Introduction
As you are about to make your final decision of what elective subjects to study in the next three years, the physics teacher is going to provide you a solid experience of what physics lessons will be in our school.

Our physics lessons adopt *FIPPPED CLASSROOM* teaching strategy. In other subjects, you learn in lessons and do homework at home. For physics, you have to learn at home through watching Youtube video prepared by your physics teacher while in physics lessons, you have to finish assignments with your classmates. In this way, teacher may have more time to do demonstration, to clarify difficult concepts and you may also have more chance to do experiments, and ask for help from teachers and classmates more easily when doing assignment.

The S3 physics test and exam will follow the settings of Paper 1 in DSE*, with MCQs and SQ. The weightings are 35% and 65% respectively. You should note that the quality of your assignment and your class performance are also important part of your assessment. The following table may give you a clear summary:

<table>
<thead>
<tr>
<th>Coursework Assessment (C.A.)</th>
<th>Term Mark Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Test</td>
<td>25%</td>
</tr>
<tr>
<td>• Assignment and Class Performance</td>
<td>5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Examination</th>
<th>70% of Term Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Multiple Choice Questions</td>
<td>24.5 % ( = 0.35*70% )</td>
</tr>
<tr>
<td>• Short Questions</td>
<td>45.5 % ( = 0.65*70% )</td>
</tr>
</tbody>
</table>

So, how to get high marks?
Easy! **Watch videos and finish all questions before every lesson.** Bring your Exercise book. Finish all assignment with quality answers; show your steps clearly and neatly. When your exercise book is returned, read the feedbacks from teachers carefully. Do not leave questions unanswered, always ask for help from your physics teachers as soon as possible! Test and examination questions are very similar to those questions in your notes!

*For format and marks allocation of DSE physics exam, please refer to the appendix in Chinese.
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Chapter 1 – Temperature and Thermometer

1.1 Temperature is an objective measurement of hotness

A cup of tea is cold for you but can be hot for someone else. Whether something is hot or cold is a kind of subjective feeling. To compare hotness, temperature of the object is an objective measurement is measured by a thermometer.

If you first put your fingers in two different beakers of water at different temperatures, and then put them into the same beaker of water. Your fingers will experience different degrees of hotness, and therefore different subjective feelings. This shows that hotness, which is a feeling, is a subjective.

Source: Physics at Work (Oxford)

The tap water has uniform temperature, but the two fingers feel differently.

In the above example, if we put a thermometer in the middle beaker, it will only measure a single temperature only, although your two different fingers give you different feelings.
Question 1.
Our feeling is not reliable for comparing hotness as feeling is subjective. We need a(n) ______________ measurement such as ______________ to measure hotness and the instrument that we may use is called ______________.

Question 2.
There are two beakers of water, A and B. The temperature of A and B are 40°C and 5°C. If you put both your hands into a beaker C of tap water at 22°C, and then your right and left hand into A and B respectively. You right hand will feel ______________ (hotter/colder) than the left hand.

Question 3.
There are two beakers of water, A and B. The temperature of A and B are 40°C and 5°C. If you put your right and left hand into A and B respectively and then both into a beaker C of tap water at 22°C. You right hand will feel ______________ (hotter/colder) than the left hand.

Question 4.
There are two beakers of water, A and B. The temperature of A and B are 40°C and 5°C. If there are two thermometers X and Y and are put into A and B respectively and then both into a beaker C of tap water at 22°C. The temperature reading on thermometer A will be ______________ (higher than/lower than/the same as) that on thermometer B.

Question 5.
Peter puts his hands into two beakers of different temperature, one being iced water and the other being hot water. He then puts his hands into the same tank of tap water. Which of the following is/are possible result?
(1) The hand that was in hot water would feel cold in tap water.
(2) The hand that was in iced water would feel hot in tap water.
(3) His two hands will feel different hotness in the same tank of water.
A. (1) and (2) B. (2) and (3) C. (1) and (3) D. (1), (2) and (3)
1.2 Celsius Scale

There are different temperature scales used by different nations. In HK, people use **Celsius scale** while in US, people use **Fahrenheit Scale**. Our body temperature is 37°C or 98.6°F in degree Celsius and degree Fahrenheit respectively.

<table>
<thead>
<tr>
<th>Fahrenheit</th>
<th>Freezing</th>
<th>Human Body Temperature</th>
<th>Boiling</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40°</td>
<td>0</td>
<td>80°</td>
<td>200°</td>
</tr>
<tr>
<td>-20°</td>
<td>40°</td>
<td>120°</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>37°</td>
<td>160°</td>
<td></td>
</tr>
<tr>
<td>32°</td>
<td>98.6°</td>
<td>212°</td>
<td></td>
</tr>
<tr>
<td>60°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Celsius**

Source: [http://omp.gso.uri.edu/ompweb/doee/science/physical/tscale.gif](http://omp.gso.uri.edu/ompweb/doee/science/physical/tscale.gif)

If you are supplied with a conversion table (or chart) as shown above or on the left, you may use it to convert temperatures expressed in *degree Celsius* and that in *degree Fahrenheit*.

**Question 6.**

Using the above temperature conversion chart, fill in the following table:

<table>
<thead>
<tr>
<th>Degree Celsius / °C</th>
<th>-40</th>
<th>0</th>
<th>37</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree Fahrenheit / °F</td>
<td>0</td>
<td>98.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On the other hand, you may be given one of the following formulae to convert temperatures in different scales:

\[ C = \frac{5}{9} (F - 32) \quad \text{or} \quad F = \frac{9}{5} C + 32 \quad \text{...... Equation (1)} \]

*C: Celsius Temperature, F: Fahrenheit Temperature*

**Question 7.**

Convert 37°C to temperature in Fahrenheit.
Question 8.
Read the temperature readings of the following thermometers:

Source: http://www.thecalculatorsite.com/articles/units/how-to-convert-fahrenheit-to-celsius.php

Reading: _____ °C OR _____ °F

Question 9.
Convert 98.6°F to temperature in Celsius.

Ans: \[\frac{98.6 - 32}{1.8} = 37\] °C

Question 10.
Convert 220°C to temperature in Fahrenheit.

Ans: \[\frac{220 - (-459.4)}{1.8} = 428\] °F

Question 11.
Convert 400°F to temperature in Celsius.

Ans: \[\frac{400 - 32}{1.8} = 204\] °C

Question 12.
Fill in the missing figures using Equation (1).

<table>
<thead>
<tr>
<th>Degree Celsius / °C</th>
<th>-273</th>
<th>0</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree Fahrenheit / °F</td>
<td>0</td>
<td>98.6</td>
<td></td>
</tr>
</tbody>
</table>
**Experiment - Making a Homemade Thermometer**

Watch the following video:
How to Make a Homemade Thermometer | Science Projects
Source: https://www.youtube.com/watch?v=qwHvXSJlp-s

**Procedure** (Source: http://www.ehow.com/how_4966531_make-homemade-thermometers.html)

1. Fill a clear bottle 1/4 full with equal amounts of water and rubbing alcohol. Add food coloring and mix well.

2. Arrange the clay around the opening of the bottle and place the straw in the middle. The straw should not touch the bottom and you may close the opening with the clay. Ensure that no air can get into the bottle.

3. Test your thermometer by putting it into hot water bath. Watch as the liquid mixture rises through the straw, then decreases after the bottle is removed and cools off.

4. Cut two lines out of the middle of the index card to fit the straw through. Mark the card with lines representing the temperature at which the liquid expands or contracts. This will enable you to read your temperature.

5. To calibrate your thermometer, place it in tap water bath. Mark that temperature on your paper indicating the temperature told by the teacher. Remove the thermometer and replace it in warm water bath, mark that temperature on the card.

6. Fill in the rest of the numbers for your thermometer to calibrate the temperature.

**Question 13.**

Give one reason *why rubbing alcohol was used* to make the homemade thermometer.

**Question 14.**

Explain, in terms of particle motion (i.e. kinetic theory), why the length of coloured liquid column increases with temperature.
1.3 Calibrating a thermometer on the Celsius Scale

For the very last step to make your very own thermometer on the last page, you have to mark the index card to produce a scale. This is called calibration of thermometer.

An unmarked thermometer is just a closed glass tube with a liquid column inside, with both ends closed. An unmarked thermometer has to be calibrated. After calibration, it will have a scale with temperature marks and then it will be ready to measure temperature.

The Celsius scale is defined by two fixed points; the ice point and steam point. The ice point is defined as 0°C while the steam point is defined as 100°C. The length between 0°C and 100°C marks is divided into 100 equal divisions. The experiment on the next page explains how to calibrate an unmarked thermometer in Celsius scale.

Before calibrating an unmarked thermometer in Celsius scale, we have to reproduce the fixed points. Therefore, we have to prepare a 0°C environment and also a 100°C environment.

Temperature of Ice-water mixture and steam-water mixture:

Water has three states, solid, liquid and vapour. They are called ice, water and steam respectively. They exist at different temperatures. Ice exists at or below 0°C. Liquid water exists between 0°C and 100°C. And for steam, it exists at or above 100°C.

Question 15.

When ice and water exist at the same time, the temperature must be _______. This is the temperature of melting ice or ice-water mixture.

Question 16.

When water and steam exist at the same time, the temperature must be _______.

This is also the boiling point of water.
**Experiment - Calibrating a thermometer**

1. An unmarked thermometer is first put into a beaker of ice-water mixture. Record the length of liquid column ($L_0$) and mark on the glass tube as 0°C.

2. Then, put the unmarked thermometer into boiling water. Record the length of liquid column ($L_{100}$) and mark on the glass tube as 100°C.

3. Lastly, divide the length between 0°C and 100°C into 100 equal divisions.

4. The thermometer is now ready for measuring unknown temperature.

**Modification:**

Change “ice water” to “ice-water mixture” in the diagram.
For a liquid-in-glass thermometer, if the length of liquid column is \( L_0 \) and \( L_{100} \) respectively at 0°C and 100°C, then when the length of liquid column is \( L_T \), the unknown temperature \( T \) is given by

\[
X = \frac{L_X - L_0}{L_{100} - L_0} \times 100 \degree C \quad \text{Equation (2)}
\]

In such calculation, we assume that the length of liquid column increases linearly with temperature. The following figure explains the formula by graphical method:

How did we get equation (3) above?
Assume the length of liquid changes linearly with temperature. The slope of the graph is given by

\[
slope = \frac{L_T - L_0}{T} \quad OR \quad \frac{L_{100} - L_0}{100} \quad \text{Equation (3)}
\]

Therefore \( T = \frac{L_T - L_0}{L_{100} - L_0} \times 100 \degree C \) which is the same as Equation (2) above.

Note that if the length of liquid does not changes linearly with temperature, Equation (2) does not apply anymore.
Question 17.
Under normal condition, the temperature of ice-water mixture is _____________ °C.
The temperature of boiling water is _____________ °C.

Question 18.
There are two fixed points for the Celsius temperature scale they are
A. _________________________: the temperature of ice-water mixture (or melting ice). It is taken as _______ °C.
B. _________________________: the temperature of steam-water mixture (or boiling water). It is taken as _______ °C.

Question 19.
The ice point and steam point are chosen as fixed points for Celsius scale because they are easily _________________________.

Question 20.
To calibrate a liquid-in-glass thermometer on the Celsius Scale, an ____________ thermometer is first put into ____________ and then into ____________ water.
The ____________ of liquid column is marked in each case and the separation between the two markings is divided into _______ equal divisions. Each division represents a temperature change of _______.

Question 21.
An unmarked thermometer is put into ice-water mixture and boiling water in turn, the length of liquid column is 3.2 cm and 12.6 cm respectively. It is then put into warm water of 50°C, what will be the length of liquid column?

Method (1):

Apply equation (1) on the last page:

Method (2):
Change in length of liquid column from 0 to 50°C = 1/2 × Change in length of liquid column from 0°C to 100°C
**Question 22.**

An unmarked thermometer is put into ice-water mixture and boiling water in turn, the length of liquid column is 2.6 cm and 8.4 cm respectively. It is then put into hot oil and the length of liquid column becomes 12 cm, what is the temperature of the hot oil?

**Ans:** 162 °C

**Question 23.**

A thermometer is put into ice-water mixture and tap water at 22 °C in turn, the length of liquid column is 2.6 cm and 4.4 cm respectively. It is then put into boiling water, what will be the length of liquid column?

**Ans:** 10.8 cm

**Question 24.**

A faulty thermometer with uniform scale (like a ruler) reads 10°C and 80°C when it is placed in ice-water mixture and boiling water respectively. What should be the true temperature when the thermometer reads 30°C?

**Ans:** 28.6 °C

**Question 25.**

It was told that if the length of liquid does not changes linearly with temperature, equation (#) does not apply. Which of the following cases can we apply equation (#)?

- A
- B
- C
- D
- E
- F

Ans: A, C, F only
1.4 Features of liquid-in-glass thermometer

If I say the thermometer that you have made last time was not sensitive, how can you made it ... more sensitive?

The labelled diagram below shows different parts of a liquid-in-glass thermometer.

When temperature changes, a thermometer with large bulb and thin bore may produce large change in length of liquid column, it is a sensitive thermometer. A sensitive thermometer produces a large change in liquid column when there is a small temperature change.

A thermometer with a thin glass wall and conducting liquid (e.g. mercury) inside conducts heat quickly. It produces quick respond to temperature change. When the temperature changes, it changes its length of liquid column very quickly.
For different purposes, different thermometers are designed. The following diagram shows a clinical thermometer. It has a constriction which prevents the liquid from running back to the bulb too quickly. This design gives more time for the nurse to read the body temperature more accurately.

Question 26.

Label the diagram below using the following words:

stem, mercury column, bulb, bore

A.  B.  C.  D.
Question 27.

By making TWO improvements of the following thermometer, draw another thermometer which is more sensitive than the one below.

![Thermometer Image]

Question 28.

Explain briefly why the bulb of a quick respond liquid-in-glass thermometer should have thin glass wall.

Question 29.

Give ONE advantage and ONE disadvantage of having thin glass wall for the bulb of a liquid-in-glass thermometer. Explain your answer briefly.

Question 30.

The stem of a thermometer should not have thin glass wall. Why?

Question 31.

Clinical thermometers are sterilized by alcohol but not hot water. Why?
1.5 Mercury-in-glass and Alcohol-in-glass thermometers

Mercury is the only metal in liquid state at room temperature. As a metal, it is a good conductor of heat. Mercury boils at a temperature of 357°C so that mercury-in-glass thermometer may measure higher temperature than alcohol-in-glass thermometer. The following table compares mercury-in-glass and alcohol-in-glass thermometer.

<table>
<thead>
<tr>
<th>Mercury-in-glass thermometer</th>
<th>Alcohol-in-glass thermometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>• It can measure high temperatures up to 357°C which is the boiling point of mercury.</td>
<td>• It can measure low temperatures down to -115°C which is the freezing point of alcohol.</td>
</tr>
<tr>
<td>• Quick response to temperature change</td>
<td>• Slow response to temperature changes</td>
</tr>
<tr>
<td>• Mercury is poisonous.</td>
<td>• Alcohol is not poisonous.</td>
</tr>
<tr>
<td>• More expensive</td>
<td>• Less expensive</td>
</tr>
</tbody>
</table>

Question 32.
Mercury and alcohol are used to make liquid-in-glass thermometers. Give one advantage and one disadvantage of using mercury over alcohol to make thermometer.

Question 33.
Despite the fact that mercury-in-glass is more sensitive and it can measure higher temperature, alcohol-in-glass thermometer is usually given to lower form students in science lessons? Why?

Question 34.
State and explain ONE advantage and ONE disadvantage of using alcohol-in-glass thermometer over mercury-in-glass thermometer.
1.6 Temperature and particle motion

The following shows the arrangement of particles in solids, liquids and gases.

The arrangement and movement of particles are different at different temperature. In general, their degree of freedom increases when temperature increases.

**solid**
- rigid
- fixed shape
- fixed volume

**liquid**
- not rigid
- no fixed shape
- fixed volume

**gas**
- not rigid
- no fixed shape
- no fixed volume

**Watch the youtube video: States of Matter (solids, liquids and gases)**
Question 35.

Particles in solids are in _____________ positions, so solids have fixed shape and volume.

Question 36.

Particles in liquids may move from one position to another, but they are still very _____________ to each other. They are not _______________ regularly. So, liquids have fixed _____________ but no fixed _______________.

Question 37.

Particles in gases are _____________________ from each other. There is no force between them and so their separation may be changed easily. So, gases have no _____________ volume. Also, the particles travel freely at high speed in random motion. So, gases have no _______________ shape.

Question 38.

Explain why when temperature decreases, a balloon becomes smaller.

Question 39.

If there are two substances at the same temperature, the particles of the one with more massive particles vibrate less vigorously than the other. Why?

Question 40.

Gases can be compressed but liquid and solid cannot. Why?

Question 41.

Explain why a lot of energy has to be supplied to vapourise a liquid?
1.7 Thermometer – how does it work?

According to kinetic theory, all matters are made up of tiny particles (atoms, molecules or ions) which are constantly in motion.

When a substance is hot, its particles vibrate more vigorously. In other words, when temperature increases, average kinetic energy of particles of a substance increases. They have larger kinetic energy on average as temperature increases.

When kinetic energy increases, particles vibrate faster. The particles will occupy more space as they vibrate more vigorously, and thus expansion results.

![Diagram of cold and hot mercury particles](http://www.bbc.co.uk/staticarchive/4e8909cebe37f6dd46758b1f5d3e55e1899e159b.gif)

When the bulb of a mercury-in-glass thermometer is put into hot water, the mercury particles gain kinetic energy. They vibrate faster and occupy more space. The liquid expands (but the particles do not expand but they only vibrate faster) and therefore increases in volume. The increase in volume pushes the liquid up the column and its length increases. The length of mercury thread increases and hence the measured temperature.

So, temperature is a measure of average kinetic energy of the particles of the object. When two objects have the same temperature, their average kinetic energies of their particles are the same.
**Question 42.**

Choose the WRONG answer. A liquid-in-glass thermometer may measure temperature of a substance because
A. volume of liquid changes with temperature
B. liquid expands when temperature increases.
C. length of liquid column increases with temperature.
D. glass expands more than liquid when temperature increases.

**Question 43.**

Which of the following statement is/are correct?
(1) For two objects at the same temperature, the average kinetic energies of their particles are the same.
(2) All particles inside an object have the same kinetic energy.
(3) Particles expand at higher temperature.
A. (1) only
B. (2) only
C. (3) only
D. (1), (2) and (3)

**Question 44.**

Explain, in less than 25 words, how liquid-in-glass thermometer works.

**Question 45.**

Explain why the liquid column of liquid-in-glass thermometer does not increase forever when dipped into hot surrounding.
Question 46.

The volume of liquid in a liquid-in-glass thermometer increases with temperature as shown below:

(a) What is the volume of liquid at 0°C? _______________________

(b) What is the volume of liquid at 100°C? _______________________

(c) The capillary tube of the thermometer has a cross-section area (bore) of 0.015 cm². Find the increase in length of liquid column when temperature changes from 0°C to 100°C.

(d) The length of liquid column of an unmarked thermometer is 2.8 cm in ice-water mixture. Find the length of liquid column when temperature is 100°C?
Particles of substance vibrate faster at higher temperature. What if the temperature keeps decreasing, how would the vibration of particles change?

When temperature decreases, the particles of a substance vibrate more slowly, therefore they vibrate with a lower average kinetic energy. Therefore, the particles will slow down their vibrations when temperature further decreases. Scientist found that all particles stop their vibration at a temperature of -273°C. Scientist called this temperature **absolute zero**, or 0 K where K stands for Kelvin, which is the unit of absolute temperature.

Therefore,

\[ K = ^\circ C + 273 \]  \hspace{1cm} \textit{Equation (4)}

In other words, we may use absolute temperature measured in Kelvin (K) as a measure of average kinetic energy of a substance. Thus, absolute temperature of a substance is directly proportional to the average kinetic energy of its particles.

Conversion between different temperature scales.

\[ ^\circ C = K - 273 \]
\[ ^\circ F = ^\circ C \times 1.8 + 32 \]
Question 47.

When the average kinetic energy of particles is reduced until it reaches a minimum, the temperature of the object cannot be further decreased. This temperature is called ___________________ and it is about _________ °C.

Question 48.

The absolute temperature of an object represents (but not equal to) ________________ kinetic energy of its particles.

Question 49.

Fill in the following table: (Show your calculations clearly)

<table>
<thead>
<tr>
<th>Degree Celsius / °C</th>
<th>-273</th>
<th>0</th>
<th>27</th>
<th>37</th>
<th>373</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute temperature /K</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Question 50.

Which of the following is wrong? At absolute zero,

A. particles do not move, they only vibrate.
B. the average kinetic energy of particles is zero.
C. the kinetic energies of all particles are zero.
D. the temperature is the lowest in the universe.

Question 51.

Explain why there is a lower limit of absolute temperature.
**Question 52.**

The volume of a balloon increases with temperature. Its volume at different temperatures are recorded and tabulated below. Using the given data, plot a V-T graph on the grid below.

<table>
<thead>
<tr>
<th>Vol / cm³</th>
<th>6.5</th>
<th>7.6</th>
<th>8.4</th>
<th>9.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp/°C</td>
<td>13</td>
<td>57</td>
<td>87</td>
<td>127</td>
</tr>
</tbody>
</table>

**Question 53.**

From the graph, we can see that the volume becomes zero when the temperature is low enough. This temperature is called absolute zero. Estimate the temperature of absolute zero in °C from the graph.
Chapter 2 - Internal Energy and Heat Transfer

Q: Which object has more energy?

An iceberg? Or ... A bucket of red-hot molten metal?

Internal energy of an object is the sum of kinetic energy and potential energy of its particles.

An iceberg has a huge number of particles. Although each particle may have little kinetic or potential energies, the internal energy of the object of an iceberg can be quite large. On the other hand, a piece of red-hot metal does not contain many particles. Even if each metal particle has large kinetic energy due to their high temperature, the internal energy of a piece of metal is much smaller than that of an iceberg.
2.1 Mechanical Energy of particles

Particles of an object have mechanical energy, which includes kinetic energy and potential energy.

**Kinetic energy and Potential energy of a mass (but not a particle)**

When a mass is held high from the ground, it has high (gravitational) potential energy *(There are also other potential energies such as elastic potential energy or electric potential energy, but we don’t discuss them here).* When it is released, its potential energy changes to its kinetic energy. As it drops, more of its potential energy is changed to its kinetic energy, so it speeds up when it falls.

When a roller coaster runs on the rail, it has kinetic energy. Kinetic energy of the roller coaster comes from its motion. When it runs faster, it has more kinetic energy. On the other hand, when the roller coaster is at a higher position, it has greater (gravitational) potential energy.
Question 54.
Roller coaster at high position has high _________________.

Question 55.
Roller coaster travelling at high speed has high _________________.

Question 56.
Fill in the table below: (the first is done for you)

<table>
<thead>
<tr>
<th>P.E. and K.E.</th>
<th>Low Speed</th>
<th>High Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Position</td>
<td>High PE, Low KE</td>
<td></td>
</tr>
<tr>
<td>Low Position</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As a coaster car loses height, it gains speed; PE is transformed into KE. As a coaster car gains height it loses speed; KE is transformed into PE. The sum of the KE and PE is a constant.

Question 57.
Shade the bar charts below to show the amount of P.E. and K.E. of the roller coaster at different points of the rail.

Hint: Note that the TOTAL (mechanical energy) should conserve!

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Question 58.
Describe the potential energy and kinetic energy change of a ball released from height and bounces a few times on the ground.

---
2.2 Internal energy of an object – the total mechanical energy of its particles

Internal energy of an object is the total mechanical energies of particles, which is the sum of kinetic energy and potential energy of particles.

Particles of an object also possess kinetic energy and potential energy. Kinetic energy of particles is due to particle motions. Potential energy of particles is due to the force between them, and increases with their separations. The sum of kinetic energy and potential energy of particles is called internal energy of the object.

When particles vibrate faster, the average kinetic energy of particles increases. This happens when temperature increases.

When separation between particles increases, the potential energy stored between particles also increases. This happens when solid changes to liquid, or when liquid changes to gas.

The following diagram shows the arrangement and motions of particles in solids, liquids and gases. The separation between particles increases when the substance changes from solid to liquid (e.g. when ice melts to water) or from liquid to vapour/gases (e.g. when water vaporizes to become steam).

We see that when there is change of states (from solid to liquid to gas), the separation between particles increases, so potential energy between particles increases when solid melts or liquid vapourises. On the other hand, potential energy of particles decreases when vapour condenses or liquid freezes.
Note that kinetic energy of particles and kinetic energy of an object are different. The former refers to particle vibrations while the latter refers to motions of the object.

<table>
<thead>
<tr>
<th>Boiling Soup</th>
<th>Water Tank Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average kinetic energy of particles of hot water is high, but the kinetic energy of water is low as the pot of water does not travel.</td>
<td>Kinetic energy of water is high when the truck is running fast on road, but the average kinetic energy of water particle is low due to its low temperature.</td>
</tr>
</tbody>
</table>

Similarly, potential energy between particles is due to separation between particles while (gravitational) potential energy of an object depends on its height from the ground.

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in average PE of particles (from left to right)</td>
<td>An snowball at the top of hill has high gravitational PE but its particles has low average PE</td>
</tr>
</tbody>
</table>
Question 59.

The sum of kinetic and potential energies of particles of an object is called ________________ energy of the object. If there are two glasses of water at the same temperature, the one with a ________________ mass has a larger internal energy.

Question 60.

The internal energy of an object is the __________ of kinetic and potential energy of all its particles.

Question 61.

The internal energy of an object increases when the average kinetic energy of particles increases due to increase in _________________. The internal energy of an object also increases when the substance changes from _________ to liquid, or from liquid to __________, as the _______________ energy between particles increases.

Question 62.

Describe the increase in particle PE or KE as ice from the freezer at -10°C is heated to melt to become water and finally to become steam. State, for each of the arrow below, whether particle PE or KE increases.

-10°C ice → 0°C ice → 0°C water → 100°C water → 100°C steam

Question 63.

Which of the following must be correct?

A. All solids have more internal energy than any liquid.
B. A hot object carry more internal energy than a cold object.
C. The particles of a hot object always carry more potential energy than a cold object.
D. The particles of a hot object have higher average kinetic energy than when the object is cold.
2.3 Heat and energy transfer (Heating and Doing work)

If you touch a piece of hot iron, it hurts. You feel hot because a lot of heat energy flows from the hot iron to your finger.

![Hot Touch Warning Illustration](http://www.jeffjonesillustration.com/images/illustration/00446-hot-touch-warning.jpg)

When there are two objects at different temperatures, the one at a higher temperature will transfer heat to the other one until they have the same temperature. When they have the same temperature, we say they are in thermal equilibrium.

![Thermal Equilibrium Graph](http://www.physicsclassroom.com/Class/thermalP/u18l1d5.gif)

**Thermal equilibrium – if you want to know more ....**

“Thermal equilibrium” means no NET exchange in heat energy between objects. When two objects are in contact, it takes time for the heat to flow from the hotter one to the colder one and then there will be thermal equilibrium when their temperatures are the same.

When there is thermal equilibrium, there is still heat exchange between the objects, but there is no NET heat exchange between them. There is still heat that flows from A to B, but the same amount of heat flows from B to A.
The energy transfer due to temperature difference is called heat (energy), and the process of heat transfer (or heat flow) is called heating. When you hold a boiling tube over a flame, heat is transferred from the hot flame to the tube and the process is heating. Similarly, an immersion heater also transfers heat to water by heating as the heater is hotter than the water.

Another way of energy transfer is by doing work. If you rub your hands, you will feel warm due to the work done against friction between your hands.
Question 64.

Fill in the table below:

<table>
<thead>
<tr>
<th></th>
<th>30000000000 kg Iceberg</th>
<th>3 kg iron at 500°C</th>
<th>Choice of word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of particles</td>
<td></td>
<td></td>
<td>More/Less</td>
</tr>
<tr>
<td>Internal Energy</td>
<td></td>
<td></td>
<td>More/Less</td>
</tr>
<tr>
<td>Average kinetic energy</td>
<td></td>
<td></td>
<td>More/Less</td>
</tr>
</tbody>
</table>

So, heat will be transferred from _________________ to _________________.

Question 65.

Heat flow is due to _________________ difference. Heat (energy) always flows from objects at a _________________ temperature to another at a _________________ temperature. The internal energies of the objects do not affect the flow of heat (energy).

Question 66.

A glass of hot water at 70°C is left in room temperature of 22°C for 30 minutes and finally reach thermal equilibrium.

(a) Sketch the change in temperature of water versus time. (hint: it starts from 70°C and finally reach 22°C)

(b) Label on the temperature axis the temperatures 70°C and 22°C.

(c) What would you say about the heat loss of hot water at the beginning and after 20 minutes?

Question 67.

A glass of hot lemon tea is at 40°C. Many ice cubes are added in a short time so that its temperature changes to 0°C. Then, the icy lemon tea is left and finally it returns to room temperature of 28°C. Sketch the change in temperature of lemon versus time. Mark the time when ice cubes are added as C. Label on the temperature axis the temperatures 40°C, 28°C and 0°C.
2.4 Power – rate of energy flow

When an immersion heater heats up water, energy is transferred from heater to water at a constant rate. An immersion heater of power 30W transfers 30J of energy to its surroundings each second. The units of power and energy are Watt (W) and Joule (J) respectively where $1W = 1J/s$.

The electric kettle in the diagram has a power of 2.2kW! Therefore, it converts 2200 J of electrical energy to heat in each second.
If the power of an electric heater is known, we may measure the time of heating to find the energy supplied by the following equation:

\[ Q = Pt \]

**Equation (5)**

<table>
<thead>
<tr>
<th>Electrical appliance</th>
<th>Power rating (W)</th>
<th>Time of usage</th>
<th>Energy consumption (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>1200</td>
<td>0.5 hour</td>
<td>(1200 \times 0.5 \times 60 \times 60) = 2 160 000</td>
</tr>
<tr>
<td>Iron</td>
<td>1200</td>
<td>1.0 hour</td>
<td>(1200 \times 1 \times 60 \times 60) = 4 320 000</td>
</tr>
<tr>
<td>Kettle</td>
<td>1500</td>
<td>7 minutes</td>
<td>(1500 \times 7 \times 60) = 630 000</td>
</tr>
<tr>
<td>Kettle</td>
<td>2000</td>
<td>7 minutes</td>
<td>(2000 \times 7 \times 60) = 840 000</td>
</tr>
</tbody>
</table>

For example, an electric kettle of power 1500 W converts 1500 J of electrical energy to heat energy per second. In 7 minute, it converts \(1500 \times 7 \times 60\) J (=63000J) of electrical energy to heat energy.

If the power of a heater is unsure, we may use a joulemeter to measure the energy supplied directly. Your teacher will show you how to use a joulemeter in the next lesson.
The above diagram shows an experimental setup to heat water using an immersion heater. When using a joulemeter, we have to mark down its initial reading before heating and final reading after heating. The difference of the readings is the energy supplied.

When heat is transferred from the immersion heater to the water, the temperature of water rises. As more energy is transferred, the temperature of water rises more. The temperature rise increases linearly with the energy supplied.

The following is a plot of temperature of water versus time of heating in such an experiment.

Precaution:
Measure the highest temperature reached after the heater is turned off. Take this as the final temperature.
4. **Enjoy the fantastic world of mirrors.** Mirror hallway, Mirror maze, Kaleidoscopes, Periscope, Semi-transparent mirror, Mirrors of invisibility and Funny mirrors. Take some photos there.

Photo(s)

5. **Explain ONE of the following effects of reflection by mirrors with diagram:**
   - [ ] Your own profile
   - [ ] Your back
   - [ ] Total reverse
   - [ ] Twins
   - [ ] Sliding
   - [ ] Reverse
   - [ ] Vanishing body
S3 Science Museum Visit (2015-2016)

Go to the science museum in TST, find the experiments of visible light and complete the worksheet below.

1. **Total Internal Reflection**
   Find the tank with a ray of green laser. Use the set up to find the critical angle of the liquid in the tank.

   The critical angle of the liquid is _____, so the refractive index of the liquid is probably equal to _____.

2. **Real Image in Air**
   Find the “Spring Challenge”. You can see a spring. Feel it with your hand. Can you touch it? Explain in your own words how it happens. (You may draw a diagram to aid explanation)

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________

3. **Telescope**
   Look through the lens of the telescope. Is the image seen larger or smaller than the object? What do you notice about the orientation of the image? Can you take a photo of the image?

   ________________________________
   ________________________________
   ________________________________
   ________________________________
   ________________________________
   ________________________________
   ________________________________
   ________________________________

   Photo
4. **Enjoy the fantastic world of mirrors.** Mirror hallway, Mirror maze, Kaleidoscopes, Periscope, Semi-transparent mirror, Mirrors of invisibility and Funny mirrors. Take some photos there.

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   - [ ] Total reverse
   - [ ] Twins
   - [ ] Sliding
   - [ ] Reverse
   - [ ] Vanishing body
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2. **Real Image in Air**
   Find the ‘Spring Challenge”. You can see a spring. Feel it with your hand. Can you touch it? Explain in your own words how it happens. (You may draw a diagram to aid explanation)

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________

3. **Telescope**
   Look through the lens of the telescope. Is the image seen larger or smaller than the object? What do you notice about the orientation of the image? Can you take a photo of the image?

   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
   _________________________________________________________________
Question 68.
When the heater is turned off, the temperature will keep rising for a short time. Why?
Explain briefly.

Question 69.
A 30W immersion heater heats a beaker of water. Calculate the heat transferred by the heater in one minute to the surrounding.

Question 70.
The initial and final joulemeter readings in a heating process is 234 000 J and 345 000 J. Find the amount to energy supplied by the heater.

Question 71.
Many people use electric heater in their bathroom. Calculate the energy used by a 3000W water heater in 15 minutes.

Question 72.
The initial and final joulemeter readings in a heating process is 876 000 J and 123 000 J (Tricky!!). Find the amount to energy supplied by the heater.

Question 73.
An immersion heater of power 120 W is used to heat some water in 10 minutes. The heat loss to the surroundings in the 10 minutes is about 250 J. Find the net energy gain of the water.
Question 74.

Draw a diagram using all the following apparatus to measure the energy to heat a cup of water using an immersion heater.

Source: http://www.bckss.edu.hk/CustomPage/26/g3.gif

Question 75.

Suppose you have the correct setup in the last question, list the steps to measure the heat supplied in a 3-min heating.

Question 76.

Refer to the last question, describe how you may measure the temperature rise in the 3-min heating.
Chapter 3 - Heat Capacity and Specific Heat Capacity

3.1 Heat Capacity

When heating water by immersion heater, the temperature rise of water increases with the amount of heat transferred. The following experiment investigates the relationship between energy supplied $Q$ and temperature rise $\Delta T$.

Experiment – Relationship between energy supplied $E$ and temperature rise $\Delta T$.

1. Set up the apparatus as shown above.
2. Measure the initial temperature of water ($T_1$).
3. Turn on the heater for 1 minute. **Keep stirring during heating to ensure the temperature in the cup is uniform.**
4. Measure the maximum temperature of water after the heater is turned off. This is the final temperature ($T_2$).
5. Temperature rise is the difference between the initial and final temperatures. Therefore, ($\Delta T = T_2 - T_1$)
6. Repeat step 3 several times and plot a graph of temperature rise $\Delta T$ against time of heating.
Result: *(Fill in the result from the measurement in the video)*

Initial temperature: __________

<table>
<thead>
<tr>
<th>Time of heating / s</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature / °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Rise / °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If y-x graph is a straight line passes through the origin as shown below,

\[ y = kx \]

Then \( y \) is directly proportional to \( x \), i.e. \( y \propto x \)

Conclusion: The temperature rise \( \Delta T \) is directly proportional to the energy supplied \( Q \) for a fixed mass of water. Therefore, \( Q \propto \Delta T \), thus we may write \( Q = C \Delta T \) where \( C \) is a constant called *heat capacity*. The unit of heat capacity is \( J^\circ C^{-1} \).

*What is the meaning of Heat Capacity?*

A small cup of water has a heat capacity of 250 \( J^\circ C^{-1} \). Thus, it absorbs 250 \( J \) of energy when its temperature increases by 1 \( ^\circ C \). And it absorbs 500 \( J \) of energy when its temperature increases by 2 \( ^\circ C \) and so on.

\[ Q = C \Delta T \quad \text{Equation (6)} \]

Thus, *Heat Capacity* \( C = \frac{Q}{\Delta T} \) \quad \text{Equation (7)}

Nevertheless, the change in temperature decreases when the substance being heated (in this case, water) has a larger mass. Therefore, a larger volume of water has a larger heat capacity.
Question 77.

From the graph plotted on the last page, find an experimental value of Heat Capacity of the cup of water.

Question 78.

In the above experiment, why a foam cup is used, but not a glass beaker?

Question 79.

Why is the lid necessary? What would happen to the temperature rise without the lid?

Question 80.

What is the use of the stirrer?

Question 81.

One precaution of the experiment is to keep stirring to ensure the temperature of water is uniform. The other precaution is to ensure the heater is totally immersed in the water when it is on. What would happen if it is not so?

Question 82.

The temperature keeps rising for a short time after the heater is off, how should you measure the temperature rise more accurately?

Question 83.

When a fixed amount of energy is supplied, the temperature rise is affected by one physical quantity of the substance being heated. Name the physical quantity.
Question 84.
A small cup of water has heat capacity $300 \, J^\circ C^{-1}$.
(a) Find the energy absorbed by the water when its temperature increases by $5^\circ C$.
(b) How long does it take for an immersion heater of 20W to heat the water to raise its temperature by $5^\circ C$?

Question 85.
A big piece of rock has a heat capacity of $10000 \, J^\circ C^{-1}$. It absorbs energy from the sun on a sunny day at a rate of 500 W.
(a) What is its temperature rise in five minutes?
(b) The temperature does not rise so much as your answer in (a), give one possible reason.

Question 86.
For 0.2 kg of water, it absorbs 4200 J of energy to raise its temperature by $5^\circ C$. Find the heat capacity of 0.2 kg of water.

Question 87.
Using the information from the last question, find the heat capacity of 1 kg of water.

Question 88.
For 2 kg aluminium block, it absorbs 3600 J of energy to raise its temperature by $2^\circ C$. Find the heat capacity of the aluminium block.

Question 89.
Using the information from the last question, find the heat capacity of 1 kg of aluminium block.
### 3.2 Specific Heat Capacity

The *heat capacity* of an object depends on its mass. The larger the mass, the greater the heat capacity. If the object is a pure substance, it would be more convenient to tell the *heat capacity per kilogram* of the substance.

The *heat capacity per kilogram* of a substance is called *specific heat capacity*.

\[
Specific \ Heat \ Capacity \ C = \frac{Heat \ Capacity \ C}{mass} = \frac{Q}{m \ \Delta T} \quad ... \quad Equation \ (8)
\]

Thus, \( Q = mc\Delta T \) \quad ... \quad Equation \ (9)

The *specific heat capacity* of a substance is the heat capacity of 1 kg of the substance. For example, the specific heat capacity of water is 4200 J/kg°C. Thus, when the temperature of 1 kg of water increases by 1°C, it absorbs 4200 J of energy. On the other hand, when the temperature of 2 kg of water decreases by 4°C, it releases \( 2 \times 4 \times 4200 \) J (= 33600 J) of energy.

The following table shows the *specific heat capacity* of other materials:

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific Heat Capacity [J/kg°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>4200</td>
</tr>
<tr>
<td>Alcohol</td>
<td>2500</td>
</tr>
<tr>
<td>Ice</td>
<td>2100</td>
</tr>
<tr>
<td>Aluminium</td>
<td>900</td>
</tr>
<tr>
<td>Concrete</td>
<td>800</td>
</tr>
<tr>
<td>Glass</td>
<td>700</td>
</tr>
<tr>
<td>Steel</td>
<td>500</td>
</tr>
<tr>
<td>Copper</td>
<td>400</td>
</tr>
</tbody>
</table>


Note that *specific heat capacity* only applies to pure substances. For compound substances, *heat capacity* is used instead. For example, we may talk about the specific heat capacity of water, aluminium or alcohol, but for an electric kettle, we usually talk about its heat capacity.
Experiment – Determine the specific heat capacity of water.

1. Set up the apparatus as shown above.
2. Measure 200cm$^3$ of water and pour it into the container. Therefore mass of water, m = 200g = 200/1000 kg)
3. Measure the initial temperature ($T_1$) of water and initial joulemeter reading ($J_1$).
4. Turn on the heater until the temperature of water rises for about 8°C. Keep stirring during heating to ensure the temperature in the cup is uniform.
5. Measure the maximum temperature of water after the heater is turned off. Take it as final temperature ($T_2$) and the final joulemeter reading ($J_2$).
6. Calculate the specific heat capacity of water by ……

Specific Heat Capacity $c = \frac{\text{Heat Capacity} \ C}{\text{mass}} = \frac{Q}{m \Delta T} = \frac{(\quad)}{m \ (\quad)}$

Question 90.

State TWO precautions of the above experiment. Explain briefly.

Question 91.

Using the above setup, the experimental value of specific heat capacity of water is larger than its standard value of 4200 Jkg$^{-1}$C$^{-1}$. Give a possible explanation.
Question 92.

Give a suggestion on improvement of the experimental procedure to reduce the error as you have mentioned in the last question. Explain your answer.

Question 93.

Given that the specific heat capacity of water is $4200 \text{ Jkg}^{-1}\text{C}^{-1}$. Calculate the energy absorbed by 0.4 kg of water when its temperature increases by 3°C.

Question 94.

Three foam cups of liquid and the same mass were heated by the same immersion heater. Their temperature rise are shown in the graph below:

Which liquid has the highest specific heat capacity?

Question 95.

Refer to the last question. If the mass of A, B and C are all equal to 0.4 kg and the immersion heater has a power of 50W. Find the specific heat capacities of A, B, and C.
Question 96.
When hot water is mixed with cold water, which of the following will never happen?
(1) The temperature of the mixture is half of that of the hot water.
(2) The average kinetic energy of the water molecules of the ‘mixture’ is half that of the hot water.
(3) The specific heat capacity of the mixture is half that of the hot water.
A. (2) only
B. (3) only
C. (2) and (3) only
D. (1), (2) and (3)

Given that the specific heat capacity of water is 4200 Jkg\(^{-1}\)\(^\circ\)C\(^{-1}\). Finish the followings:

Question 97.
Calculate the time required for heating 10 kg of water to increase its temperature from 25\(^\circ\)C to 40\(^\circ\)C by an electric heater of 1500 W.

Question 98.
Given that the specific heat capacity of water is 4200 Jkg\(^{-1}\)\(^\circ\)C\(^{-1}\). A kettle heats up 0.45 kg of water from 10\(^\circ\)C to 80\(^\circ\)C in 2 minutes. What is the power of the kettle?

Question 99.
Calculate the energy released by 1 kg of water when its temperature changes from 80\(^\circ\)C to 75\(^\circ\)C. If the temperature changes in 30 seconds, find the power of heat loss to surroundings.

Question 100.
Calculate the energy released by a beaker of 250g water at 60\(^\circ\)C when its temperature falls to 40\(^\circ\)C. The heat capacity of the beaker is 100J\(^\circ\)C\(^{-1}\).
Question 101.

500 g of water in a metal container is heated by an immersion heater. The initial temperature was 22°C. The heat capacity of the metal container is 200 J°C⁻¹. Find the time of heating to raise its temperature to 40°C if the power of heater is 140W.

Ans: 295.7s

Question 102.

What will keep you warmest on a cold night? 1-kg of iron at 100°C? or 1-kg water at 100°C?

Ans: Water, due to higher heat capacity

Question 103. (Challenging)

An electric heater of power 250W heats up some water from 25°C to 60°C in 10 minutes. Assume the average rate of energy loss to the surrounding is 40W. Find the mass of water.

Ans: 0.857 kg

Question 104. (Challenging)

Find the time of heating to raise the temperature of 0.8 kg of water from 20°C to 60°C by an electric heater of power 300W, given that the average rate of energy loss to the surroundings is 50W for 0.8kg of water at 30°C.

Ans: 537.6s

Question 105. (Challenging)

In the last question, the actual time taken is more than your calculated answer. Explain why briefly.
Question 106.

The following graph shows the temperature change when 1.5 kg of a liquid is heated by an immersion heater of power 200 W.

Calculate the specific heat capacity of the liquid.

Question 107.

There are 4 different substances of different masses. Calculate the temperature rise of each of them when 5000 J of energy is supplied. Arrange their labels (A to D) in ascending order of temperature rise.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Mass</th>
<th>Specific heat capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 kg</td>
<td>2000 J°C⁻¹</td>
</tr>
<tr>
<td>B</td>
<td>1.5 kg</td>
<td>1200 J°C⁻¹</td>
</tr>
<tr>
<td>C</td>
<td>2 kg</td>
<td>1100 J°C⁻¹</td>
</tr>
<tr>
<td>D</td>
<td>4 kg</td>
<td>560 J°C⁻¹</td>
</tr>
</tbody>
</table>
**Question 108.** (Challenging)

There are two radiators, one is oil-filled and the other is water-filled.

The temperature of the oil and water inside the radiators change as follows:

The specific heat capacity of water is 4200 J°C⁻¹kg⁻¹ while that of oil is 2100 J°C⁻¹kg⁻¹. The mass of oil and water are 8kg and 5 kg respectively.

(a) Oil-filled radiator is popular because it heats up the room faster. Which curve, the solid or the dotted, is that of oil-filled radiator?

(b) Calculate the energy absorbed by the oil when its temperature increases from 17 to 22°C.

(c) Calculate the energy released by oil and water respectively during the time interval from t = 40 min to 50 min.

Ans: (a) dotted, (b) 84000J, (c) oil: 168000J water: 309750J
3.3 Specific heat capacity - metal cylinder

We may also use immersion heater to determine the specific heat capacity of a good conductor of heat such as a metal block. The following experiment determines the specific heat capacity of a solid conductor such as a metal block.

Experiment – Determine the specific heat capacity of aluminium.

1. Set up the apparatus as shown above.
2. Put a few drops of oil into the holes for thermometer and heater to improve thermal conduction between them.
3. Measure the initial temperature ($T_1$) of water and initial joulemeter reading ($J_1$).
4. Turn on the heater until the temperature of metal block rises for about 8°C.
5. Measure the maximum temperature of water after the heater is turned off. Take it as final temperature ($T_2$) and the final joulemeter reading ($J_2$).
6. Calculate the specific heat capacity of aluminium by ……

$$\text{Specific Heat Capacity } c = \frac{\text{Heat Capacity } C}{\text{mass}} = \frac{Q}{m \Delta T} = \frac{(\text{ })}{m (\text{ })}$$

Question 109.

Compare with the last experiment on page 46, this setup has no stirrer. How does it affect the experimental result?
Question 110.
Can we use the same apparatus to find the specific heat capacity of glass?

Ans: No, as glass is NOT a good heat conductor

Question 111.
What is the use of adding a few drops of oil into the holes for thermometer and heater?

Ans: improves thermal contact between the block and heater/thermometer

Question 112.
The experimental value of specific heat capacity of aluminium is larger than its standard value which is 900 Jkg\(^{-1}\)\(^\circ\)C\(^{-1}\). Give a possible explanation.

Question 113.
Give a suggestion on improvement of the setup so as to reduce the error you have mentioned in the last question.

Question 114.
When 7000 J of energy has been supplied to a 3 kg metal block, the temperature of the block rises by 5\(^\circ\)C. What are the specific heat capacity and heat capacity of the block?

Ans: 

Question 115.
With the aid of diagram, describe an experiment to measure the specific heat capacity of a metal block. You should draw a diagram of the whole setup including a power supply. You should also state the experimental procedure step by step. Also, you should state clearly what measurements you will take. And lastly you should tell how to calculate the specific heat capacity of the metal block using the measurements.

Question 116. (Challenging)
A hot metal block of mass 2.5 kg is cooled byimmersing into a tank of water. There is 5kg of water in the tank and its temperature increases by 8\(^\circ\)C after the hot metal block is immersed into it. Find the energy absorbed by the water. The temperature of metal drops by 70\(^\circ\)C, find the specific heat capacity of the metal.
3.4 “Mixture” – Calculation based on conservation of energy

When hot water and cold water are mixed together, there will be heat exchange – heat will flow from the hot water to the cold water so that their final temperatures become the same.

Similarly, when a piece of hot metal is dropped into cold water, there will be heat transferred from the metal to the water so that their final temperatures are the same. By conservation of energy, we know:

\[ \text{Heat loss by hot object(s)} = \text{heat gain by cold object(s)} \]

\[ \text{Equation (10)} \]

**Question 117.**

Watch the video of the experiment and then state one precaution of the experiment. Explain the importance of the precaution.
Question 118.

When 0.5 kg of water at 80°C is mixed with 0.2 kg of water at 20°C in a foam cup, find the final temperature.

Assume there is no energy loss to the surrounding, and let the final temperature be \(X\),

\[
\text{Heat loss by hot water} = \text{heat gain by cold water}
\]

\[
(0.5) \times (4200) \times (80-X) = (0.2) \times (4200) \times (X-20)
\]

\[X = \ldots\]
Question 119.

0.15 kg of copper at 90°C is put into 2 kg of water at 20°C in a foam cup. Find the final temperature.

Assume ....

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific Heat Capacity [J/kg°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>4200</td>
</tr>
<tr>
<td>Alcohol</td>
<td>2500</td>
</tr>
<tr>
<td>Ice</td>
<td>2100</td>
</tr>
<tr>
<td>Aluminium</td>
<td>900</td>
</tr>
<tr>
<td>Concrete</td>
<td>800</td>
</tr>
<tr>
<td>Glass</td>
<td>700</td>
</tr>
<tr>
<td>Steel</td>
<td>500</td>
</tr>
<tr>
<td>Copper</td>
<td>400</td>
</tr>
</tbody>
</table>


http://www.alanpedia.com/physics_specific_heat_capacity/specific_heat_capacity_questions_and_equation_clip_image004.jpg

Question 120.

1 kg of water at 60 °C is in a container which has a heat capacity of 300 Jkg⁻¹. When 2 kg of water at 20°C is added, find the final temperature of the mixture.
Question 121.

What is the assumption in the last two questions about mixing substance of different temperatures?

Question 122.

If there is no heat flow between two bodies when they are in contact, the two objects must have the same
A. Temperature  
B. Internal energy  
C. Heat capacity  
D. Specific heat capacity

Question 123.

A 1 kg aluminium block at 90°C is added to 2 kg of water at 25°C. Given the specific heat capacity of aluminium is 900 Jkg⁻¹°C⁻¹.
(a) Find the final temperature of the mixture.
(b) What are the temperature changes of
i. the water and  
ii. the aluminium block?
(c) Which has a smaller temperature change? Why?

Question 124.

A 2 kg steel block at 100°C is put into some water at 20°C. The temperature of the water finally reaches 23°C. What is the mass of the water? Given the specific heat capacity of steel is 500 Jkg⁻¹°C⁻¹.
Question 125.

The following experiment measures the specific heat capacity of metal. The calorimeter has a heat capacity of $50\text{J}^\circ\text{C}^{-1}$. 1 kg of water at temperature $t_1 = 22^\circ\text{C}$ is added to the calorimeter, and then a metal block of mass 0.3 kg at temperature $t_b = 80^\circ\text{C}$ is added. The final temperature is $t_2 = 26^\circ\text{C}$. Find the specific heat capacity of the metal.

\[ m_1 = \text{Mass of calorimeter} \]
\[ m_2 = \text{Mass of calorimeter and water} \]
\[ m_3 = \text{Mass of calorimeter, water, and metal block} \]

Source: http://www.webassign.net/kelterchem08/p5-98.gif

Question 126.  (Challenging)

A piece of 0.2 kg copper is held over a Bunsen flame for 10 minutes. It is then dropped into a big beaker of 3 kg water at 25°C. Given the specific heat capacity of copper is $400 \text{J}^\circ\text{C}^{-1}$ and the heat capacity of beaker can be ignored.

(a) Teacher says that the initial temperature of the copper block is the temperature of the Bunsen flame. Why? Explain briefly.

(b) The final temperature is found to be 30°C. Assume that there is no heat loss to the surroundings. Find the temperature of the Bunsen flame.

(c) The Bunsen flame has a higher temperature than your answer in part (a). Explain one possible source of error.
**Question 127.** (Challenging)

1 kg of water at 20°C is added to 3 kg of soup at 98°C in a 2 kg aluminium container, find the final temperature. Given that the specific heat capacity of soup is 3500 Jkg⁻¹°C⁻¹ and that of aluminium is 900 Jkg⁻¹°C⁻¹.

**Ans:** 78.145°C

**Question 128.** (Challenging)

Sandra is making a bowl of beef ball noodle. The mass of each beef ball is 90g. The specific heat capacity of beef is 2400 Jkg⁻¹°C⁻¹. Sandra puts 2 beef balls at 4°C into 1.2 kg of water at 40°C. After a while, she heats the beef balls and water mixture over a stove. Assume that the container has negligible heat capacity and there is no heat loss to the surroundings.

(a) What is the temperature of the mixture before it just before it was heated?

(b) If it takes 5 minutes to heat the mixture up to 90°C, what is the power of the stove?

(c) He then puts 500 g of noodles at 15°C into the water. It takes another one minute to heat the mixture up to 90°C using the same setting. What is the specific heat capacity of the noodle?
3.5 Importance of high specific heat capacity of water

Comparing with other liquids and many other substances, the specific heat capacity of water is rather high. The high specific heat capacity of water means water absorbs (releases) a large amount of energy when its temperature increases (decreases).

(1) Water as coolant

As water absorbs a large amount of energy resulting in a small change in temperature only, water is used as a coolant in air conditioning and cooling system as it can carry a lot of energy away from the heat source.

When the temperature of water changes, it has to absorb/release a large amount of energy. When time is limited and thermal equilibrium cannot be reached, the water temperature does not change so much as expected. In this way, the high specific heat capacity of water may limit temperature change which results in mild climate and body temperature regulation.
(2) Climate Effect

For example, one day in summer, the air temperature in HK changes from 25°C to 35°C in the morning but the sea temperature only changes from 27°C to 32°C.

For the same reason, the temperature change of the coastal area is less than the inland because of the presence of the sea. Thus, the coastal area has a cooler summer and a milder winter than the inland area.

For example, Hong Kong is a coastal city, we have the Victoria harbour and our city is just next to the South China Sea. The plenty of water around our city means the temperature change of our city is slow and limited. Thus, the weather here does not fluctuate as much as an inland city such as Nagpur.
(3) Regulating body temperature

Our body is mostly water. Our body temperature does not change too much as water in our body have to absorb (release) a large amount of energy to produce an increase (decrease) of body temperature. This is important to us because a stable body temperature is necessary for many biological processes in our body.

Question 129.

Soup egg noodles are often cooked using a very large bowl of soup, as shown on the picture. A large bowl of soup ensures its temperature does not fall much when noodles are put into it. Explain briefly why.
Question 130.

The diagram below shows the formation of sea breeze in day time. During day time, the temperature of land rises and becomes ____________ than the sea. The air above the land becomes hot and rise up. Then, ...


Question 131.

The diagram below shows the change of air temperature in HK. Sketch the variation of sea temperature.

```
Temperature / °C

29 26 23 20

Time / hr

Solid line: air temperature, dotted line: sea temperature
```

Question 132.

The diagram below shows the change of air temperature in Nagpur. Sketch the variation of land temperature.

```
Temperature / °C

29 26 23 20

Time / hr

Solid line: air temperature, dotted line: sea temperature
```
Chapter 4 - Heat Transfer by Conduction

Conduction, convection and radiation are three major processes of heat transfer. In this chapter, we will talk about conduction.

4.1 Energy transfer by conduction

When one end of a metal rod is heated, the heat energy is slowly transferred to the other end of the rod. The heat is transferred by means of conduction, due to energy exchange between hot and cold areas, through the particle collisions.

Different substances have different heat conductivity. Those substances that conduct heat efficiently are called good heat conductors while those conduct heat poorly are called heat insulators.

The following experiment compares the heat conductivity of different metals.

Source: Physics at Work (Oxford) - Comparing heat conductivity of different materials
If the rods have the same diameter, then the one that has the drawing pins falling down first has the highest heat conductivity.

The following table shows the relative conductivity of various materials. In general, conductivity of metal is higher.

<table>
<thead>
<tr>
<th>Material</th>
<th>Heat Conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver</td>
<td>429</td>
</tr>
<tr>
<td>Copper</td>
<td>338</td>
</tr>
<tr>
<td>Aluminium</td>
<td>237</td>
</tr>
<tr>
<td>Iron</td>
<td>80</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>15.2</td>
</tr>
<tr>
<td>Glass</td>
<td>1</td>
</tr>
<tr>
<td>Water</td>
<td>0.6</td>
</tr>
<tr>
<td>Plastic (various)</td>
<td>0.2</td>
</tr>
<tr>
<td>Foam</td>
<td>0.03</td>
</tr>
<tr>
<td>Wood (various)</td>
<td>0.15</td>
</tr>
<tr>
<td>Foam (polystyrene)</td>
<td>0.03</td>
</tr>
<tr>
<td>Air</td>
<td>0.03</td>
</tr>
</tbody>
</table>

In the following experiment, the ice at the bottom of the boiling tube does not melt. Water does not conduct heat to the bottom very well. The experiment shows that water is a poor heat conductor.
Question 133.
A boiling tube of water is heated over a Bunsen flame as shown on the last page. The ice at the bottom of the does not melt. What does it tell you about the conductivity of water? Explain your answer briefly.

Question 134.
In Chinese cuisine, hot pot is sometimes dished with ceramic pot. You may have seen the hot pot keeps boiling for some time when it is tabled. What does this observation tell you about the conductivity of ceramic? Is its conductivity high or low? Explain your answer briefly.

Question 135.
Refer to the diagram below. Compare the conductivity of materials A, B, C and D.

An experiment is set up to find out which metal is the best conductor of heat. Balls are stuck with wax to rods made from different metals, as shown in diagram X. The rods are heated at one end. Some of the balls fall off, leaving some as shown in the diagram Y.

Source:
4.2 Microscopic explanation of heat conduction

When one end of a metal rod is heated, energy is transferred from the hot flame to the metal particles at this end. The average kinetic energy of those particles increases. So, these particles at the hot end vibrate faster than those at the cold end. These faster vibrating particles collide with their neighbouring slower particles and transfer their kinetic energies to them.

_Microscopically, by particle collision, kinetic energy of the more energetic particles is transferred from the hot end of the rod to the other. _Macroskopically, heat is conducted from the hot end to the cold end._

In metals, there are also _free electrons_ that also help the conduction of heat. As the free electrons are free to travel inside the metal body, these energetic electrons from the hot end may _travel to the cold end directly_, carrying with them their above-average kinetic energy.

When the energetic electrons collide with atoms or other electrons, they transfer part of their kinetic energy to them, and macroscopically, increase the temperature at that point. In this way, heat is conducted to the cold end at a higher rate. This explains why metals are good conductors of heat.
4.3 Examples of conduction and insulation

Birds and mammals are **warm-blooded**. They have *feather* and *hair* respectively to trap a layer of air over their body as a *heat insulator* to reduce conduction of body heat to the surroundings, and in this way, **reduce heat loss**.

Warm-blooded animals like mammals and birds living in cold climate, have *fur* and *specialized feather*, to trap a **thick** layer of air to reduce heat loss in cold weather condition.

---


Source: [https://metrouk2.files.wordpress.com/2014/11/ad_152748327-e1416837832439.jpg](https://metrouk2.files.wordpress.com/2014/11/ad_152748327-e1416837832439.jpg)

Specialized feathers of penguin are short with an under-layer of fine woolly down

Human beings also **put on clothes** to trap an extra layer of air over their body, as a way to keep body heat, and hence reduce heat loss to the surroundings.

Cooking utensils like cooking pots are made of metals, while their handles are made of insulators. Some cooking pots even have a sandwich design, with a layer of aluminium sandwich between two layers of stainless steel. The aluminium layer conducts the heat to all parts of the pot while the stainless steel outside layer provides strength and shiny outlook of the pot. *(Refer to the last question below)*
Question 136.

If we pour boiling water into a thick glass or a milk glass bottle, the glass often breaks. However, a thin glass does not break so easily. Explain briefly.

Question 137.

Explain why metal railing feels colder than a wooden railing even if they have the same temperature as the surroundings.

Source:
http://1.imimg.com/data/G/6/MY-1254661/stainless-steel-railing_10663295_250x250.jpg

Source:
http://thumbs.dreamstime.com/x/wooden-railing-22083311.jpg
Question 138.

Explain the function of the layer of fat under the skin (subcutaneous fat) of many animals, including mammals and birds, in terms of heat conduction.

Source:
http://blog.drseymourweaver.com/dermatology-blog/aging-effects-on-subcutaneous-fat-decreased-on-the-face-and-increased-on-the-belly/

Question 139.

Baled Alaska is a dessert made of ice cream placed on a slice of sponge cake and topped with meringue. The entire dessert is then placed in an extremely hot oven for just long enough to firm the meringue. Putting ice cream in the oven sound crazy but the ice-cream inside never melts. Explain why.

Question 140.

A 3-ply stew pot is claimed to allow even heat distribution. It is made of a layer of aluminium, sandwiched between two layers of stainless steel. Explain why the sandwich design may give an even heat distribution.


[END]
物理

被稱為自然科學之母，研究非生命體的基本現象，所建立的觀念、基本理論與知識，構成了其他科學的基礎。物理學研究宇宙的基本組成要素：即物質、能量、空間和時間的交互作用，研究由極小的粒子至極大的宇宙如何運作，作出解釋和預測。大學及大專學院之理科學系、工程學系及醫科等，都會考慮物理科的成績作為入學標準。修讀物理可從事的行業包括科學家、工程師、教師、天文台科學主任、醫生、科研中心技術人員等等。

物理學跟數學有很密切的關係。物理定律往往須要運用算式，代數或幾何學概念表達。然而，同學只須要有一般的數學能力已經足夠應付高中物理科。更重要是同學要有求知的態度，合理的語文能力和開放的心懷，從物理科的觀點理解世界。

新高中物理科課程涵蓋熱學，力學，波動學，電磁學，輻射學等部分。相比其他科目，物理科以多元化的表述形式理解及分析抽象概念，除以文字外，算式、圖像、圖表及列表等等都經常混合使用。於是，同學於不覺中學習了更有效的論述技巧，對以後的學習以至工作都有裨益。

除了以上提及的五個必修部分外，本校亦選定以下選修部分：「原子世界」及「能量和能源的使用」（課程提供的其他選修部分為「天文學和航天科學」及「醫學物理學」）。

新高中物理科的公開評核由公開考試和校本評核兩部分組成。略見於下表：

<table>
<thead>
<tr>
<th>(1) 公開考試</th>
<th>比重</th>
<th>時間</th>
</tr>
</thead>
<tbody>
<tr>
<td>試卷一 試題涵蓋必修部分</td>
<td>60%</td>
<td>兩小時三十分鐘</td>
</tr>
<tr>
<td>由甲・乙兩部分組成，甲部是多項選擇題，佔本科分數 21%；乙部由短題目、結構式題目和論述題組成，佔本科分數 39%。考生須回答試卷一的全部試題。</td>
<td></td>
<td></td>
</tr>
<tr>
<td>試卷二 試題涵蓋選修部分</td>
<td>20%</td>
<td>一小時</td>
</tr>
<tr>
<td>多項選擇題及結構式題目，涵蓋課程內四個選修課題，各佔本科分數 10%，考生須從四個選修課題中選答其中兩個選修課題的試題。</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(2) 校本評核

實驗有關作業 - 指物理科的實驗工作和探究研習。中五和中六期問，教師會就考生進行實驗和報告撰寫這兩個能力範圍進行評核。

20%

伸延閱讀：
● 教育局 http://334.edb.hkedcity.net/EN/curriculum.php
● 學友社 http://www.student.hk/s4_subject_choice/curriculum/subject/phy.php
● 維基百科(物理) http://zh.wikipedia.org/wiki/%E7%89%A9%E7%90%86

76
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers / Hints</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>objective, temperature, thermometer</td>
</tr>
<tr>
<td>2.</td>
<td>Hotter</td>
</tr>
<tr>
<td>3.</td>
<td>Colder</td>
</tr>
<tr>
<td>4.</td>
<td>the same as</td>
</tr>
<tr>
<td>5.</td>
<td>D</td>
</tr>
<tr>
<td>6.</td>
<td>-40, 17.8, 32, 37, 212</td>
</tr>
<tr>
<td>7.</td>
<td>98.6°F</td>
</tr>
<tr>
<td>8.</td>
<td>24, 76</td>
</tr>
<tr>
<td>9.</td>
<td>37°C</td>
</tr>
<tr>
<td>10.</td>
<td>428°F</td>
</tr>
<tr>
<td>11.</td>
<td>204°C</td>
</tr>
<tr>
<td>12.</td>
<td>-459.4, -32, 32, 37, 212</td>
</tr>
<tr>
<td>13.</td>
<td>0°C</td>
</tr>
<tr>
<td>14.</td>
<td>100°C</td>
</tr>
<tr>
<td>15.</td>
<td>0°C, 100°C</td>
</tr>
<tr>
<td>16.</td>
<td>ice point, 0, steam point, 100</td>
</tr>
<tr>
<td>17.</td>
<td>reproducible</td>
</tr>
<tr>
<td>18.</td>
<td>unmarked, melting ice, boiling, length, 100, 1°C</td>
</tr>
<tr>
<td>19.</td>
<td>7.9 cm</td>
</tr>
<tr>
<td>20.</td>
<td>162°C</td>
</tr>
<tr>
<td>21.</td>
<td>10.8 cm</td>
</tr>
<tr>
<td>22.</td>
<td>28.6°C</td>
</tr>
<tr>
<td>23.</td>
<td>A, C and F</td>
</tr>
<tr>
<td>24.</td>
<td>mercury column, bore, stem, bulb</td>
</tr>
<tr>
<td>25.</td>
<td>fixed</td>
</tr>
<tr>
<td>26.</td>
<td>close, arranged / packed, volume, shape</td>
</tr>
<tr>
<td>27.</td>
<td>separated / far away, fixed, fixed</td>
</tr>
<tr>
<td>28.</td>
<td>D</td>
</tr>
<tr>
<td>29.</td>
<td>A</td>
</tr>
<tr>
<td>30.</td>
<td>2.15 cm³, 2.35 cm³, 13.3 cm, 16.1 cm</td>
</tr>
<tr>
<td>31.</td>
<td>Absolute zero, -273</td>
</tr>
<tr>
<td>32.</td>
<td>Average</td>
</tr>
<tr>
<td>33.</td>
<td>0, 273, 300, 310, 100</td>
</tr>
<tr>
<td>34.</td>
<td>A</td>
</tr>
<tr>
<td>35.</td>
<td>A straight line graph through -273°C on the temperature axis</td>
</tr>
<tr>
<td>36.</td>
<td>~-270°C</td>
</tr>
<tr>
<td>37.</td>
<td>gravitational potential energy</td>
</tr>
<tr>
<td>38.</td>
<td>kinetic Energy</td>
</tr>
<tr>
<td>39.</td>
<td>top-right: {High PE, High KE}, bottom left: {Low PE, Low KE}, {Low PE, High KE}</td>
</tr>
<tr>
<td>40.</td>
<td>internal, larger</td>
</tr>
<tr>
<td>41.</td>
<td>sum</td>
</tr>
<tr>
<td>42.</td>
<td>temperature, solid, gas, potential</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>62.</td>
<td>KE, PE, KE, PE</td>
</tr>
<tr>
<td>63.</td>
<td>D</td>
</tr>
<tr>
<td>64.</td>
<td>Left column: More, More, Less, Right column: Less, Less, More, Blanks: iron, iceberg</td>
</tr>
<tr>
<td>69.</td>
<td>1800 J</td>
</tr>
<tr>
<td>70.</td>
<td>111000 J</td>
</tr>
<tr>
<td>71.</td>
<td>2700000 J</td>
</tr>
<tr>
<td>72.</td>
<td>247000 J</td>
</tr>
<tr>
<td>73.</td>
<td>71750 J</td>
</tr>
<tr>
<td>83.</td>
<td>Mass</td>
</tr>
<tr>
<td>84.</td>
<td>(a)1500J (b) 75s</td>
</tr>
<tr>
<td>85.</td>
<td>(a)15°C (b) there is heat loss to the surroundings</td>
</tr>
<tr>
<td>86.</td>
<td>840 J°C(^{-1})</td>
</tr>
<tr>
<td>87.</td>
<td>4200 J°C(^{-1})</td>
</tr>
<tr>
<td>88.</td>
<td>1800 J°C(^{-1})</td>
</tr>
<tr>
<td>89.</td>
<td>900 J°C(^{-1})</td>
</tr>
<tr>
<td>93.</td>
<td>5040J</td>
</tr>
<tr>
<td>94.</td>
<td>C</td>
</tr>
<tr>
<td>95.</td>
<td>521 Jkg(^{-1})C(^{-1}), 1000 Jkg(^{-1})C(^{-1}), 3125 Jkg(^{-1})C(^{-1})</td>
</tr>
<tr>
<td>96.</td>
<td>B</td>
</tr>
<tr>
<td>97.</td>
<td>420</td>
</tr>
<tr>
<td>98.</td>
<td>1102.5W</td>
</tr>
</tbody>
</table>
List of equations and formulae

Temperature conversion between different scales

\[ C = \frac{5}{9}(F - 32) \quad \text{or} \quad F = \frac{9}{5}C + 32 \quad \text{Equation (1)} \]

\[ K = ^\circ C + 273 \quad \text{Equation (4)} \]

Thermometer Reading

\[ X = \frac{L_X - L_0}{L_{100} - L_0} \times 100 \, ^\circ C \quad \text{Equation (2)} \]

\[ \text{slope} = \frac{L_T - L_0}{T} \quad \text{OR} \quad \frac{L_{100} - L_0}{100} \quad \text{Equation (3)} \]

Power and Heat supplied

\[ Q = Pt \quad \text{Equation (5)} \]

Heat Capacity (of an object)

\[ Q = C\Delta T \quad \text{Equation (6)} \]

\[ C = \frac{Q}{\Delta T} \quad \text{Equation (7)} \]

Specific Heat Capacity (of a pure substance)

\[ C = \frac{\text{Heat Capacity}}{\text{mass}} = \frac{Q}{m \Delta T} \quad \text{Equation (8)} \]

\[ Q = mc\Delta T \quad \text{Equation (9)} \]

Mixing – by Conservation of Energy

Heat loss by hot object(s) = heat gain by cold object(s) \[ \text{Equation (10)} \]