. You could improve the accuracy of method B by lining up straight edges along the pennies on the ends of the line, perpendicular to the ruler's markings in order to make the reading more exact. There are many other ways to improve both methods. Aiming at the pennies in method A will destroy the randomness of the results. If you direct the pen at some area of the paper, you affect its chances of falling inside or outside of a penny's outline. This likelihood, or probability, is just what you are "measuring" with the pen drops, so altering it will throw off the proportions in your results.

Connections

The nucleus of an atom is too small to measure directly. Instead, scientists use a method of indirect measurement. They shoot particles at a group of nuclei in a given area. By counting how many of the particles collide with the nuclei and how many miss, the size of a nucleus can be determined. How accurate is indirect measurement? In this procedure you compared the measurements of a penny obtained directly with a ruler and indirectly using the "hit or miss" method.

Safety Precautions

READ AND COPY BEFORE STARTING ANY EXPERIMENT

Experimental science can be dangerous. Events can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. Basic safety procedures help prevent serious accidents. Be sure to follow additional safety precautions and adult supervision requirements for each experiment. If you are working in a lab or in the field, do not work alone.

This book assumes that you will read the safety precautions that follow, as well as those at the start of each experiment you perform, and that you will *remember* them. These precautions will not always be repeated in the instructions for the procedures. It is up to you to use good judgment and pay attention when performing potentially dangerous procedures. Just because the book does not always say “be careful with hot liquids” or “don’t cut yourself with the knife” does not mean that you should be careless when simmering water or stripping an electrical wire. It *does* mean that when you see a special note to be careful, it is extremely important that you pay attention to it. If you ever have a question about whether a procedure or material is dangerous, stop to find out for sure that it is safe before continuing the experiment. To avoid accidents, always pay close attention to your work, take your time, and practice the general safety procedures listed below.

PREPARE

- Clear all surfaces before beginning work.
- Read through the whole experiment before you start.
- Identify hazardous procedures and anticipate dangers.

PROTECT YOURSELF

- Follow all directions step by step; do only one procedure at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure that there is adequate ventilation.
- Do not horseplay.
- Wear an apron and goggles.
- Do not wear contact lenses, open shoes, and loose clothing; do not wear your hair loose.
- Keep floor and work space neat, clean, and dry.
- Clean up spills immediately.
- Never eat, drink, or smoke in the laboratory or near the work space.
- Do not taste any substances tested unless expressly permitted to do so by a science teacher in charge.

USE EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives and other sharp or pointed instruments with caution; always cut away from yourself and others.
- Pull plugs, not cords, when inserting and removing electrical plugs.
- Don’t use your mouth to pipette; use a suction bulb.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.

- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use only low-voltage and low-current materials.
- Be careful when using stepstools, chairs, and ladders.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read all labels carefully.
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING INSTRUCTIONS

- Use goggles, apron, and gloves when boiling liquids.
- Keep your face away from test tubes and beakers.
- Never leave heating apparatus unattended.
- Use safety tongs and heat-resistant mittens.
- Turn off hot plates, bunsen burners, and gas when you are done.
- Keep flammable substances away from heat.
- Have a fire extinguisher on hand.

WORKING WITH MICROORGANISMS

- Assume that all microorganisms are infectious; handle them with care.
- Sterilize all equipment being used to handle microorganisms.

GOING ON FIELD TRIPS

- Do not go on a field trip by yourself.
- Tell a responsible adult where you are going, and maintain that route.
- Know the area and its potential hazards, such as poisonous plants, deep water, and rapids.
- Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold).
- Bring along a first-aid kit.
- Do not drink water or eat plants found in the wild.
- Use the buddy system; do not experiment outdoors alone.

FINISHING UP

- Thoroughly clean your work area and glassware.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Don't dispose of materials in the sink unless instructed to do so.
- Wash your hands thoroughly.
- Clean up all residue, and containerize it for proper disposal.
- Dispose of all chemicals according to local, state, and federal laws.

BE SAFETY-CONSCIOUS AT ALL TIMES