

## EXPERIMENTS WITH COINS:

### CANADIAN COINS:

#### 1. Nickels

Pity the poor coinage scientists who have to manage the costs of inflation. As the Royal Canadian Mint struggled to keep the true cost of making a coin in line with the value of its constituent materials, the composition of low denomination coins has changed markedly through the years. These changes lead to variations in properties that can lead to interesting and convenient teaching opportunities and classroom activities.

Most students know 2 facts:

1. Nickels are made of Nickel metal
2. Nickel metal will be attracted by a magnet.

**EXPERIMENT:** “Can you measure accurately?”

Have students weigh ONE nickel each (from a variety of dates) and post their observations on a blackboard. Who is right?

Have them repost the results including the year of the coin and graph to see the change in composition.... something is different...what??

**DEMONSTRATION:** Sweep a magnet over a pile of nickel coins of a variety of dates. Some will be attracted and some will not.

This chart shows the history of the Nickel:

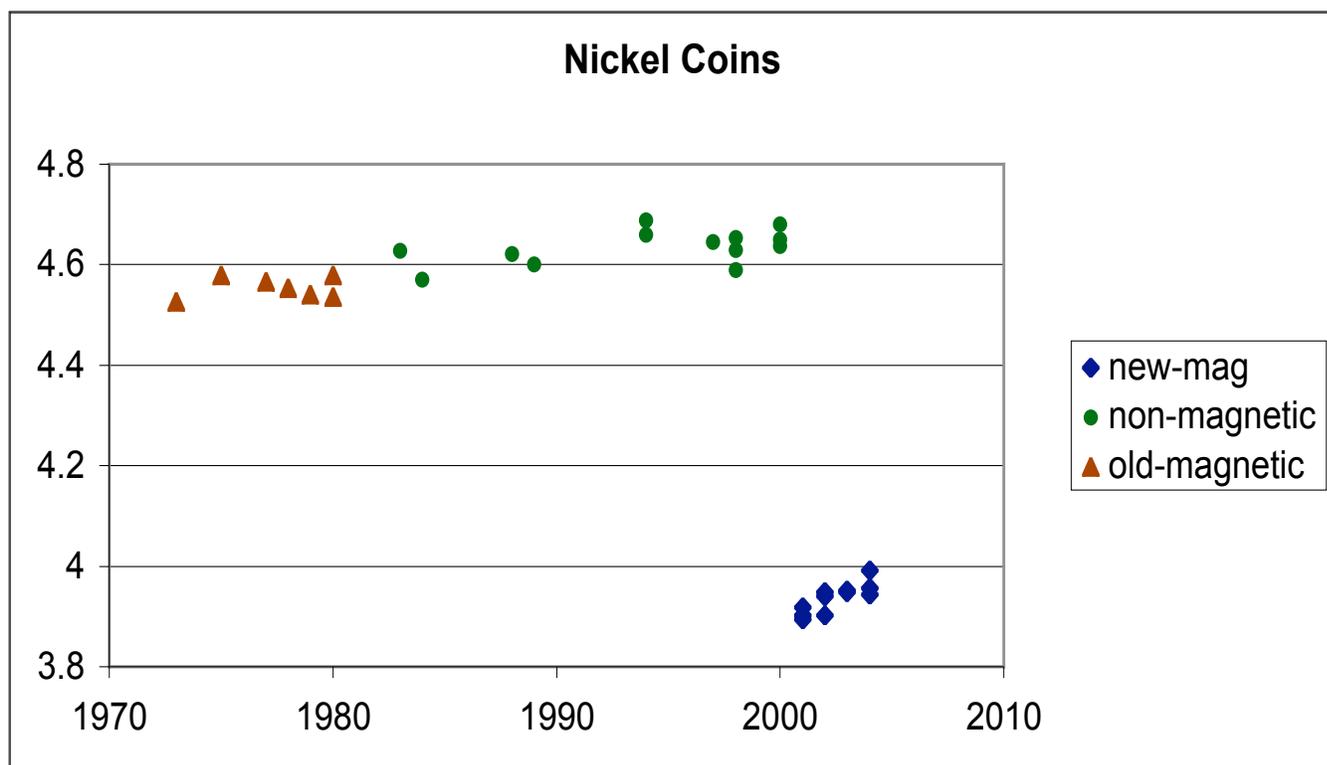
#### Composition of Canadian 5 Cent Coins

	From	To	Mass (g)	Composition
	1922	1942	4.54	99% Nickel
	1942	1943	4.54	88% Nickel , 12% Zinc
	1944	1945	4.54	Chrome plated steel
	1946	1951	4.54	99.9% Nickel
	1951	1954	4.54	Chrome plated steel
***	1955	1981	4.56	99.9% Nickel
***	1982	1999	4.60g	75% Copper, 25% Nickel
***	2000	-	3.95 g	94.5% Steel , 3.5% Copper, 2% Nickel

**EXPERIMENT:** What other differences can be observed between these coins?

Students may be able to suggest that nickel is a magnetic material. Have them test their nickel coin with a magnet. Have them correlate “attraction to a magnet” with mass and date.

This graph shows actual data from a variety of dated coins using an electronic milligram balance:



**DEMONSTRATION:** Both new and old nickels are magnetic, but they have different masses. Can we provide physical evidence to distinguish between the materials in these coins?

Clamp a ferrite (not a neodymium) magnet in place and suspend two nickels edge-to-edge from the magnet. (use one pre-1980 and one post-2000 coin). Position an empty can to catch any hot coins that fall. Heat the coins with a small flame from a propane torch, avoiding the magnet as much as possible.

If the older coin is on the bottom, it will fall off (and into the can). If the older coin is on top, both coins will fall.

The Curie temp for Nickel is 358°C. For Iron, it is 774°C.

**CAUTION: Hot coins look the same as cold coins and they roll away just as easily. Warn students not to try to pick up an “escapee coin”. Have an ice-water bath handy for First Aid just in case.**

At the Curie temperature, thermal motion overcomes the internal organization of the metal that allows it to maintain its magnetic properties. The old coins are almost pure nickel and so, once the temperature exceeds 358°C, the coin will fall from the magnet. The propane flame can heat the coin above 358°C, but not over 774°C. The newer coins have a steel core and their attraction is not affected by the heat.

[Incidentally, this is an interesting argument to say that the earth’s magnetic field is from an electromagnetic origin, not from a solid lump of magnetized iron. The earth’s core temp is above the Curie Temp of Iron, so the iron in the core cannot have a residual magnetic domain.]

This change is not permanent however. As the coin cools to below its Curie temperature, it will again be attracted to a magnet.

## **2. Pennies:**

But Copper is not attracted to a magnet, so pennies are much less confusing, right? Not so fast!

**DEMO: Sweep magnet over pennies... some stick...magnetic copper???**

[IF your class can appreciate the joke, use a Pair Of Magnets to test the pennies.... see if copper is Pair-o-magnetic! ]

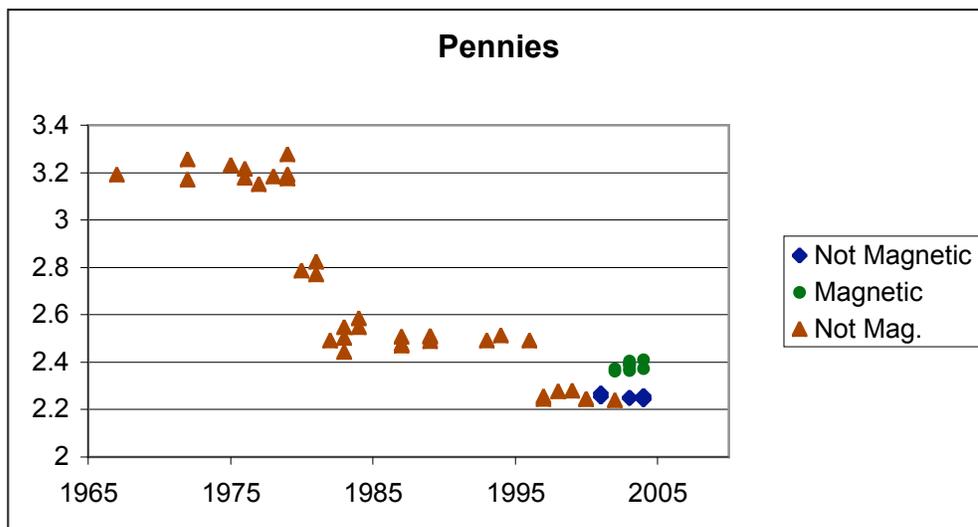
Over the years, the Royal Canadian Mint has struggled to keep the cost of the penny under one cent and they have tried different innovations over the years.

### **Composition of the Canadian One-Cent Coin**

<b>From</b>	<b>To</b>	<b>Mass (g)</b>	<b>Composition</b>
1942	1979	3.24	98% Cu , 1.75% Sn , 0.25% Zn
1980	1981	2.8	98% Cu , 1.75% Sn , 0.25% Zn
1982	1996	2.5	98% Cu , 1.75% Sn , 0.25% Zn
1997	1999	2.25	98.4% Zn , 1.6% Cu plating
2000	-	2.35	94% steel 1.5% Ni 4.5% Cu plating

Note that in 1997 they tried the US coinage formula for a penny, but quickly moved on to the steel core model.

We can detect these changes with a milligram scale weighing actual pennies. Again, a classroom experiment can be designed to have students organize data and find the changes in composition.



Note that from my graph data, they sometimes “cheated” by using old coin blanks for the new coins. I have found both magnetic and NON-magnetic pennies for the years 2002 - 2004.

### **DEMONSTRATION: “Peel a Penny”**

1. First, stretch a pair of tweezers so that the jaw stretched across the diameter of a Zinc core penny. With this arrangement, the coin should stay firmly in the tweezer’s jaw without any pressure being applied to the instrument. This is important, because you do not want the coin to slip into the acid beaker. IN A FUME HOOD, put enough concentrated nitric acid in a 100 mL beaker so that the coin can be immersed in the acid just by lowering the tweezers into the beaker.

Prepare about 300 mL of a concentrated (~2M) solution of Na HCO<sub>3</sub> in a 400 mL beaker and place it beside the acid beaker. This will be needed to stop the reaction on the coin.

**[This procedure should be done only by the teacher or a qualified technician!]** Using rubber gloves and goggles, with the fans running in the fume hood and the hood door down as far as is practical, lower the coin into the concentrated acid. Brown NO<sub>2</sub> gas will evolve rapidly. After a few seconds, as the gas evolves, lift the tweezers & coin out of the acid and stop the reaction by immersing the coin in the bicarbonate solution. If copper remains on the surface of the coin, repeat the reaction with acid.

The zinc core will appear dark, but can be cleaned with any commercial metal cleaner until it has a bright grey appearance.

2. A Zinc core penny can be nicked one or two places along the rim of the coin and the coin can then be immersed in 250 mL of 2M HCl overnight. The beaker should be left uncovered and away from any source of flame since hydrogen gas will evolve slowly. After 24 h or so, the coin will have no Zn core, but the copper plated “skin” will remain, this should be washed carefully (to prevent reaction between copper and the chemical residues of the process).

3. Now you have a hollow “penny skin” and the solid zinc core which will still bear the markings of the coin face. Present this to your classes as evidence that you can “peel a penny”.

**DO NOT allow students to perform the #1 reaction with nitric acid.**

Provide a series of pennies from a variety of dates to the class. Have them score the surface with a file.

Place the scored coins in 2 M HCl solution (using at least 0.3 moles of HCl per coin). [*This should be done by a safety-equipped teacher to avoid splashing and the related safety hazards.*]

The next day, the teacher should collect the coins, check to see that the Zn cores have been dissolved away, and then WASH the coins before returning them to students.

Not all coins will have lost their cores !

Correlate these results with the dates on the coins.

Check the coins that resisted the acid using a magnet.

Can the results be correlated with the published composition of the coins according to their year?

If the demonstrations are to be done in this sequence, you can provide discrepant events that can be resolved with a small amount of investigation or testing on the part of the students. You will have the opportunity to point out that knowledge that they take for granted may not be true (ie “a penny is like all other pennies”), but with simple evidence and organized thinking, the truth can be determined.

[Note that all US pennies since 1982 have a copper-plated zinc core and can be “peeled”. The advantage of the Canadian coins is that a variety of years can produce a variety of properties for your students to encounter.]

### **Brass Pennies:**

Both country's pennies can be brass-coated using a simple experiment. For detailed instructions, look at the recipe by Cathy Sarisky at:

[http://www.labarchive.net/labdb/get.tcl?experiment\\_id=228](http://www.labarchive.net/labdb/get.tcl?experiment_id=228).

In older methods, the clean penny is immersed in a mixture of powdered zinc and hot 6M NaOH. Ms. Sarisky's experiment requires care, but seems to be safer than the older method.

The heating of the zinc-coated penny must be done carefully, particularly if the coin has a zinc core. If a Zn core penny is hot enough, the Zinc melts and forms an entertaining blob inside a small copper sack.

However, a light heating is required to blend the metals into a brass mixture.

### **US dimes and quarters are fascinating as well...**

Both coins are now made as a "Johnson Sandwich" (After LBJ).

A copper core is covered by a 75% Cu : 25% Ni alloy.

If we heat one of these to a high enough temperature, the nickel dissolves in the copper core in a process that mimics an exothermic phase transition.

See the webpage link: [Model an Exothermic phase transition](#)

### **LOONIES AND TWONIES:**

The Loonie was supposed to be a "normal" dollar coin. For many years, we had a silver and then a nickel dollar coin bearing the image of fur-traders and natives in a cargo canoe. The stamping molds for the new coin were "misplaced" in transit from Ottawa to the mint in Winnipeg. Rather than run the risk of having counterfeit coins produced, the Mint held up production until another design was implemented. This design had the image of a Loon, symbol of the Northern Lakes. somehow, a "Loonie" was easier to say than "a new brass coloured dollar coin".

The coin is a 91.5% Nickel core plated with 8.5% "bronze".

The 2 dollar coin, introduced in 1996 has an outer ring of 99% Ni and an inner disc made from 92% Cu, 6% Al and 2% Ni.

It also has the embarrassingly simple moniker "Twonie".

Although the Curie temperature experiments work for both coins, I would advise against it since you have a fairly large hot coin rolling around after it falls off the magnet. And although the hot coins look identical to the cold ones, they don't feel the same.

Early on, people used to go to great lengths to separate the ring from the core on the Twonie, using heat, hammers, and occasionally liquid nitrogen. The novelty apparently wore off, or the cost became prohibitive (\$2 / try)

**LINKS :**

The Royal Canadian Mint has a “front door only” website, so follow these directions.

Go to           www.mint.ca  
Click on       The Passion  
then            The Museum  
then            Circulation currency  
then            Technical Specifications

Properties of U.S. coins can be found at:

[http://www.usmint.gov/about\\_the\\_mint/index.cfm?action=coin\\_specifications](http://www.usmint.gov/about_the_mint/index.cfm?action=coin_specifications)

OR:

Go to           www.usmint.gov  
Search         composition penny  
Click on       “Circulating coins”