Specific Heat Capacity of Metals
PHYS 442

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Partners:	Whole class
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1 Definitions

Heat Heat is the measure of the internal kinetic energy of a substance.

Temperature Temperature is a measure of the kinetic energy of a particle. It is the degree or intensity of heat in a substance. Celcius is a unit of temperature. One degree Celcius represents the temperature change of one gram of water when 2.39×10^{-5}Joules of heat is added to it.

Specific Heat Capacity The specific heat capacity is the energy transferred to one kilogram of substance causing its temperature to increase by one degree Celcius.**?**

Thermal Equilibrium Thermal equilibrium is a condition where two substances in physical contact with each other exchange no net heat energy. Substances in thermal equilibrium are at the same temperature.

2 Theory

The change in the internal energy of an object or substance is equal to the product of the mass and the specific heat capacity and the change in temperature.

$$\Delta U = mC_p\Delta T$$

When water and the metal samples are in thermal equilibrium the change in heat of the water is equal in magnitude to the change in heat of the metal.

$$\Delta U_{metal} = \Delta U_{water}$$

From this relationship we may derive a formula for the specific heat capacity of the metal sample given the mass of metal, mass of water, change in temperature of the water, change in temperature of the metal and the specific heat capacity of water.

$$m_{metal}C_{metal}\Delta T_{metal} = m_{water}C_{water}\Delta T_{water}$$

$$\boxed{C_{metal} = \frac{m_{water}}{m_{metal}}\frac{\Delta T_{water}}{\Delta T_{metal}}C_{water}}$$

3 Data

Metal	Mass Metal	Temp Water Initial	Temp Final
Aluminum	90.6 g	24.1 Celcius	28.0 Celcius
Zinc	64.1 g	24.4 Celcius	25.6 Celcius
Copper	203.0 g	24.7 Celcius	28.3 Celcius

Table 1: Experimental data

Material	Specific Heat Capacity
Water	4180 $^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}}$
Aluminum	900 $^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}}$
Zinc	380 $^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}}$
Copper	387 $^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}}$

Table 2: Known specific heat capacities

4 Example Calculations

This is the calculation for the specific heat capacity of copper.

$$C_{metal} = \frac{m_{water}}{m_{metal}} \frac{\Delta T_{water}}{\Delta T_{metal}} C_{water}$$

$$\Delta T_{water} = 28.3 - 24.7 = 3.6\text{Celcius}$$

$$\Delta T_{metal} = 100 - 28.3 = 71.7\text{Celcius}$$

$$C_{metal} = \frac{0.350\text{kg}}{0.203\text{kg}} \frac{3.6\text{Celcius}}{71.7\text{Celcius}} 4180\ ^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}} = 362\ ^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}}$$

The percent error is calculated as follows.

$$Error = \frac{387 - 362}{387} = 6.5\%$$

5 Results

Material	Measured C_p	Percent Error
Aluminum	875 $^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}}$	2.8%
Zinc	368 $^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}}$	3.1%
Copper	362 $^{\mathrm{J}}/_{\mathrm{kg}\cdot^\circ\mathrm{C}}$	6.5%

Table 3: Calculated specific heat capacities

6 Objective

Explored the motion of a particle under the influence of a gravitational force. Specifically we look at attractive inverse square distance forces, Hookean forces, escape velocity, circular orbits, kinetic energy, potential energy and elliptical orbits. These are defined in 10.1:

6.1 Definitions

Law of Universal Gravitation The law of universal gravitation states the force of gravity between two point masses is directly proportional to each mass and inversely proportional to the distance between them. This is also true for masses outside of spherically symmetric mass distributions.**?**

$$F_g = \frac{mMG}{r^2}$$

Hookean Forces Inside a uniformly dense sphere of mass the force is Hookean, with an attractive force proportional to the displacement from equilibrium. The effective spring constant is $K = \frac{mMG}{R^3}$.

$$F_g = \frac{mMG}{R^3} r$$

Gravitational Constant The universal gravitation constant G determines the strength of the gravity force from a given mass. It may also be considered as the force that 1 kg exerts on another 1 kg mass separated by 1 meter.

$$G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$$

Escape Velocity Escape velocity is the initial velocity required to escape gravitational attraction. An object launched at the escape velocity will never come back (escape).

$$v_{escape} = \sqrt{\frac{2MG}{r}}$$

Kinetic Energy Kinetic energy is the energy associated with motion.

$$KE = \frac{mv^2}{2}$$

Potential Energy The potential associated with the universal gravitation force is written as follows.

$$PE = -\frac{mMG}{r}$$

Circular Orbit A circular orbit is an orbit with a constant radius r.

Elliptic Orbit An elliptic orbit is a closed orbit with changing radius r.

7 Simulation

The simulation applies a central acceleration to the orbiting particle. Outside the boundary of the central mass we have the following acceleration.

$$a = \frac{K}{r^2}$$

Inside the boundary of the central mass ($r < R$) we have the following acceleration.

$$a = \frac{K}{R^3} r$$

Here R is the radius of the central mass and K is a constant determined by the user of the simulation. K is MG. For this simulation the radius was set to $R = 6$ and the constant was set to $K = -0.1$ making the acceleration attractive.

The initial position $\vec{r}_0$ and initial velocity $\vec{v}_0$ are set by the user.

8 Sample Calculation

8.1 Circular Orbit

Given $\vec{r}_0 = (10, 0)$ and $K = -0.1$ we find the $\vec{v}_0$ for circular orbit.

$$F_{net} = ma$$

$$\frac{mMG}{r^2} = m\frac{v^2}{r}$$

$$\frac{K}{r^2} = \frac{v^2}{r}$$

$$v = \sqrt{\frac{K}{r}}$$

$$v = \sqrt{\frac{0.1}{10}} = 0.1$$

The velocity must be tangential and therefore $\vec{v}_0$ must be perpendicular to $\vec{r}_0$.

$$\vec{v}_0 = (0, 0.1)$$

8.2 Escape Velocity

Given $\vec{r}_0 = (10, 0)$ and $K = -0.1$ we find the $\vec{v}_0$ for escape from the central mass' gravitational attraction. Escape is associated with a total mechanical energy of zero.

$$PE + KE = 0$$

$$-\frac{mMG}{r} + \frac{mv^2}{2} = 0$$

$$-\frac{K}{r} + \frac{v^2}{2} = 0$$

$$v_{escape} = \sqrt{\frac{2K}{r}}$$

$$v_{escape} = \sqrt{\frac{2(0.1)}{10}} = 0.14$$

9 Results and Conclusions

9.1 Circular Orbit

For the conditions $\vec{r}_0 = (10, 0)$ and $K = -0.1$ we calculate an initial velocity $\vec{v}_0 = (0, 0.1)$ will give a circular orbit. Running the simulation yields the following orbit. We can see it is circular.

9.2 Escape Velocity

For the conditions $\vec{r}_0 = (10, 0)$ and $K = -0.1$ we calculate an initial velocity $\vec{v}_0 = (0, 0.14)$ will give an escape from the gravitational attraction. We can observe in the simulation the object indeed escapes and the total energy is zero. See the following figure.

9.3 Elliptical Orbit

For the conditions $\vec{r}_0 = (10, 0)$ and $K = -0.1$ we use an initial velocity $\vec{v}_0 = (0, 0.12)$ that is between the one for circular orbit and escape. As the figure shows the resulting orbit is elliptical.

10 Objective

Explores the motion of a particle under the influence of a gravitational force. Specifically we look at escape velocity, circular orbits, Kinetic energy, potential energy and elliptical orbits. (as defined in 10.1):

$$F_g = \frac{mMG}{r^2}$$

10.1 Definitions

Gravitational Constant The universal gravitation constant G determines the strength of the gravity force from a given mass. Force 1 kg exerts on another 1 kg mass separated by 1 meter .

$$G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$$

Escape Velocity Escape velocity is the initial velocity required to escape gravitational attraction. An object launched at the escape velocity will never come back (escape)

$$v_{escape} = \frac{2MG}{r}$$

Kinetic Energy Kinetic energy is the energy associated with motion.

$$KE \frac{mv^2}{2}$$

The potential associated with the universal gravitation force is written as follows.
$PE : -\frac{mMG}{r}$

Potential EnergyCircular Orbit A circular orbit is an orbit with constant radius r.

Ellipthic Orbit An ellipthic orbit is a closed orbit with changing radius r.

11 Experimental Data

Mass of empty crucible	7.28 g
Mass of crucible and magnesium before heating	8.59 g
Mass of crucible and magnesium oxide after heating	9.46 g
Balance used	#4
Magnesium from sample bottle	#1

12 Sample Calculation

Mass of magnesium metal	= 8.59 g - 7.28 g
	= 1.31 g
Mass of magnesium oxide	= 9.46 g - 7.28 g
	= 2.18 g
Mass of oxygen	= 2.18 g - 1.31 g
	= 0.87 g

Because of this reaction, the required ratio is the atomic weight of magnesium: 16.00 g of oxygen as experimental mass of Mg: experimental mass of oxygen or $\frac{x}{1.31} = \frac{16}{0.87}$ from which, $M_{\mathrm{Mg}} = 16.00 \times \frac{1.31}{0.87} = 24.1 = 24\,\mathrm{g\,mol^{-1}}$ (to two significant figures).

13 Results and Conclusions

The atomic weight of magnesium is concluded to be $24\,\mathrm{g\,mol^{-1}}$, as determined by the stoichiometry of its chemical combination with oxygen. This result is in agreement with the accepted value.

14 Discussion of Experimental Uncertainty

The accepted value (periodic table) is $24.3\,\mathrm{g\,mol^{-1}}$ **?**. The percentage discrepancy between the accepted value and the result obtained here is 1.3%. Because only a single measurement was made, it is not possible to calculate an estimated standard deviation.

The most obvious source of experimental uncertainty is the limited precision of the balance. Other potential sources of experimental uncertainty are: the reaction might not be complete; if not enough time was allowed for total oxidation, less than complete oxidation of the magnesium might have, in part, reacted with nitrogen in the air (incorrect reaction); the magnesium oxide might have absorbed water from the air, and thus weigh "too much." Because the result obtained is close to the accepted value it is possible that some of these experimental uncertainties have fortuitously cancelled one another.

15 Answers to Definitions

a. The *atomic weight of an element* is the relative weight of one of its atoms compared to C-12 with a weight of 12.0000000..., hydrogen with a weight of 1.008, to oxygen with a weight of 16.00. Atomic weight is also the average weight of all the atoms of that element as they occur in nature.

b. The *units of atomic weight* are two-fold, with an identical numerical value. They are g/mole of atoms (or just g/mol) or amu/atom.

c. *Percentage discrepancy* between an accepted (literature) value and an experimental value is

$$\frac{\text{experimental result} - \text{accepted result}}{\text{accepted result}}$$

$$F_g = \frac{mMG}{r^2}$$

Description	Symbol	Quantity
Gravitational Constant	G	$6.67 \times 10^{-11}\,\mathrm{N{\cdot}m^2/kg^2}$
Mass of Earth	m_{earth}	5.98×10^{24}kg
Mass of Moon	m_{moon}	7.36×10^{22}kg
Radius of Earth	R_{earth}	6.38×10^{6}m
Radius of Moon	R_{moon}	1.74×10^{6}m
Orbital Radius of Earth	r_{earth}	1.50×10^{11}m
Orbital Radius of Moon	r_{moon}	3.84×10^{8}m
Period of Earth's Orbit	T_{earth}	365.24 days
Period of Moon's Orbit	T_{moon}	27.3 days

Table 4: A list of physical quantities.

16 Physical principles

[In physics, mass spectrometer is an analytical instrument in which can measure the masses and relative concentrations of atoms and molecules.Which ions, produced from a sample, are separated by electric or magnetic fields according to their ratios of charge to mass]

Mass spectrometry works by ionizing chemical compounds to generate charged molecules or molecule fragments and measuring their mass-to-charge ratios. In other words you do ionization, acceleration, and selection of a single velocity particles, the ions move into a mass spectrometer region where the radius of the path and thus the position on the detector is a function of the mass. The bigger mass the molecule has the faster it will fall down back to the spectrometer and on the opposite if the mass of the molecule is lighter it will make a bigger radius and come back slower.

If a charge moves into a magnetic field with direction perpendicular to the field, it will follow a circular path. The magnetic force, being perpendicular to the velocity, provides the centripetal force

16.1 Calculation

Radius of path produced by magnetic field:

$$r = \frac{mv^2}{qvB} = \frac{mv}{qB}$$

If the velocity v is produced by an accelerating voltage V

$$\frac{1}{2}mv^2 = qV$$

16.1.1 (Why we use mass spectrometer

[Mass spectrometer is used for all kinds of chemical analyses ranging from environmental analysis to analysis of petroleum products, trace metal and biological materials. It also is being used for carbon dating and other radioactive dating processes.]

17 examples exams

1.find centripetal acc of moon

$$a = \frac{v^2}{r} or Fa = Ma = \frac{mMg}{r^2} = ma = a = \frac{MG}{r^2}$$

2. Determine the speed of the moon

$$V = \frac{2(pi)r}{T} = wr$$

3.Find the angular velocity

$$W = \frac{\triangle\theta}{\triangle T}$$

T must be in seconds and answer is in rad/sec
Determine mass of the sun

$$ma = \frac{mMG}{r^2}$$

$$M = \frac{r^2}{mg} 36 * 10^{21} 1$$

$$M = \frac{(1.5 * 10^{11})(36 * 10^{21})}{(6 * 10^{24})(6.67 * 10 -^{1\ 1})} = 2 * 10^{30}$$

Centripetal forces,gravity,electrostatic, Magnetic Force, Friction car in circle.

18 examples exams 2

B field goose around around current, hold current with thumb in direction of current. Thumb=current and Fingers=B-field.

$$V = IR$$

Speed of electrons

$$I = \frac{\triangle Q}{\triangle T}$$

$$electrons * e(16 * 10^-19) = Q$$

V= Voltage, I=Current, R= Resistance
Increase V, Increase E, increase F, increase velocity, increase current
Show the mass to charge ratio is Br$_{\overline{V}}$

$$Fb = ma$$

$$qvB = \frac{mv^2}{r}$$

$$Ampere = \frac{coul}{sec}$$

19 Torques

Torques¿ Action of forces acting on rigid bodies. Rigid body is a massive object extended in space,That does not deform. torque always has a point around which it acts. Without determine a point there is no Torque, changing the point can change the torque.

$$T = r * F.orT = rFsin\theta$$

r is in meter and Torque is nM
I moment of inertia

$$I = \Sigma mr^2$$

Linear-Rotation Force-Torque Acc-angular acc