GUEST LECTURE ON THERMOGRAPHY

Anti-Icing Materials International Laboratory: AMIL – UQAC
08th August 2023

Hassan Abbas Khawaja
Associate Professor
Research Group Leader of IR, Spectroscopy and Numerical Modelling Research Group
UNIVERSITY OF TROMSØ

AGENDA

- About me
- About my Research
- What is Multiphysics?
- UiT The Arctic University of Norway
- Poem from Robert Frost
- Thermography lecture (Main Focus)

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ABOUT ME

Research Group Leader, UiT, Norway (2015-)

Associate Professor, UiT, Norway (2014-)

Post-Doctorial Researcher, UiT, Norway(2012-2013)

Mphil and PhD, Cambridge, UK (2008-2012)

Bachelors in Aeropsace Engineering,
NUST, Pakistan (2002-2007)

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ABOUT MY RESEARCH

MULTIPHYSICS

FLUID MECHANICS

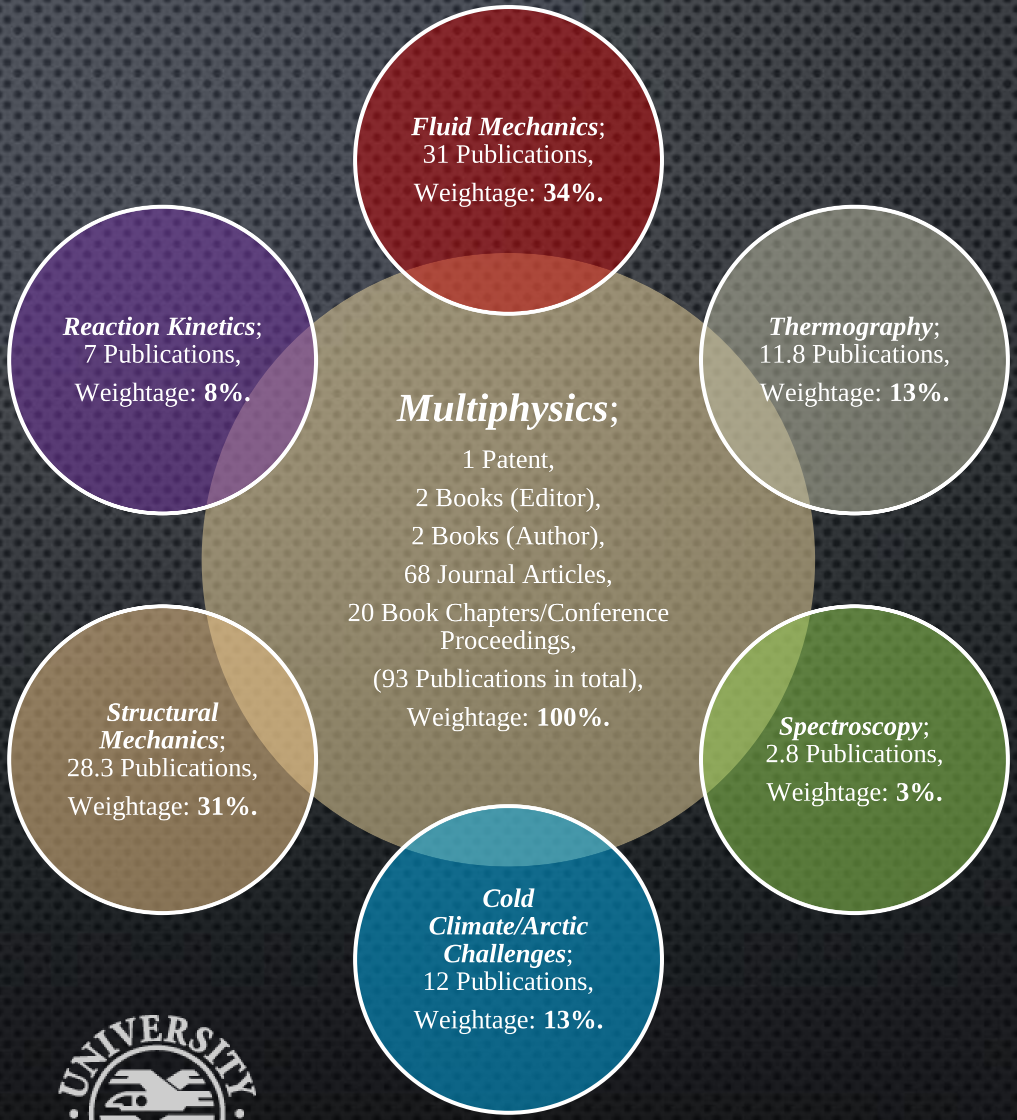
THERMOGRAPHY

SPECTROSCOPY

REACTION KINETICS

STRUCTURAL MECHANICS

COLD CLIMATE/ARCTIC CHALLENGES



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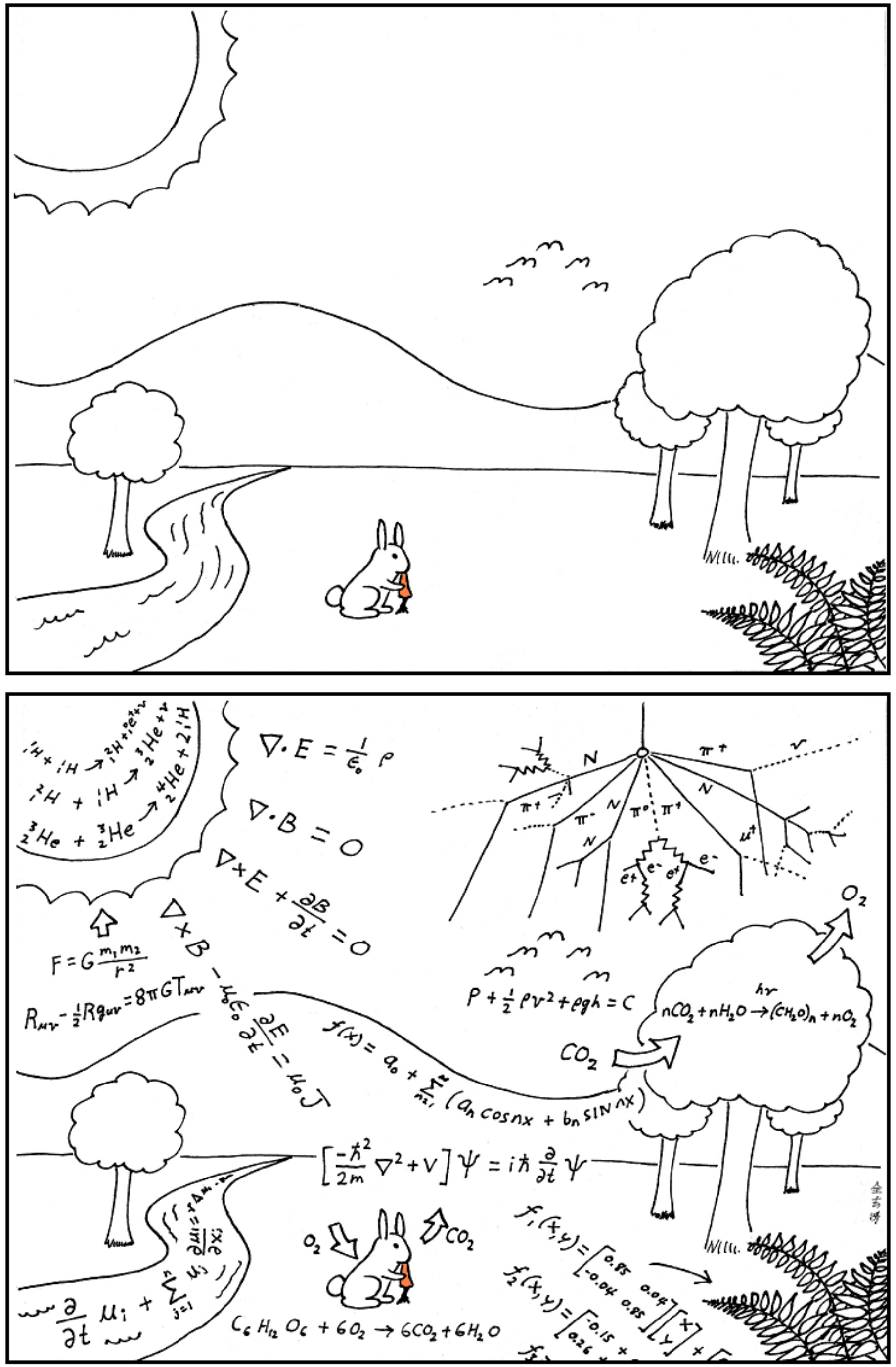
What is Multiphysics?

The International
Society of Multiphysics
www.multiphysics.org

The International
Conference of Multiphysics
www.multiphysics.org/connference

The international
Journal of Multiphysics
www.multiphysics.org/journal



This is how scientists see the world.

UIT THE ARCTIC UNIVERSITY OF NORWAY

4 CAMPUSES

70° NORTH (LATITUDE)

3500 STAFF (1700 ACADEMICS)

17000 STUDENTS

"The sun was warm but the wind was chill.

You know how it is with an April day.

When the sun is out and the wind is still,

You're one month on in the middle of May.

But if you so much as dare to speak,

a cloud come over the sunlit arch,

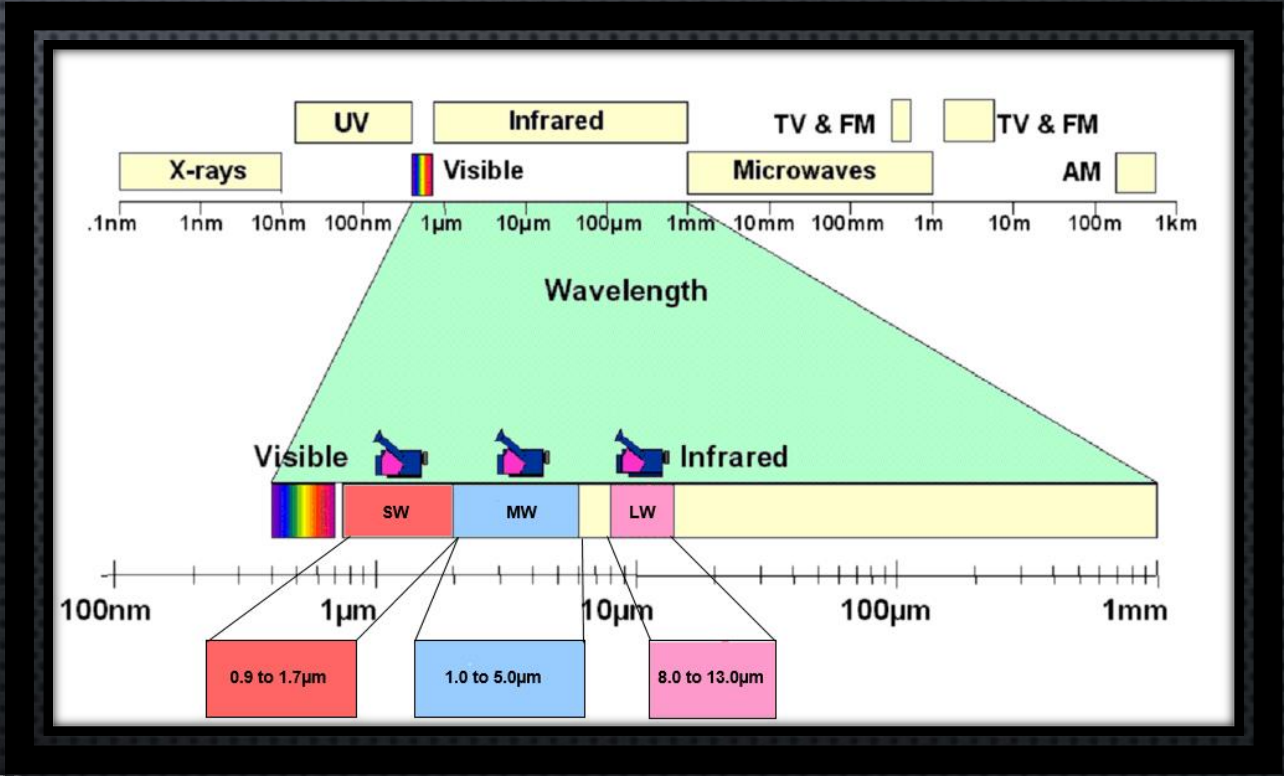
And wind comes off a frozen peak,

And you're two months back in the middle of March."

Robert Frost

INFRARED THERMOGRAPHY

- IR Thermography Requires IR Camera
    - Shortwave Infrared Camera (SW)
    - Midwave Infrared Camera (MW)
    - Longwave Infrared Camera (LW)



INFRARED CAMERA

- FLIR® T1030sc Camera Specifications
  - 1024 X 768 Thermal Pixels
  - High Speed Interface (30Hz, 120Hz, 480Hz)
  - NETD <20mK
  - LW Sprectral Range (7.5 -14 micrometer)
  - Uncooled Microbolometer Detector
  - Cost: Around 50,000 USD

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WORKING PRINCIPLE

- PLANK'S LAW

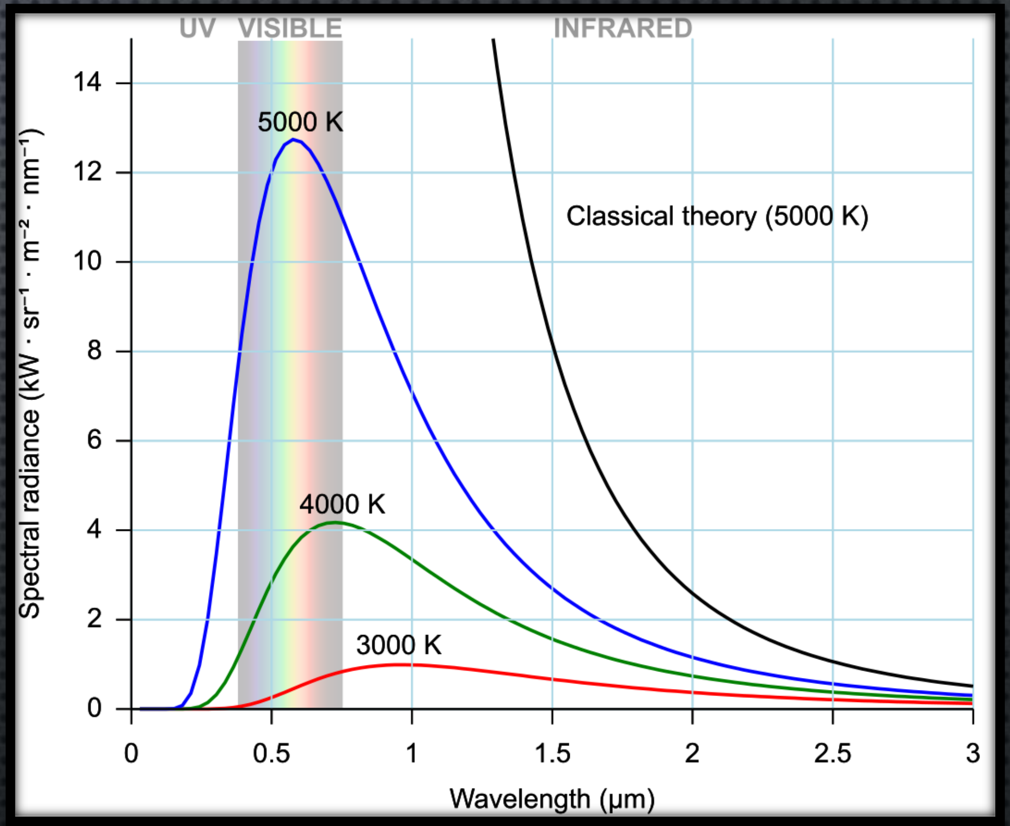
$$B_\lambda(kW.sr^{-1}.m^{-2}.nm^{-1}) = \frac{2hc^2}{\lambda^5}\frac{1}{e^{\frac{hc}{\lambda k_B T}}-1}$$

- WIEN'S LAW (DIFFERENTIATING PLANK'S LAW)

$$\lambda_{max}(\mu m) = \frac{2898}{T}$$

- STEFAN BOLTZMANN'S LAW (INTEGRATING PLANK'S LAW)

$$W(Watt.m^{-2}) = \epsilon\sigma T^4$$



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WORKING PRINCIPLE CONT.

- INFRARED RADIATION SOURCES (ABSORBTION/EMITTANCE, REFLECTION, & TRANSMISSION)

$$\alpha_\lambda + \varphi_\lambda + \tau_\lambda = 1 \quad \text{OR} \quad \varepsilon_\lambda + \varphi_\lambda + \tau_\lambda = 1$$

- BLACK BODY

$$\alpha_\lambda = \varepsilon_\lambda \quad \text{OR} \quad \epsilon_\lambda = 1$$

- GRAY BODY

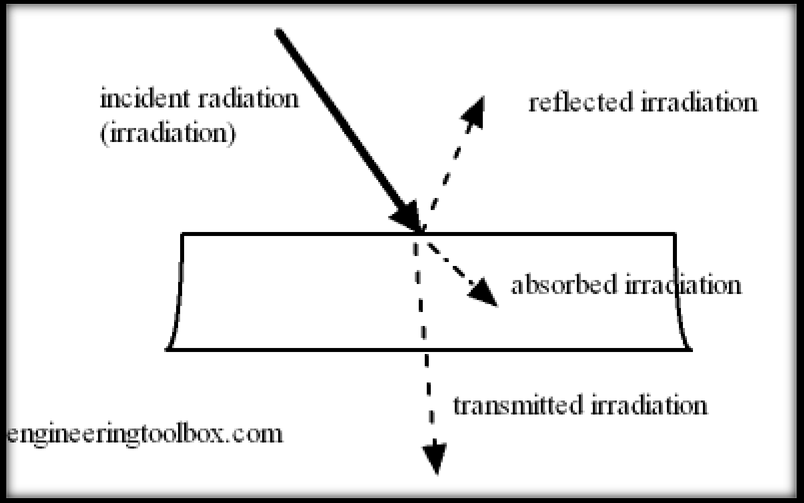
$$\epsilon_\lambda = \alpha_\lambda = constant$$

- WHITE BODY

$$\varphi_\lambda = 1$$

- REAL BODY

$$0 < \epsilon_\lambda/\alpha_\lambda < 1 \quad \text{AND} \quad 0 < \varphi_\lambda < 1 \quad \text{AND} \quad 0 < \tau_\lambda < 1$$



CASE 1: ICE THERMAL CONDUCTIVITY

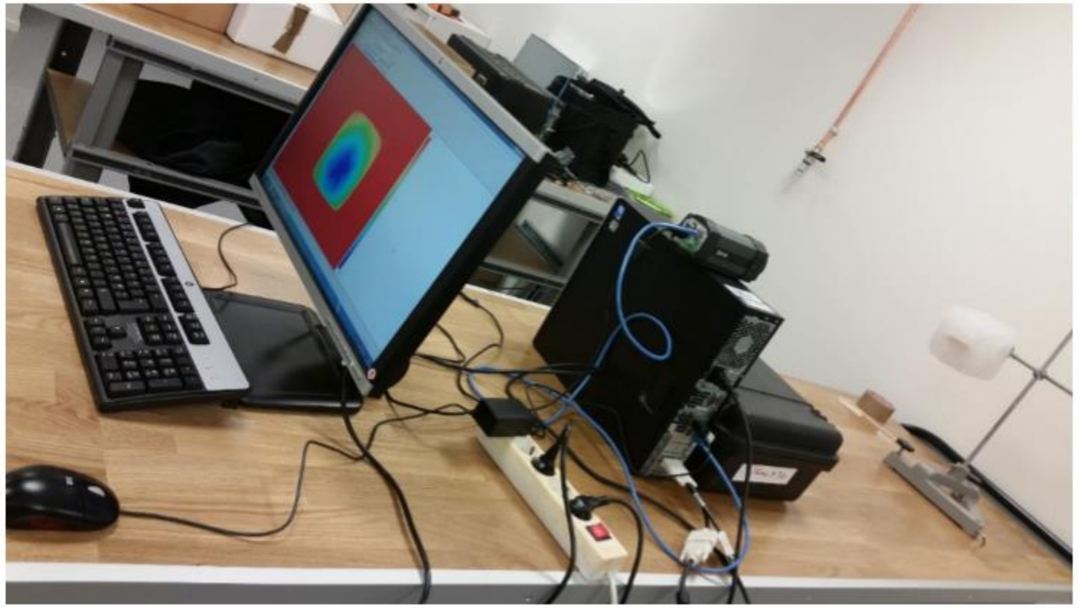


Figure 5: Actual Infrared Imaging Experiment Setup

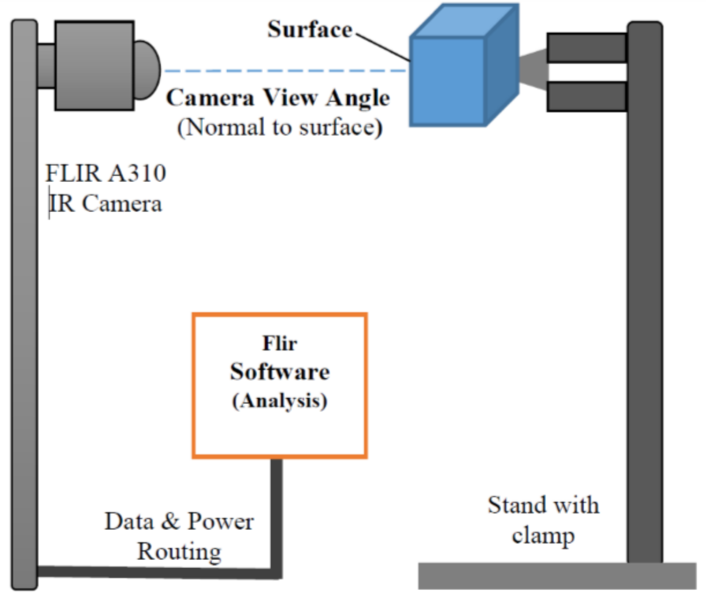


Figure 4: Infrared Imaging Experiment Schematics. Infrared camera is facing the surface of ice block [22, 23].

Case 1: Ice Thermal Conductivity cont.

- Thermal Diffusion is governed Heat Equation

$$\frac{\partial T}{\partial t} = \frac{k}{\rho c}\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right)$$

- Forward Time Central Space (FTCS) Discretization using Finite Difference Method can be used to solve the above equation.

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CASE 1: ICE THERMAL CONDUCTIVITY CONT.

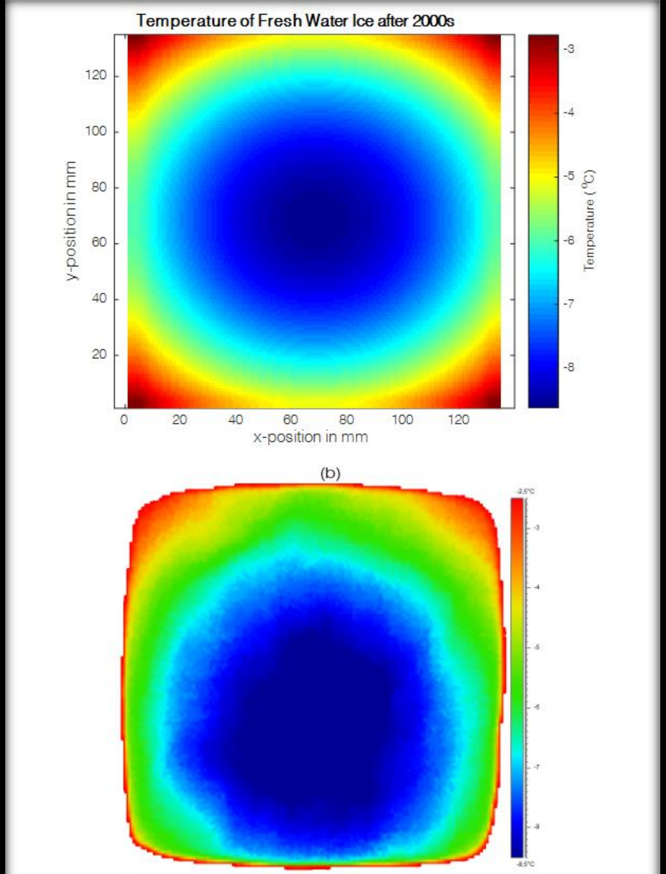


Figure 6: Variation in Temperature of the Fresh Water Ice Cube after 2000 s; (a) Finite Difference Method (MATLAB®); (b) False Infrared Image (A310 FLIR®)

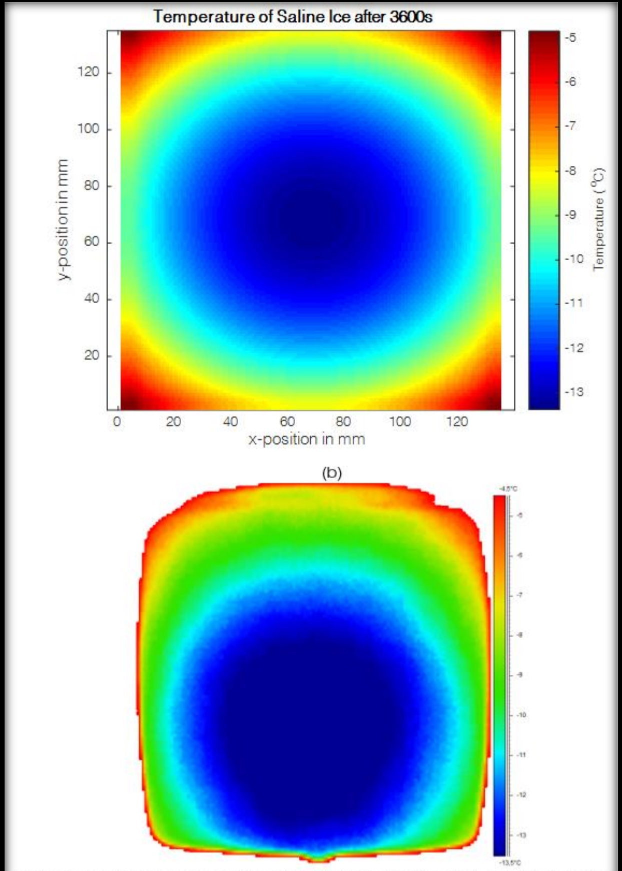
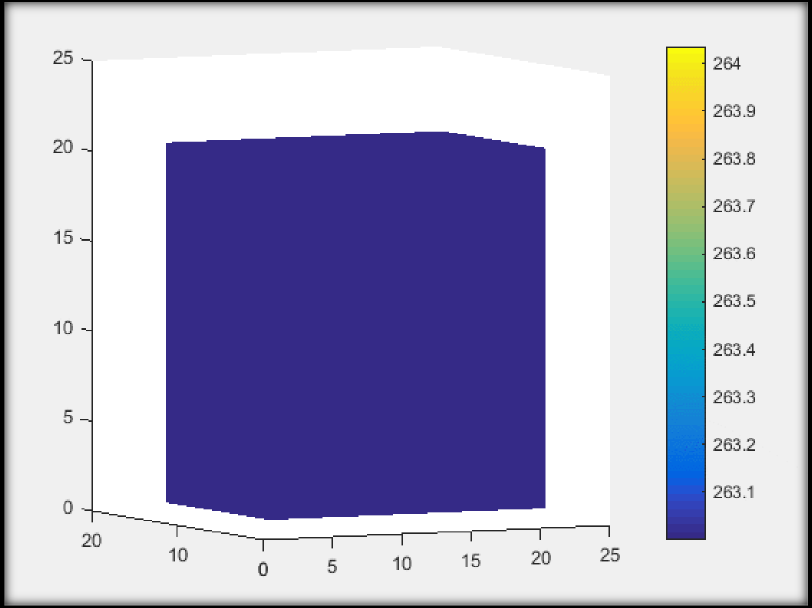
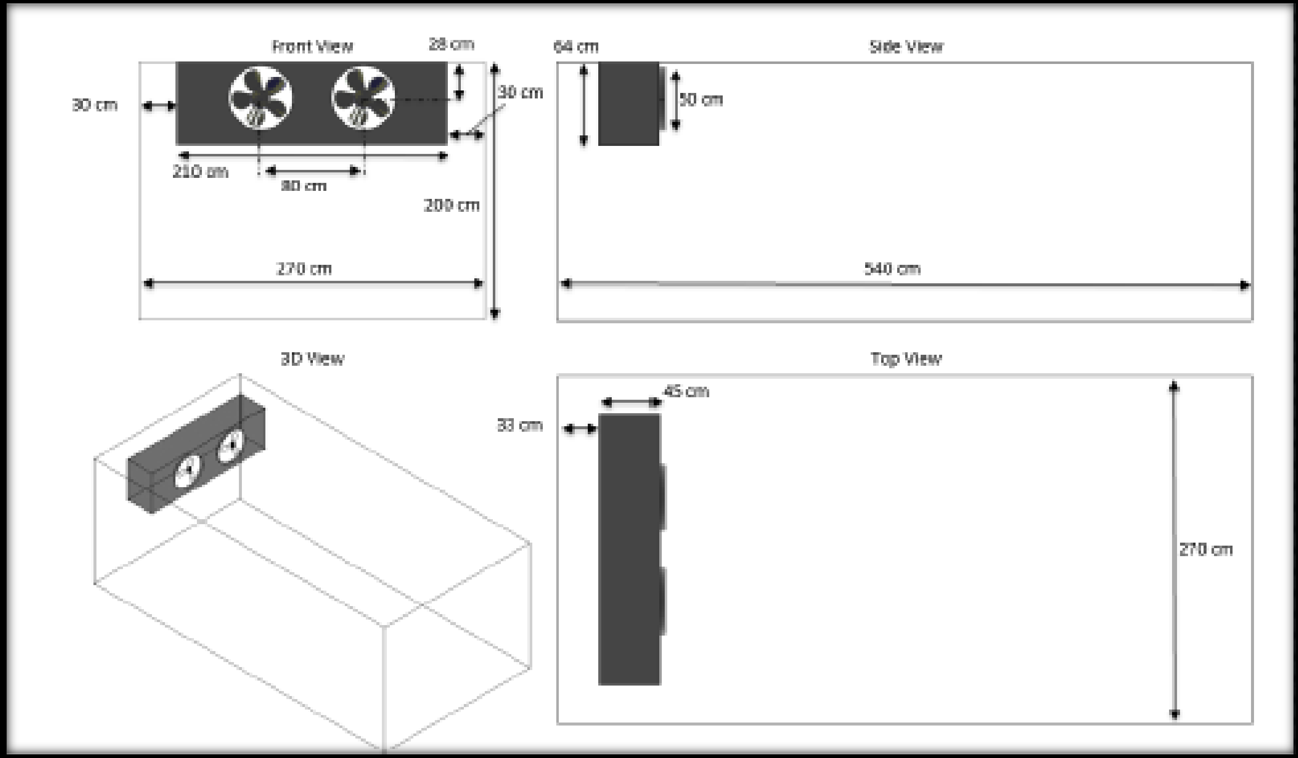


Figure 7: Variation in Temperature of the Saline Water Ice Cube after 3600s; (a) Finite Difference Method (MATLAB®); (b) False Infrared Image (A310 FLIR®)

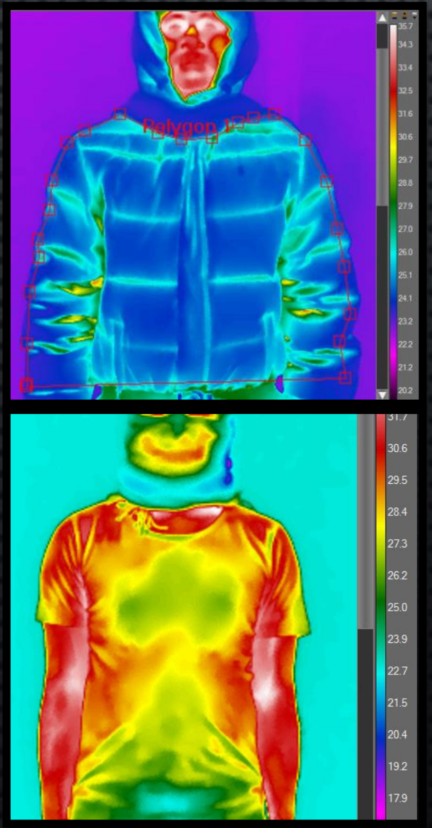


CASE 2: REQUIRED INSULATION (IREQ)

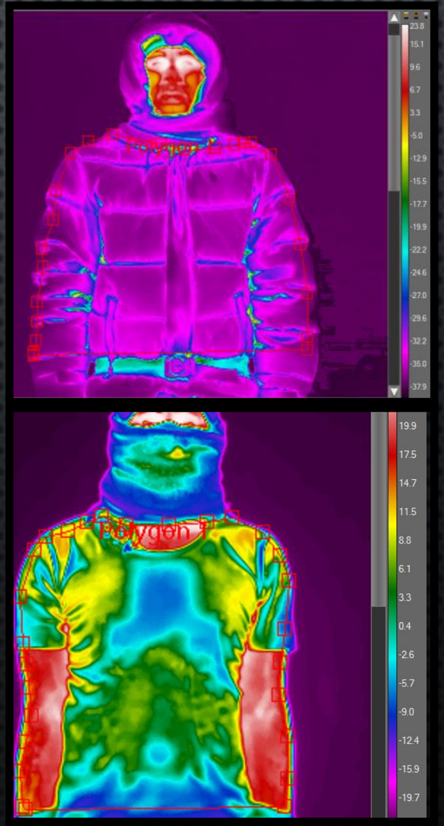


CASE 2: REQUIRED INSULATION (IREQ) CONT.

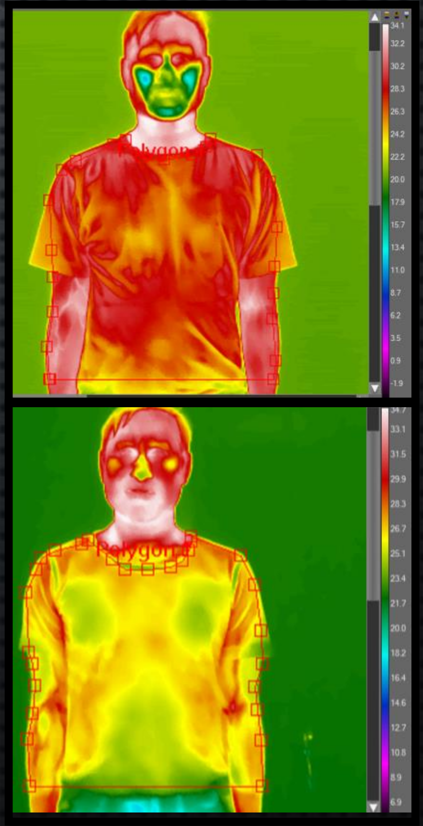
Before Cold Room



Insider Cold Room T_{cl}



After Cold Room T_{sk}



CASE 2: REQUIRED INSULATION (IREQ) CONT.

- Required Clothing Insulation (IREQ)

$$\frac{\bar{T}_{sk} - T_{cl}}{R + C} = IREQ$$

- IREQ Value of Winter Jacket ~ 390 Clo
- IREQ Value of Summer Jacket ~ 280 Clo
- IREQ Value of Sweater ~ 220 Clo
- IREQ Value of T-Shirt ~ 120 Clo

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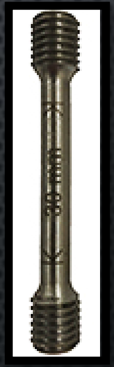
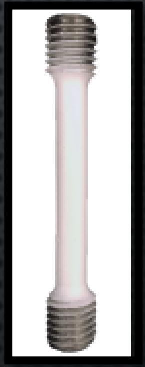
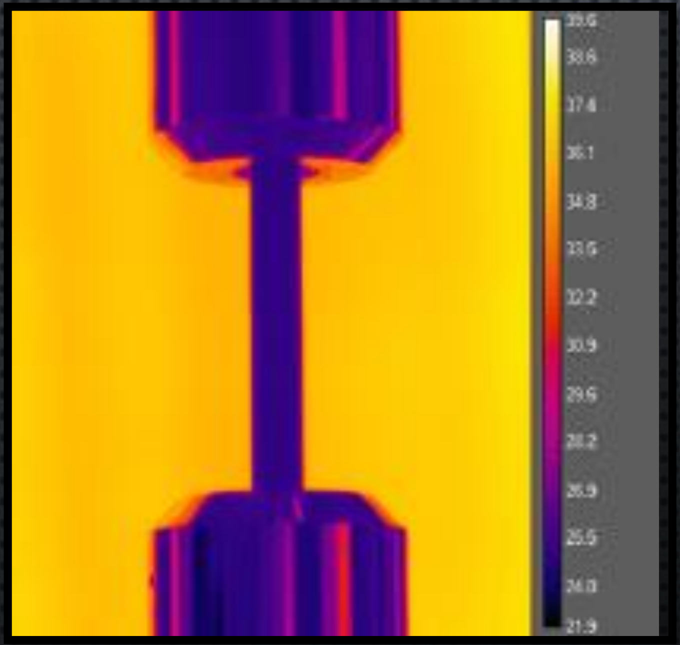
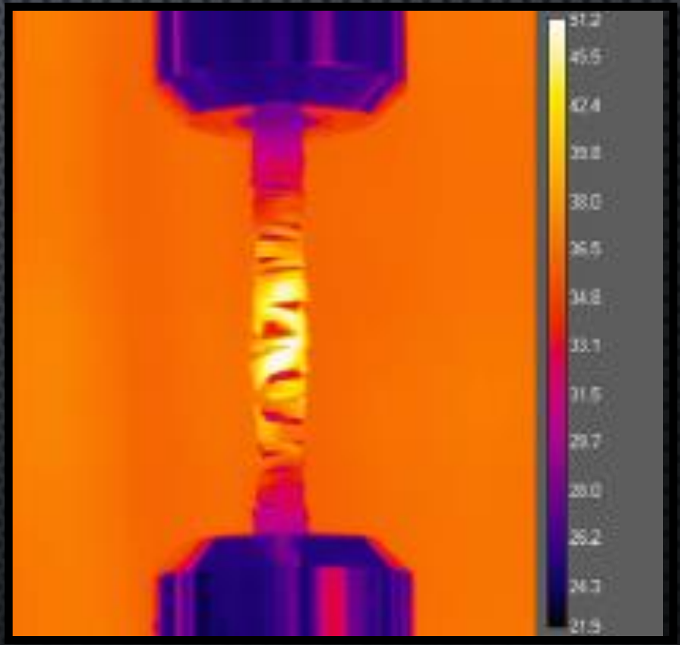
CASE 3: TENSILE TESTS OF STEEL SPECIMENS





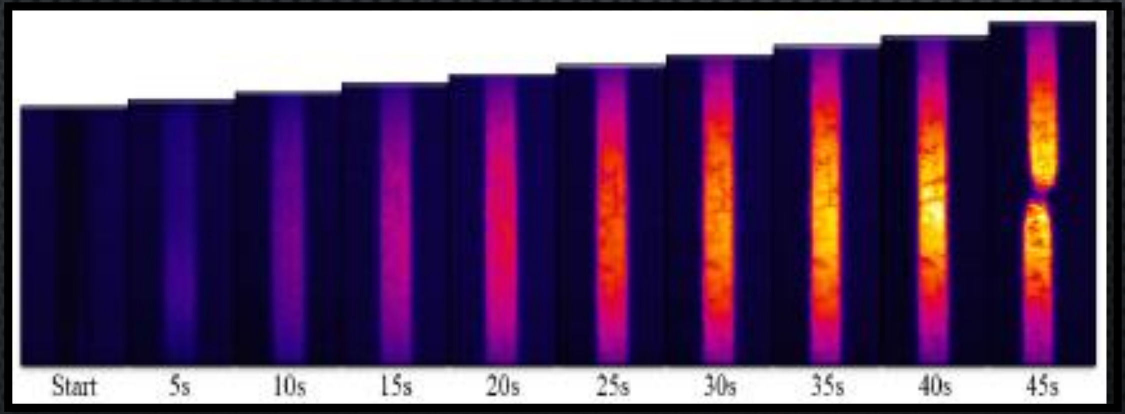
CASE 3: TENSILE TESTS OF STEEL SPECIMENS CONT.



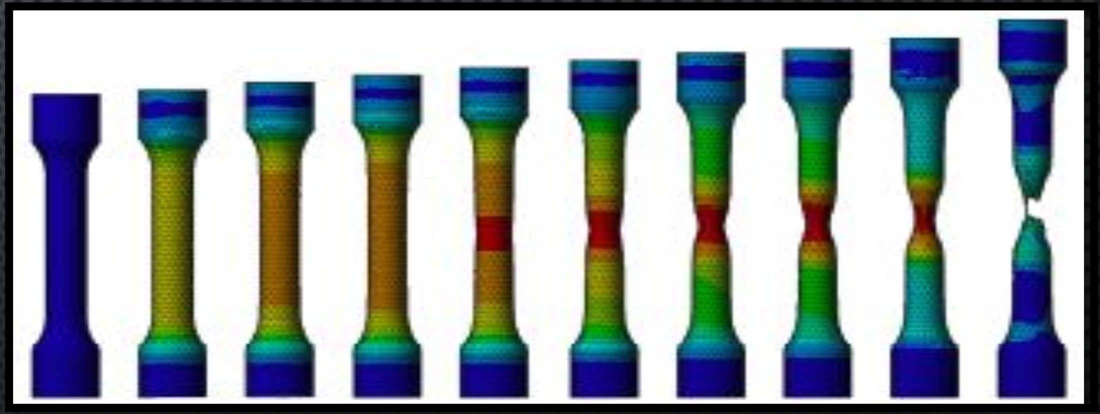


CASE 3: TENSILE TESTS OF STEEL SPECIMENS CONT.

Thermography



Finite Element Analysis



REFERENCES

Ahmad, Tanveer; Rashid, Taimur; Khawaja, Hassan Abbas; Moatamedi, Mojtaba. **Study of the required thermal insulation (IREQ) of clothing using infrared imaging.** The International Journal of Multiphysics 2017; Volum 11 (4). ISSN 1750-9548.s 413 - 426.s doi: 10.21152/1750-9548.11.4.413.

Rashid, Taimur; Khawaja, Hassan Abbas; Edvardsen, Kåre. **Determination of Thermal Properties of Fresh Water and Sea Water Ice using Multiphysics Analysis.** The International Journal of Multiphysics 2016; Volum 10 (3). ISSN 1750-9548.s 277 - 291.s doi: 10.21152/1750-9548.10.3.277.

FINDING ON DAY 1 (TEMP. AT NUCLEATION)