

天父的花园

—The Father's Garden—

完整版

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编配：Joa

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选自专辑《沙漠中的赞美》

可爱的、欢快的 ♩=96

Piano

mp

8^{va}

4

8^{va} ----- mp

8

12

16

20

mp

Detailed description: This is a piano score for the piece 'The Father's Garden'. It is written in 4/4 time with a key signature of one flat (B-flat). The score is divided into five systems, each with a measure number (4, 8, 12, 16, 20) at the beginning. The first system starts with a piano (mp) dynamic and a tempo marking of ♩=96. The notation includes treble and bass clefs, with various musical symbols such as notes, rests, and chords. There are also performance markings like '8^{va}' and 'mp' throughout the piece.

天父的花园 (演唱：赞美之泉 专辑：沙漠中的赞美)

小小花园里，红橙黄蓝绿
每朵小花都美丽
微风轻飘逸，蓝天同欢喜
在天父的花园里
你我同是宝贝，在这花园里
园丁细心呵护不让你伤心
刮风或下雨，应许从不离开你
天父的小花成长在他手里

小小花园里，红橙黄蓝绿
每朵小花都美丽
微风轻飘逸，蓝天同欢喜
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天父的小花成长在他手里
别担心，你的成长在他手里

the Absolute scale, and one degree on it is the same as one degree centigrade, which is $\frac{9}{5}$ of a degree Fahrenheit. The difference between the Centigrade and Absolute scales is the zero label.

0 degrees Celsius is equal to 273.15 degrees Kelvin: $0\text{ }^{\circ}\text{C} = 273.15\text{ K}$

The coldest place in nature is the depths of outer space. There it is 3 degrees above Absolute Zero.

For almost a century we have been able to build refrigerators that get to lower than 3 degrees above Absolute Zero, and for quite a while we have been able to even get lower than $\frac{1}{1000}$ of a degree above Absolute Zero. However, a big step was when Cornell and Wieman cooled a small sample of atoms down to only a few billionths (0.000,000,001) of a degree above Absolute Zero!

How are temperatures close to absolute zero achieved and measured?

First, let me introduce the scientific meaning of temperature: it is a measure of the energy content of matter. When air is hot, the molecules move fast and they have high kinetic energy. The colder the molecules are, the smaller their velocities are and, subsequently, their energy. Temperature is simply a way to characterize the energy of a system.

Temperature can be measured in different units. In everyday life the Celsius and Fahrenheit scales are common, but they both lack the natural property that the zero of the temperature scale should correspond to zero velocity of the gas particles (that is, zero energy). Thus the natural temperature scale is the absolute temperature measured in Kelvin. Zero kelvin is the lowest possible temperature. At absolute zero, all motion comes to a standstill. It is obvious that a lower temperature is not feasible because there is no velocity smaller than zero and no energy content less than nothing. (As a side remark, energy in this instance means only the energy that can be taken away from the particles and does not include the rest mass or quantum mechanical zero-point energies for confined particles.) Absolute zero corresponds to -273 degrees Celsius and -460 degrees Fahrenheit.

Cooling an object requires extracting energy from it and depositing it somewhere else. In household refrigerators, for example, the heat exchanger at the back gets warm because the energy extracted from the objects inside is deposited there. (In addition, there is some heat created just from running the refrigerator.)

In the 1980s and 1990s new methods for cooling atomic gases were developed: laser cooling and evaporative cooling. By combining these methods, temperatures below one nanokelvin (one billionth of a degree Kelvin) have been achieved. The lowest temperature recorded so far, described in a publication from our group in the September 12, 2003 issue of *Science*, is 450 picokelvins, which beat the previous record holder by a factor of six. Two recent Nobel prizes (in 1997 and 2001) were awarded for these developments.

In laser cooling, atoms scatter laser light. An incoming laser photon is absorbed and then reemitted in a different direction. On average, the color of the scattered photon is slightly shifted to the blue relative to the laser light. That is, a scattered photon has a slightly higher energy than an absorbed photon did. Because total energy is conserved, the difference in photon energy is extracted from the atomic motion—the atoms slow down. Shifts in wavelength can occur because of the Doppler effect (which is a shift proportional to the atomic velocity) or because of Stark shifts (due to the electric field of the laser beams) and offers one explanation of how the atoms lose energy.

A second description emphasizes how momentum is transferred to the atoms. If atoms are exposed to several laser beams with carefully chosen polarization and frequency values, then they preferentially absorb photons from the forward hemisphere, where the photon angular momentum and the atomic velocity are at an angle larger than 90 degrees. The photon momentum has a component that is opposite to the atomic motion and, as a result, the momentum kick of the absorbed photon slows the atom down. The subsequent emission of a photon occurs at random angles and as a result, averaged over several absorption-emission cycles, there is no momentum transferred due to the photon emission. The crucial step is making the atoms absorb photons preferentially from the forward direction and is achieved by utilizing the Doppler shift. When the photon momentum and the atomic velocity are at an angle larger than 90 degrees, the atom and the light are counterpropagating and the Doppler shift is an

upward shift in frequency. When the laser light is detuned to the red of the atomic resonance, the Doppler shift brings the light closer into resonance and enhances the light absorption. For light coming from the backward direction, for which the angle between the photon momentum and the atomic velocity is smaller than 90 degrees, the Doppler shift is opposite and shifts the light even further away from the atomic resonance, decreasing its absorption.

When an atomic cloud becomes denser and colder, the cooling effect described above becomes dominated by other processes, which cause heating. This includes energy release in collisions between atoms, and the random recoil kicks in light scattering, which average to zero, but still result in some trembling motion of the atoms and therefore limit the lowest achievable temperature. At this point, however, the atoms are cold enough that they can be confined by magnetic fields. We choose atomic species that have an unpaired electron and therefore a magnetic moment. As a result, these atoms behave like little bar magnets. External magnetic fields exert forces on them, levitate them against gravity and keep them together; the atoms are trapped in a magnetic cage with invisible walls formed by magnetic fields.

Further cooling is done by evaporative cooling, by selective removal of the most energetic atoms from the system. The same process cools a cup of coffee when the most energetic molecules escape as steam, thus lowering the average energy and therefore the temperature of the remaining molecules. In a magnetic trap, the most energetic atoms can move farther against the pull of the magnetic forces, and can therefore reach regions with higher magnetic fields than the colder atoms can. At those high magnetic fields, they get into resonance with radio waves or microwaves, which changes the magnetic moment in such a way that the atoms fly away and escape from the trap. Nice animations of the cooling procedure can be found at <http://www.colorado.edu/physics/2000/bec/temperature.html>

How do we measure very low temperatures of atoms? One way is to simply look at the extension of the cloud. The larger the cloud is, the more energetic the atoms must be, because they can move farther against the magnetic forces. This is similar to the atmosphere on Earth, which is about 10 kilometers thick. That is, 10 kilometers is how far atoms at room temperature can move against the gravitational force of our planet. If the temperature of the air were 10 times smaller (which is about 30 K or -240 degrees C), the atmosphere would be only one kilometer thick. At 30 microkelvins, the atmosphere would shrink to a mere millimeter, and at 30 nanokelvins, the height of the atmosphere would be one micron, or a hundred times less than the thickness of the human hair. (Of course, air is not an ideal gas and would have liquified by then.) In our experiments, the atoms are exposed to both magnetic and gravitational forces. In the center of the cloud, the gravitational force is exactly compensated by the magnetic force.

The size of the atomic cloud is determined by illuminating the cloud with laser light, which is strongly absorbed by the atoms, and they cast a shadow. With the help of several lenses, the shadow is imaged onto an electronic sensor similar to those in digital cameras. Because the magnetic fields are precisely known, the size of the cloud is an absolute measure of the atoms' energy and temperature. (More scientifically, the density distribution of the atoms reflects the distribution of potential energy.)

Another method to determine temperature is to measure the kinetic energy of the atoms. For that, the magnetic trap is suddenly switched off by switching off the current running through the magnet coils. In the absence of magnetic forces, the atoms simply fly away, and the cloud expands ballistically. The cloud size increases with time, and this increase is a direct observation of the velocity of the atoms and therefore their temperature. (More technically, an absorption image of an expanding cloud shows the distribution of the kinetic energy in the cloud.) For a fixed time of ballistic expansion, the size of the

shadow is a measure of the temperature (temperature is proportional to the square of the size). The achievement of lower and lower temperature is monitored by a shrinking shadow. When Bose-Einstein condensation was discovered in 1995, its hallmark was that the shrinking shadow suddenly showed a dense core of atoms at extremely low energy, the Bose-Einstein condensate (see image).

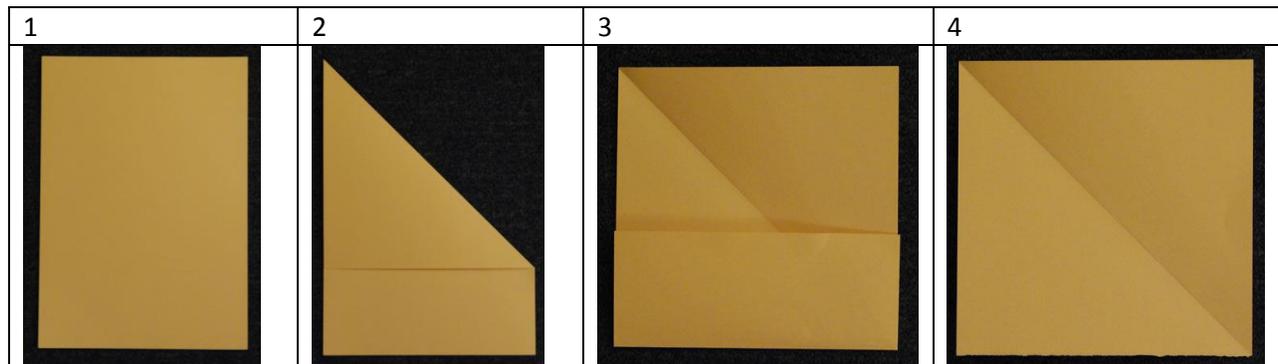
Gabriel Fahrenheit (1686-1736) created the Fahrenheit scale. He set the freezing point of water at 32 degrees and the boiling point at 212 degrees. These two points formed the anchors for his scale.

Anders Celsius (1701-1744) invented the Celsius scale. Using the same anchor points, he determined the freezing temperature for water to be 0 degree and the boiling temperature 100 degrees.

The Kelvin scale is designed to go to zero at this minimum temperature.

Paper container (Jan 09 2015 Friday)

Step 1-4: Making a paper square from a rectangular sheet



Step 5: Diamond shape

Rotate the square to form a diamond shape, with the single crease horizontal.

Step 6: Triangle

Lift the bottom point of the diamond up, to meet the top point.

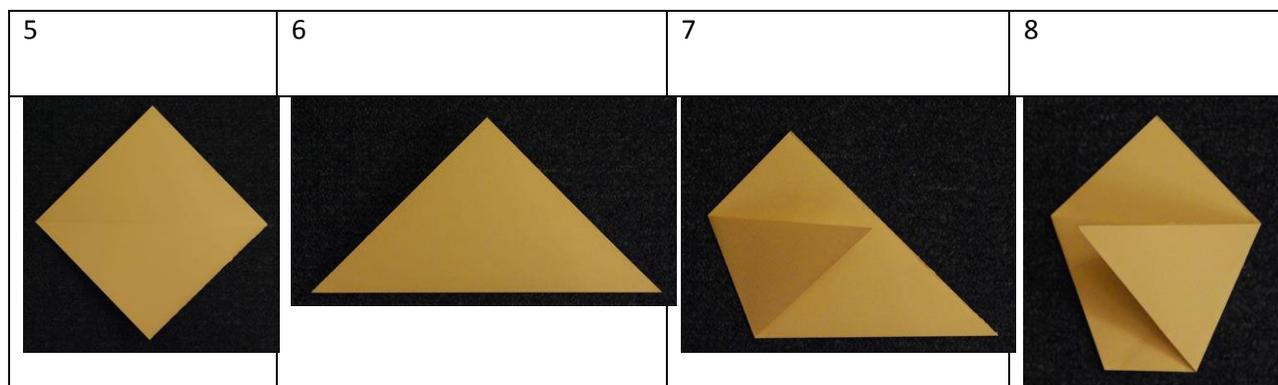
Crease the center fold sharply.

Step 7: Left side

Bring the left point of the triangle across to meet and stop at the right, sloping edge. Keep what was the lower left edge of the double skin of paper parallel to the base of the triangle.

Step 8: Right side

Repeat the previous step, but at this time do it for the right side, bringing it over and on top of the left side flap.



Step 9: Front top flap

Fold the top front flap down, over the two side flaps, keeping the fold in line with the points at each side, creasing it sharply to hold them in place. The point will line up with the apex of the small triangle which has appeared by itself at the base of the container. The top front flap locks things down.

Step 10: Rear flap

Turn the whole assembly over and fold down the rear flap. The container is flat at this stage and you are going to open it out, gently, and squeeze it into a cup shape, or a truncated cone, rather like the ones used in some office drinking water dispensers.

Step 11: Dent the base

Push your thumb into the base of the container, to make a dimple. It may help to put two or three fingers into the mouth of the cup, to oppose the force of your thumb pushing the paper in.

Step 12: Squeeze into shape

Squeeze the folded seams of the sides of the container together, making a cup shape. The container is not free-standing but will lean quite happily against something else.

