Specific Heat of Aluminum

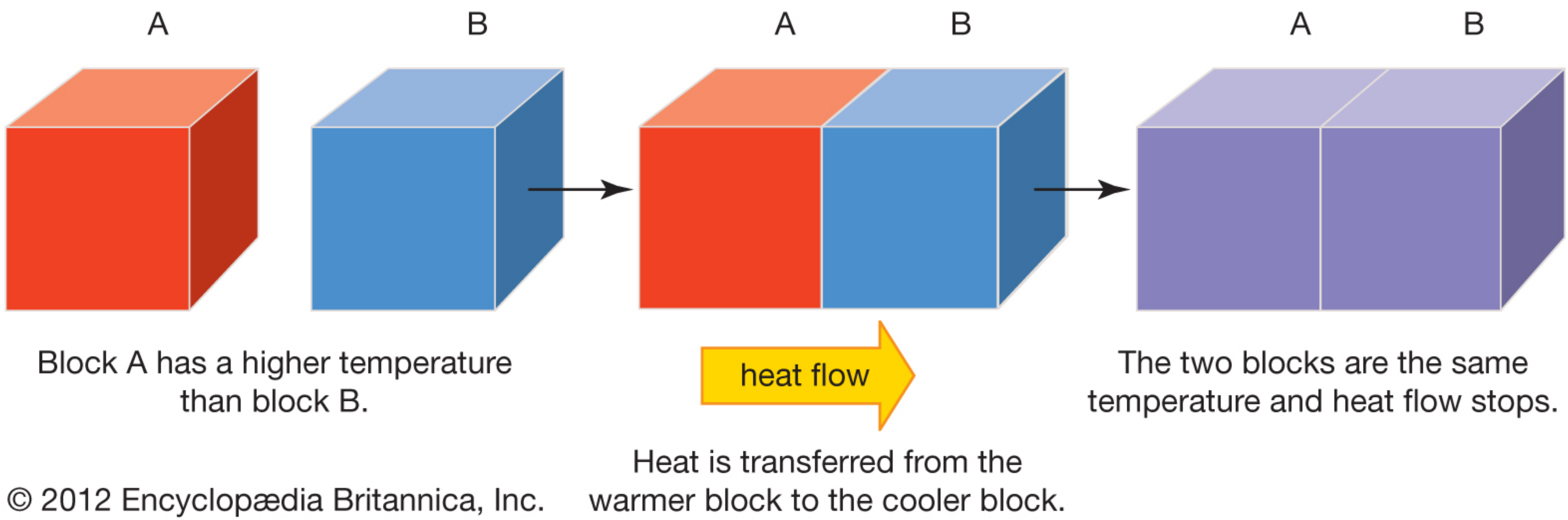
Experiment #3

PHYSIC 182 - Summer 2020

Dept. of Physics

UMASS Boston

Exp. 3 - Introduction: Heat Transfer



$$\underset{\text{Change in Heat}}{\Delta Q} = \overset{\text{Mass}}{m} c \underset{\text{Change in Temperature}}{\Delta T}$$

c = **Specific Heat Capacity:**

Amount of heat energy (calories) required to raise **1g** of a material by **1˚C**

On a Close System Heat is conserved

$$heat\ lost\ by\ Al = heat\ gained\ by\ water$$

Which we can write as :

$$-\Delta Q_{Aluminum} = \Delta Q_{water}$$

Replacing the identity of change in heat:

$$-m_{Al}C_{Al}\left(T_{f,Al} - T_{i,Al}\right) = m_w C_w \left(T_{f,w} - T_{i,w}\right)$$

Finally, Solving for the specific heat of Aluminum:

$$C_{Al} = -\frac{m_w C_w \left(T_{f,w} - T_{i,w}\right)}{m_{Al}\left(T_{f,Al} - T_{i,Al}\right)}$$

Exp. 3 - Specific Heat of Aluminum

General Procedure:

- Collect a set of mass measurements on Al cube
- Collect a set of temperature measurements*
- Hang Al cube in boiling water (and wait)
- Record mass** and temperature of cup of water
- (Quickly) transfer the hot cube to the water cup
- Monitor the temperature until it peaks
- Record this peak: this is the final temperature

* This set of measurements is used only to quantify the precision of the thermometers that were used

** Two measurements: empty then filled with water

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Exp. 3 - Initial Sets of Measurements

	A	B	C	D	E	F	G	H	I
1	m_{al}		T		m_{cup}	$T_{i,w}$	ΔT_w	$\bar{c}_{Al,exp}$	$\bar{c}_{Al,acc}$
2	(g)		(°C)		(g)	(°C)	(°C)	(cal/(g°C))	(cal/(g°C))
3	43.50		23.1		7.4	22.2			0.215
4	43.55		23.3		m_{cup+w}	$T_{i,Al}$	$S_{\Delta Tw}$	$S_{\bar{c}\_Al,exp}$	$\bar{c}_w$
5	43.70		23.1		(g)	(°C)	(°C)	(cal/(g°C))	(cal/(g°C))
6	43.50		23.5		99.1	**100**			0.99823
7	43.65		23.2		m_w	T_f	ΔT_{Al}		
8					(g)	(°C)	(°C)	Reported Value	%diff
9						29.6		______ ± ______	
10					S_{m_w}		$S_{\Delta T\_Al}$		
11					(g)		(°C)		
12									

Example Dataset

Set of thermometer measurements (<u>outside experiment</u>)

Set of mass measurements of the aluminum cube

1D Stats will be done on each set which will yield experimental results (Mean & Standard Error) while also providing a measure of the <u>precision</u> of each instrument (<u>standard deviation</u>)

Exp. 3 - Initial Sets of Measurements

	A	B	C	D
1	m_{al}		T	
2	(g)		(°C)	
3	43.50		23.1	
4	43.55		23.3	
5	43.70		23.1	
6	43.50		23.5	
7	43.65		23.2	
8				
9				
10				
11				
12				

Run 1D Stats

Ctrl+Shift+D

	A	B	C	D
1	m_{al}	N	T	N
2	(g)	5	(°C)	5
3	43.50	$\bar{m}_{Al}$	23.1	$\bar{T}$
4	43.55	(g)	23.3	(°C)
5	43.70	####	23.1	####
6	43.50	S_m	23.5	S_T
7	43.65	(g)	23.2	(°C)
8		####		####
9		$S_{\bar{m}\_Al}$		$S_{\bar{T}}$
10		(g)		(°C)
11		####		####
12				

These two describe the Aluminum cube: $m_{Al} = \bar{m}_{Al} \pm S_{\bar{m}_{Al}}$

Standard deviations can be used to describe instrument precision:

If single measurements for mass (7.4g) & temp. (22.2°C) were made with the same equipment then each can be reported as:

$$m = (7.4 \pm S_m)\ g \qquad T = (22.2 \pm S_T)\ °C$$

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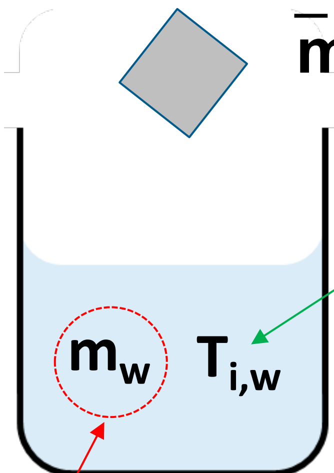
Exp. 3 - Experimental Measurements

Aluminum cube left in continually boiling water long enough to assume it has reached the same temperature.

$T_{i,Al} = 100^\circ C$



$\bar{m}_{Al}$

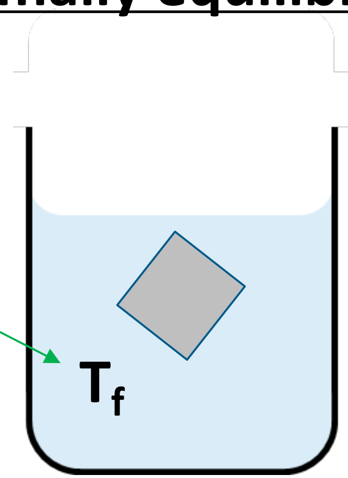
Given Data

Hot aluminum cube placed in water at room temperature and allowed to <u>thermally equilibrate.</u>

m_{cup}	$T_{i,w}$
(g)	( )
7.4	22.2
m_{cup+w}	$T_{i,Al}$
(g)	( )
99.1	**100**
m_w	T_f
(g)	( )
Needed	29.6

$$m_w = m_{cup+w} - m_{cup}$$

Needed   Given Data



<u>Same final temperature for water and aluminum.</u>

A quick word on errors

$$S_{something} = the\ error\ associated\ with\ \text{“}something\text{”}$$

For instance:

$$S_{m_{Al}} = error\ associated\ with\ the\ \ mass\ of\ Aluminum$$

For this Lab:

$$S_{m_{Al}} = S_{m_{cup+water}} = S_{m_{cup}}$$

And:

$$S_{T_{Al}} = S_{T_f} = S_{T_{i,w}}$$

Error YOU have to Calculate

$$S_{m_{water}} = error\ in\ the\ calculation\ of\ mass\ of\ water$$

$$S_{\Delta T_w} = erro\ in\ the\ change\ of\ temparatue\ of\ water$$

$$S_{c_{Al,exp}} = error\ of\ the\ experimental\ specific\ heat\ of\ Al$$

Exp. 3 - Excel Calculations/Analysis

	A	B	C	D	E	F	G	H	I
1	m_{al}	N	T	N	m_{cup}	$T_{i,w}$	ΔT_w	$\bar{c}_{Al,exp}$	$\bar{c}_{Al,acc}$
2	(g)	5	(°C)	5	(g)	(°C)	(°C)	(cal/(g°C))	(cal/(g°C))
3	43.50	$\bar{m}_{Al}$	23.1	$\bar{T}$	7.4	22.2	####	####	0.215
4	43.55	(g)	23.3	(°C)	m_{cup+w}	$T_{i,Al}$	$S_{\Delta Tw}$	$S_{\bar{c}\_Al,exp}$	$\bar{c}_w$
5	43.70	####	23.1	####	(g)	(°C)	(°C)	(cal/(g°C))	(cal/(g°C))
6	43.50	S_m	23.5	S_T	99.1	**100**	####	####	0.99823
7	43.65	(g)	23.2	(°C)	m_w	T_f	ΔT_{Al}		
8		####		####	(g)	(°C)	(°C)	**Reported Value**	**%diff**
9		$S_{\bar{m}\_Al}$		$S_{\bar{T}}$	####	29.6	####	______ ± ______	####
10		(g)		(°C)	S_{m_w}		$S_{\Delta T\_Al}$		
11		####		####	(g)		(°C)		
12					####		####		

Result: Specific Heat

$$c_{Al,exp} = \frac{m_w c_w \Delta T_w}{\bar{m}_{Al} \Delta T_{Al}}$$

$$S_{c_{Al,exp}} = c_{Al,exp} \sqrt{\left(\frac{S_{m_w}}{m_w}\right)^2 + \left(\frac{S_{\Delta T_w}}{\Delta T_w}\right)^2 + \left(\frac{S_{\bar{m}_{Al}}}{\bar{m}_{Al}}\right)^2 + \left(\frac{S_{\Delta T_{Al}}}{\Delta T_{Al}}\right)^2}$$

Each of these steps are shown in the manual

%-Difference:

~ 5 - 10%