BEYOND THE CARNOT LIMIT: PERPETUAL HEAT FLOW IN GRAVITATIONAL AND ROTATIONAL NON-EQUILIBRIUM SYSTEMS

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AIM AND INTRODUCTION

- Aim: **To accelerate research into perpetual heat flow systems.**
- Growing commercial interest in partnering and funding further research into this topic.
- Please reach out if you are interested.

PERPETUAL HEAT FLOW SYSTEM DEFINITION

A perpetual heat flow system is a thermodynamic system in which a continuous internal flow of heat is maintained in a non-equilibrium steady state, induced by external acceleration fields—such as gravity or rotation—that generate and sustain stable temperature gradients within the system.

CAN A GRAVITATIONAL FIELD SUSTAIN A TEMPERATURE GRADIENT IN A MEDIUM?

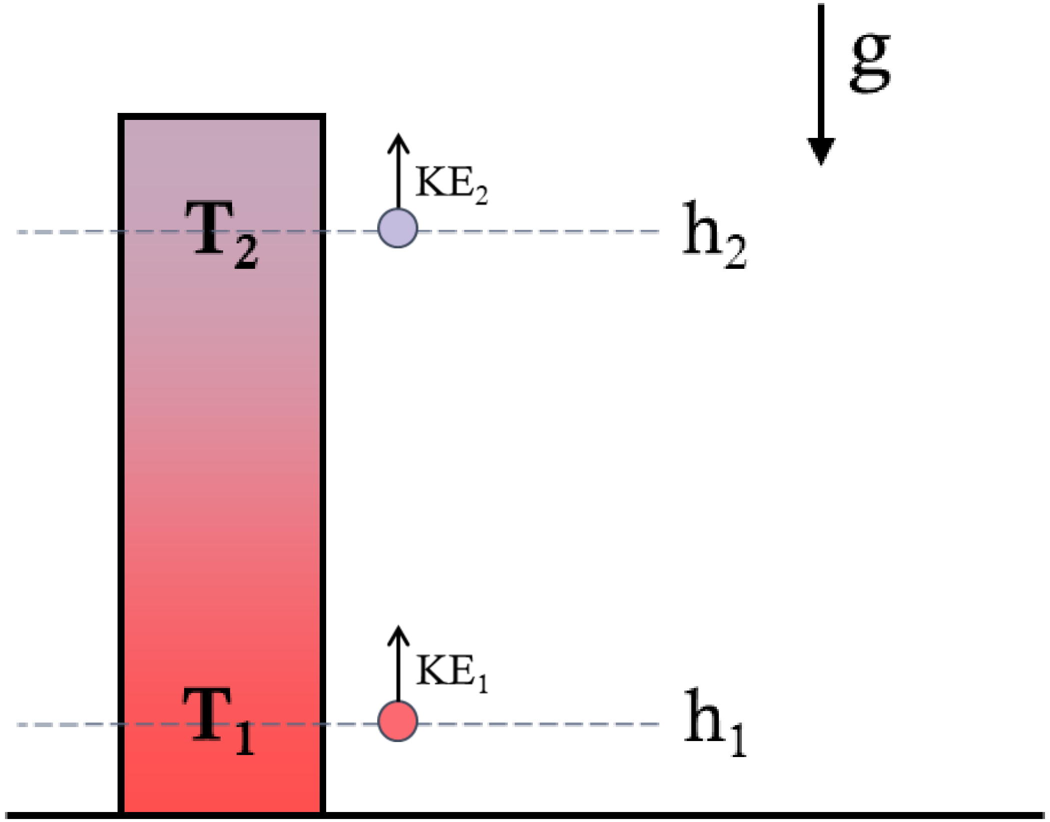

Fig. 1: Gravity and Temperature Concept

- Loschmidt proposed that gravity would induce a **stable temperature gradient in a gas**, as particle kinetic energy must decrease with height due to energy conservation.
- Maxwell claimed the **temperature of a gas must remain uniform** to be in thermal equilibrium.
- Maxwell assumed the gas column was a thermal reservoir, so internal gradients would enable work from a single reservoir — **violating classical interpretations of the second law**.
- Maxwell claimed solids exhibit uniform temperature at equilibrium, and therefore gases must too — otherwise, **connecting a gas and solid column could enable a continuous heat flow** and enable work extraction due to differing gradients.

EXPERIMENTAL EVIDENCE FOR GRAVITY INDUCED TEMPERATURE GRADIENTS

- Studies have measured temperature gradients in solid, liquid, and gas mediums under gravity – with the systems at a steady state with no net mass flow.
- Temperature gradients under gravity can be produced.
- Differing mediums produce differing temperature gradients under gravity.
- Hatsopoulos–Keenan framework generalises the second law to non-equilibrium conditions, permitting stationary non-equilibrium states; enables properties like temperature to vary with position, assuming no net mass flux and no entropy production.
- Under this framework, **gravity can sustain a temperature** gradient in a medium as a **stable non-equilibrium steady state, consistent with the second law.**
- Could mediums with different temperature gradients be connected to enable a perpetual heat flow?

Table 1: Experimental Results

Medium	Temperature Gradient
Water	0.04 $K{\cdot}m^{-1}$
Air-Sawdust mixture	2.2 $K{\cdot}m^{-1}$
Potassium Iodide	0.02 $K{\cdot}m^{-1}$

GRAVITATIONAL PERPETUAL HEAT FLOW SYSTEM CONCEPT

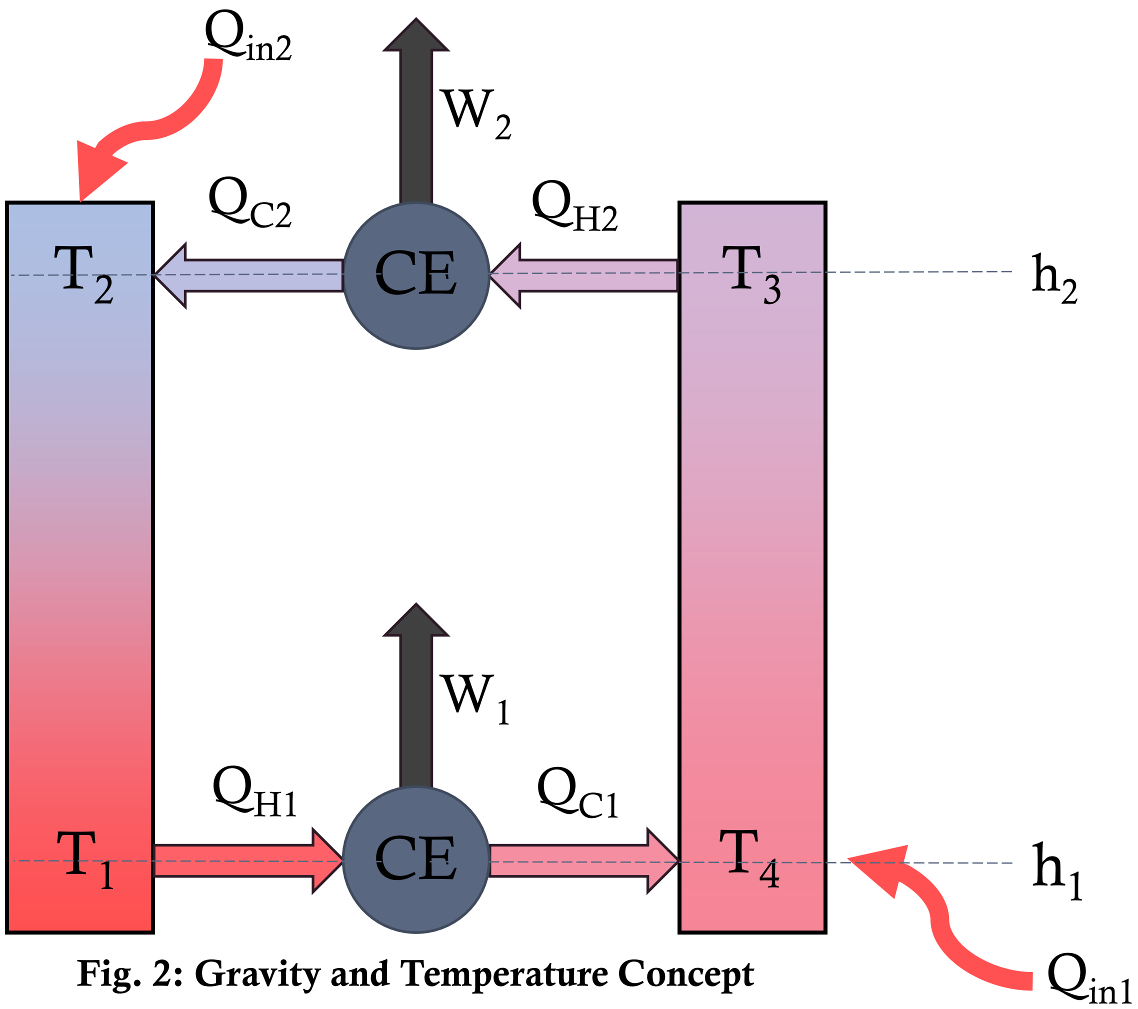

Fig. 2: Gravity and Temperature Concept

- **A first medium** has a temperature gradient under gravity such that $\mathbf{T_1 > T_2}$
- **A second medium** has a different temperature gradient under gravity such $\mathbf{T_4 > T_3}$
- At height h_1: $T_1 > T_4 \rightarrow$ heat flows from the first medium to the second.
- At height h_2: $T_3 > T_2 \rightarrow$ heat flows from the second medium to the first.
- Any heat returning to the first medium at h_2 being redistributed throughout the first medium to maintain the temperature gradient.
- **Heat engines** (CE) placed at h_1 and h_2 could **extract work** from the heat flowing between the two mediums.
- Simulated using existing models.

GRAVITY INDUCED TEMPERATURE GRADIENT MODELS

Equilibrium (classical thermodynamics — solids)

- Assumes a classical equilibrium system under gravity with:
  - **no net mass flow**
  - **no microscopic energy redistribution**
  - **no net heat or energy flux**
- Temperature gradient over a finite height arises from the balance of gravitational potential and internal thermal energy, resulting in a state of **maximum entropy** under gravity.

$$\frac{\Delta T}{\Delta h} = -\frac{(1+\alpha T)g}{C_p}$$

- Using thermal expansion coefficient, α, and specific heat capacity, C_p.
- Aligns well with experimental results for **solids**, where heat transfer is dominated by **lattice vibrations (phonons)** rather than particle motion.

Non-equilibrium (kinetic model — gases)

- Assumes a non-equilibrium steady state system under gravity, with:
  - **no net mass flow**
  - **microscopic energy redistribution**
- The temperature gradient over a finite height arises from balancing the **downward kinetic energy flux** Φ_{KE} induced by gravity, with the **upward conductive heat flux**, determined by the medium's thermal conductivity, k.

$$\frac{\Delta \mathrm{T}}{\Delta \mathrm{h}} \approx \frac{\Phi_{\mathrm{KE}}}{\mathrm{k}} \qquad where\ \Phi_{KE} = \frac{-cg^2M^2\rho_0}{6RT}$$

- Using molar mass, M, temperature, T, molecular speed, c, and molar density, ρ_0.
- Aligns well with experimental results for **gases-based systems**, where **molecular motion** dominates heat transfer.

SIMULATION VALIDATION: GRAVITATIONAL INDUCED TEMPERATURE GRADIENT

- 2D simulation uses Fourier's Law with an added gravitational temperature gradient term: $\Delta \boldsymbol{T}_{\boldsymbol{g}} = \frac{\boldsymbol{\Delta T}}{\boldsymbol{\Delta h}}$
- Classical thermodynamic model applied to solids; non-equilibrium kinetic model applied to gases.

$$\boldsymbol{q} = \frac{[\boldsymbol{k}(\boldsymbol{T}_1 - \boldsymbol{T}_2) - \Delta \boldsymbol{T}_{\boldsymbol{g}} \boldsymbol{d}]}{\boldsymbol{d}}$$

- Validation through replication of experimental results.
- Insulated medium divided into 1 m^2 segments, initially at 300 K.
- System evolved to a steady-state with a gravity-induced temperature gradient, and balanced internal heat flux (Fig 3).
- Results match prior experimental data (Table 2).

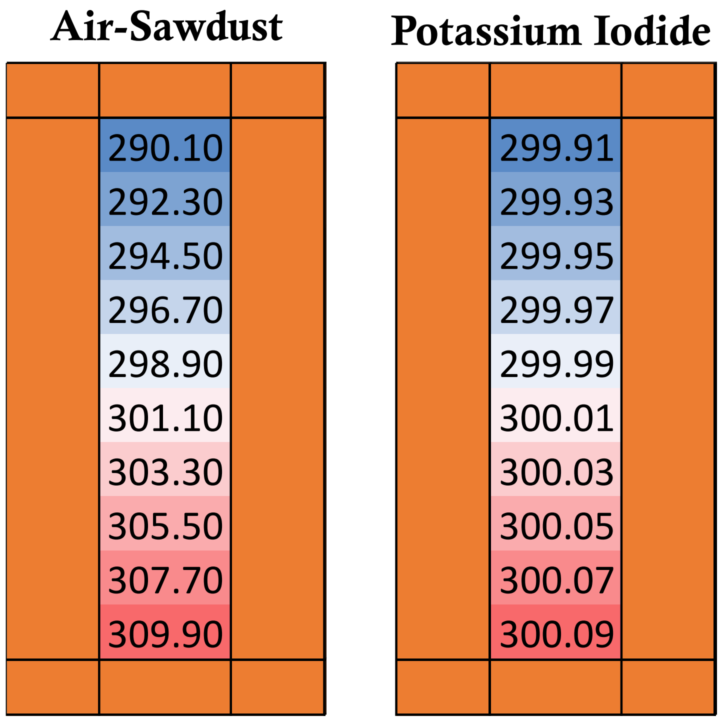

Fig. 3: Simulation Single Column Validation

Table 2: Simulation and Prior Research Comparison

		Air-Sawdust		Potassium Iodide
Prior Research		2.2 $K \cdot m^{-1}$		0.02 $K \cdot m^{-1}$
Simulation		2.2 $K \cdot m^{-1}$		0.02 $K \cdot m^{-1}$

GRAVITATIONAL PERPETUAL HEAT FLOW SYSTEM SIMULATION

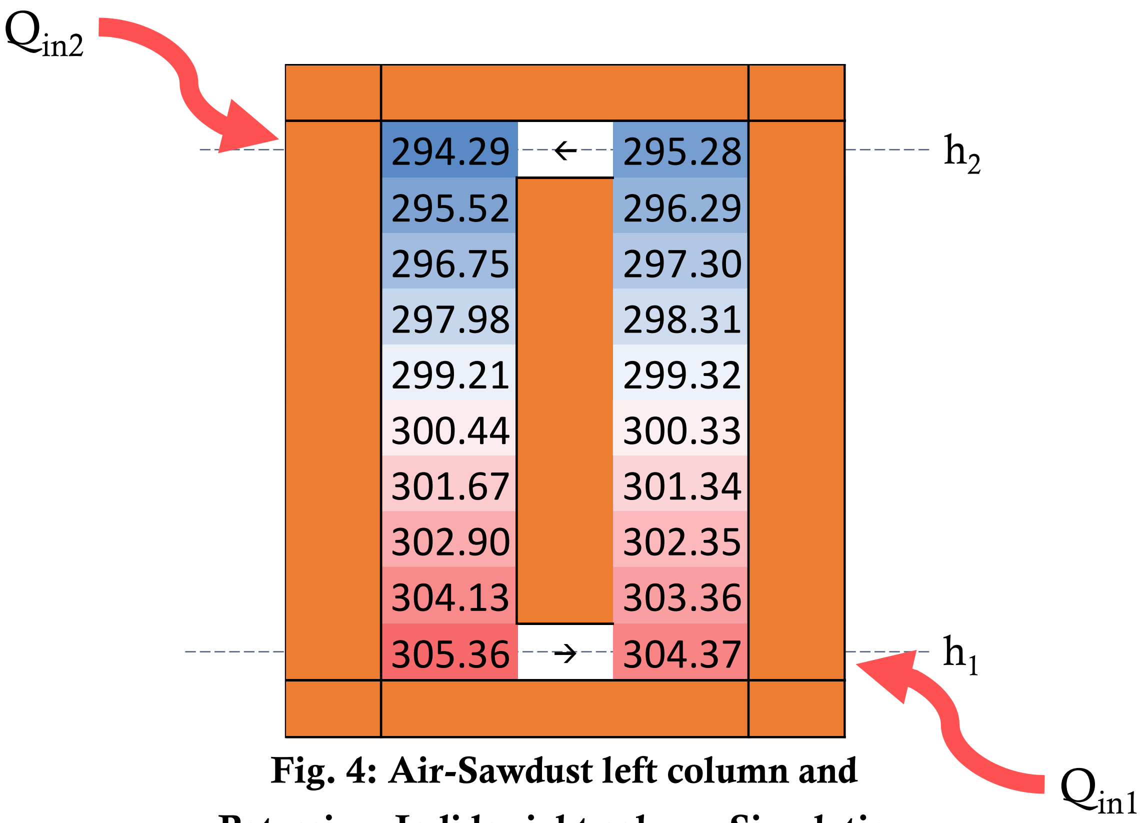

Fig. 4: Air-Sawdust left column and Potassium Iodide right column Simulation Temperature Results

- Simulation extended to two mediums in thermal communication under gravity (Air-Sawdust and Potassium Iodide).
- Simulation results show a **stable internal heat flow** is established, forming a **non-equilibrium steady state** with stable temperature gradients.
- **Work can be extracted** via heat engines placed at h_1 and h_2, driven by internal heat flow between the mediums.
- When $Q_{in1} = W_1$ and $Q_{in2} = W_2$, the total heat input equals the total work output, allowing the system to maintain steady-state operation with stable temperature gradients.

$$\boldsymbol{Q_{in1} + Q_{in2} = W_1 + W_2}$$

- Although **each heat engine cannot exceed the Carnot limit**, the **overall system can convert all added heat into work** under ideal (reversible) conditions.

PERPETUAL HEAT FLOW SYSTEM WITH UNIFORM TEMPERATURE GRADIENT

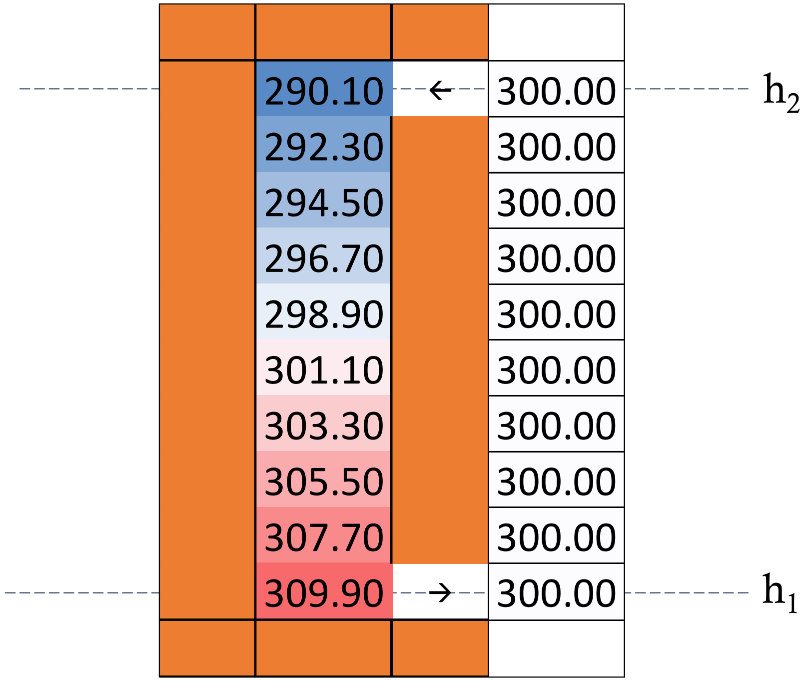

Fig. 5: Air-Sawdust mixture in left column with constant temperature gradient on the right Simulation Temperature Results

- **Heat engine efficiency** can be improved by increasing the temperature difference between the mediums at $\mathbf{h_1}$ and $\mathbf{h_2}$.
- In this simulation (Fig. 5), the **gravitational temperature gradient** was eliminated in one medium, creating a **uniform temperature medium**; achieved through convection, radiation, or by using an open system.
- Heat exchange with the **Air–Sawdust mixture** was balanced (**heat rejected at $\mathbf{h_1}$ equalled heat added at $\mathbf{h_2}$**) to maintain its temperature gradient.
- As a result, the **temperature differences at $\mathbf{h_1}$ and $\mathbf{h_2}$ increased**, compared to systems where both mediums develop gradients – enabling greater work output and heat engine efficiency over a **smaller height** using a uniform temperature

THE THERMAL CONDUCTIVITY LIMIT

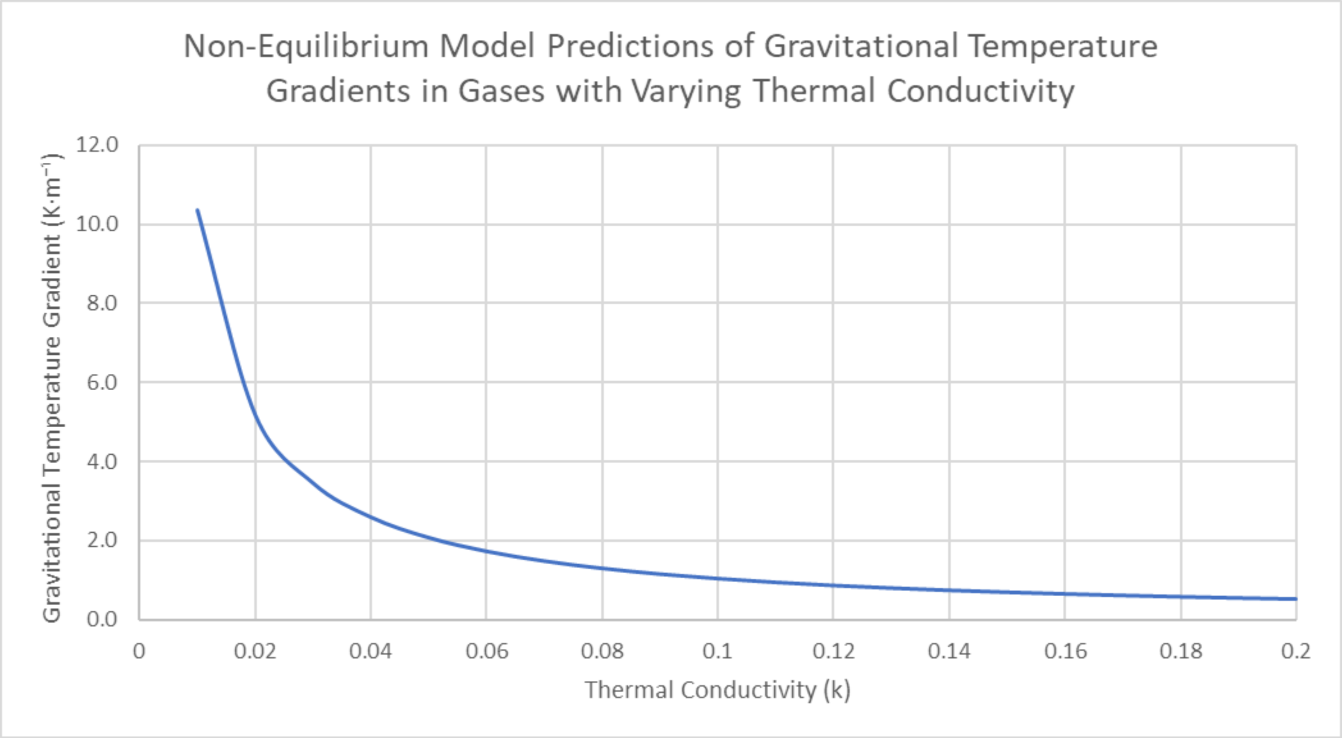

Fig. 6: Temperature Gradient Vs Thermal Conductivity

- System power output should also be considered in practical systems, which is influenced by:
  - temperature gradient
  - heat flow rate through the medium.
- Gravitational temperature gradient reduces as thermal conductivity increases (Fig. 6)
- Imposing dimensional constraints on practical systems.
- Experimental evidence has shown that **temperature gradients measured in solids under gravity can be replicated under rotational acceleration.**

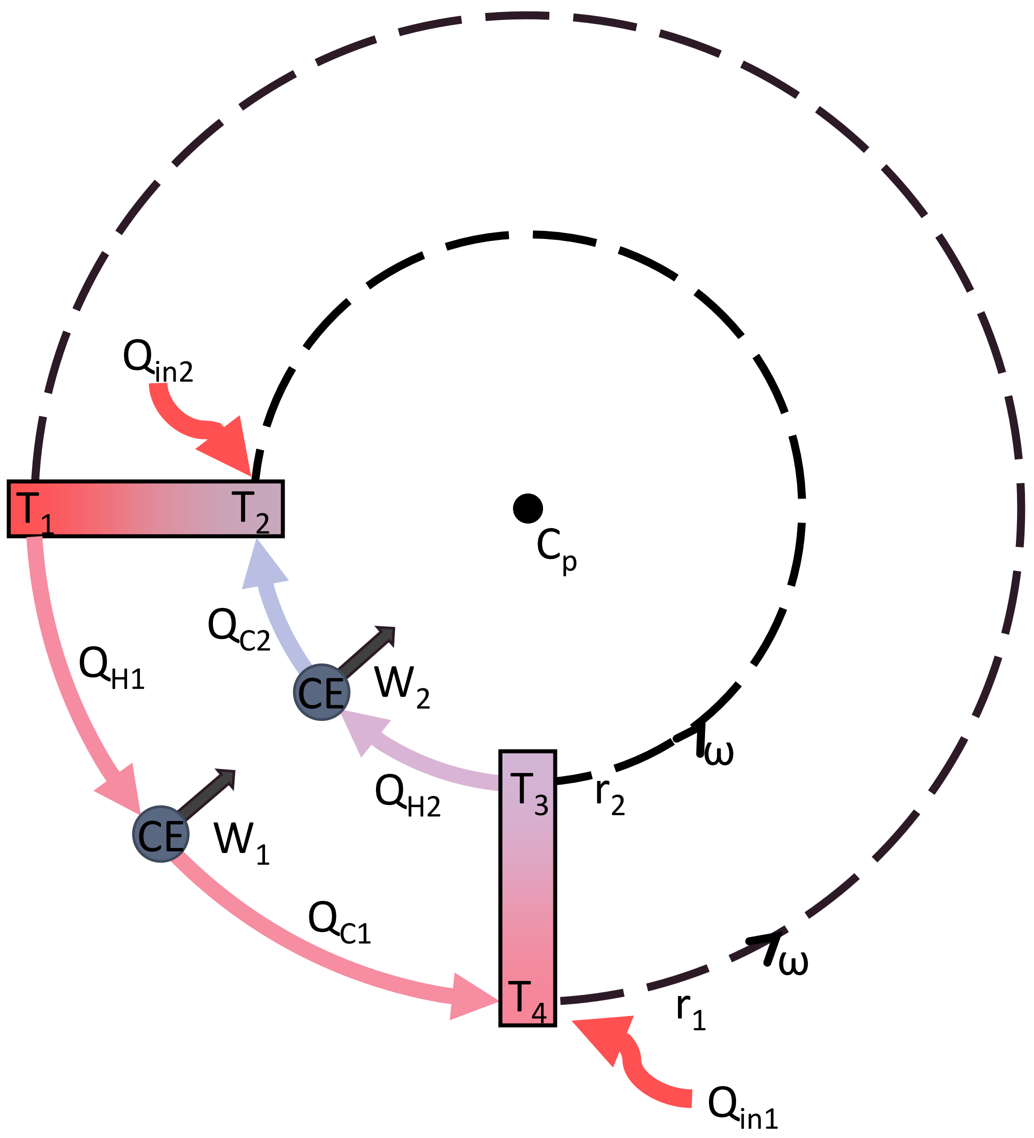

Fig. 7: Two Medium Rotational Concept

ROTATIONAL PERPETUAL HEAT FLOW SYSTEM CONCEPT: TWO MEDIUMS

- Two mediums rotated about a centre point establish different temperature gradients.
- No net mass flow occurs within the solid medium (no change in rotational KE).
- At radial distance r_1: $T_1 > T_4 \rightarrow$ heat flows from the first medium to the second.
- At radial distance r_2: $T_3 > T_2 \rightarrow$ heat flows from the second medium to the first.
- **Heat engines** (CE) placed at r_1 and r_2 could **extract work** from the heat flowing between the two mediums.

ROTATIONAL PERPETUAL HEAT FLOW SYSTEM CONCEPT: SINGLE MEDIUM

- A medium rotated about a centre point establish a temperature gradient.
- No net mass flow occurs within the solid medium (no change in rotational KE).
- Heat flows from T_1 to T_2 through a **stationary heat engine outside the rotating frame**, allowing work extraction $\mathbf{W_{out}}$ from the gradient.
- Heat rejected from the heat engine is added at T_2.
- Heat added to the system, Q_{in} and redistributed throughout the solid medium via conduction, without mass movement.

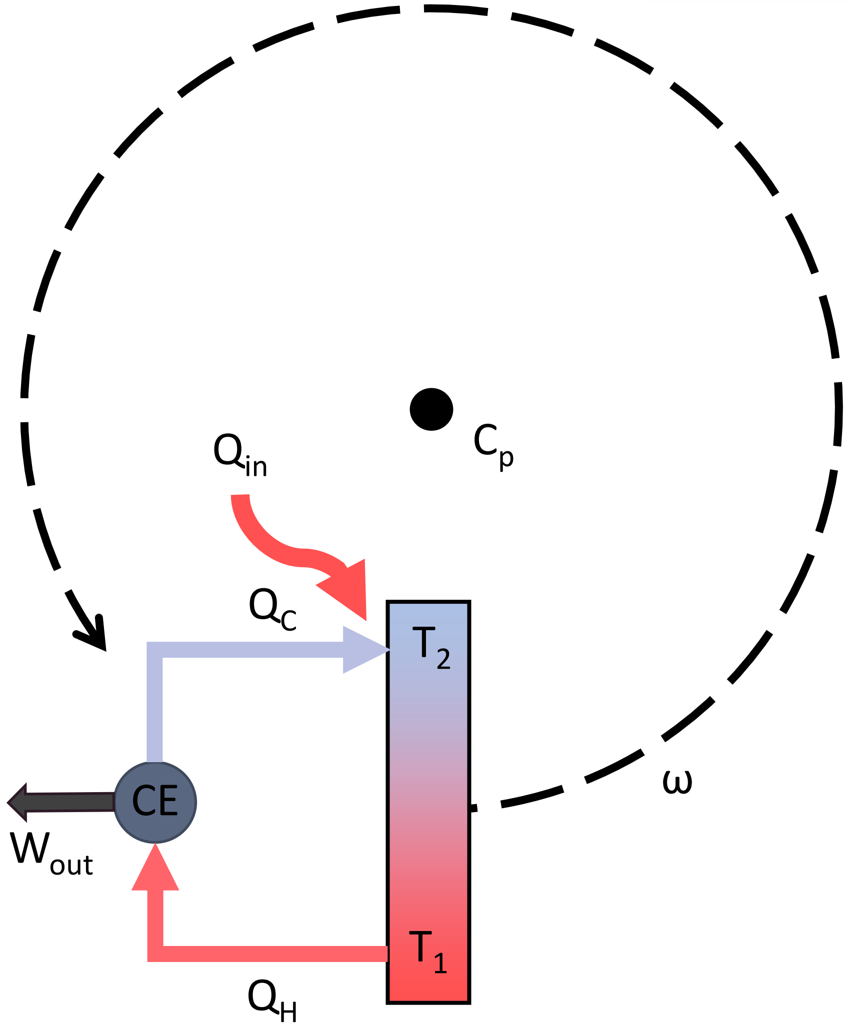

Fig. 8: Single Medium Rotational Concept

SIMULATING A ROTATIONAL TEMPERATURE GRADIENT

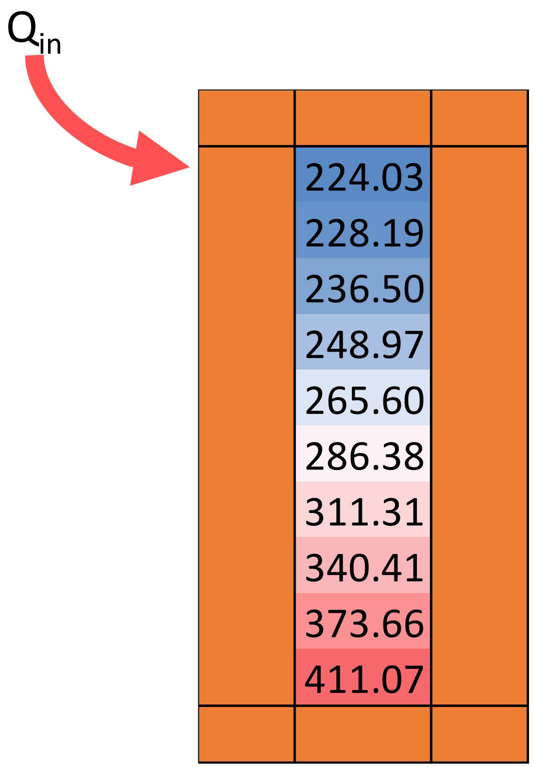

Fig. 9: Simulated radial temperature distribution in Potassium Iodide at 40 rad/s, showing steep temperature gradients under rotation

- A modified **Classical thermodynamic model** and **Non-equilibrium kinetic model** were used to simulate temperature gradients under rotation:

$$\frac{\boldsymbol{\Delta T}}{\boldsymbol{\Delta r}} = -\frac{(\mathbf{1}+\boldsymbol{\alpha T})\boldsymbol{\omega}^{2}\boldsymbol{r}}{\boldsymbol{C_p}} \qquad \frac{\boldsymbol{\Delta T}}{\boldsymbol{\Delta r}} \approx \frac{\boldsymbol{\Phi_{KE}}}{\boldsymbol{k}} \qquad where\ \Phi_{KE} = \frac{-cM^{2}\mathrm{Pr}^{2}\omega^{4}}{6R^{2}T^{2}}$$

- Simulations are **consistent with experimental results for solids** under rotation; experimental data for gases under rotation does not currently exist.
- 2D simulations for solids show that rotation induces **significantly larger** temperature gradients than gravity—**up to 37.41 K·m^{-1} at 40 rad/s**, compared to **0.02 K·m^{-1}** under gravity.
- Rotation enables **high-conductivity materials** to sustain temperature gradients compatible with existing heat engine technologies.
- The total heat input Q_{in} equals the total work output W_{out} allowing the system to maintain steady-state operation with stable temperature gradients.

$$\boldsymbol{Q_{in} = W_{out}}$$

PERPETUAL HEAT FLOW SYSTEM SUMMARY

- **Temperature gradients** have been experimentally measured in **solid, liquid, and gas** mediums.
- Simulations show a system could achieve a **perpetual heat flow**, enabling **100% efficiency under reversible conditions** — without violating the second law.
- **Rotational systems** can achieve **larger temperature gradients** than gravity-based systems, potentially allowing **greater power output**.
- **Future work** will require interdisciplinary collaboration, including:
  - **further modelling validation**
  - **experimental validation**
  - **proof-of-concept systems**
- Potentially leading to **new energy harvesting technologies**.