9:00 – 9:30	Refreshments and gathering	
9:30 – 9:40	Opening words	
9:40 – 10:00	Mor Mega, Ariel University	***Multi-Directional Laminate: Assessing Mixed Mode Fracture Behavior***
10:00 – 10:20	Shmuel Rubinstein, Hebrew University	***Predicting* Catastrophic Failure in Defect Sensitive Shells**
10:20 – 10:40	Haim Diamant Tel Aviv University	***Time-dependent viscous flow through channels surrounded by compliant media: Sensitivity to system size***
11:00 – 11:20	Omri Ram, Technion	***Using refractive index matching to study transient flow phenomena near highly curved or sharp surfaces.***
11:20 – 11:40	Coffee break and refreshments	
11:40 – 12:00	Evgeniy Boyko, Technion	***Longstanding contradiction in non-Newtonian fluid mechanics: Flow rate–pressure drop relation of viscoelastic fluid flows in non-uniform geometries***
12:00 – 12:20	Aslan Miriyev, Ben Gurion University	***Ionic Electromechanical Systems for Physical AI***
12:20 – 12:40	Ilana Nisky, Ben Gurion University	***Kinematic invariances in human movement as signatures of surgical skill***
12:40 – 13:00	Gil Marom, Tel Aviv University	***Optimizing the functionality and durability of left ventricular expanders for heart failure***
13:00 – 13:40	Lunch	
13:40 – 14:10		Posters Presentation
14:10 – 14:30	Mark Schvartzman, Ben Gurion University	***2D and 3D microstructures for mechanical cell guidance – from basic mechanobiology to advances in immunotherapy*.**
14:30 – 14:50	Eyal Karzbrun, Weizmann Institute	***Tubular morphogenesis in a dish***
14:50 – 15:10	Leeya Engel, Technion	***Microfabricated cell culture substrates for cryo-electron tomography***
15:10 – 15:30	Tomer Markovich, Tel Aviv University	***Chiral active fluids are both \`odd' and non-reciprocal***
15:30 – 15:50	Coffee break and refreshments	
15:50 – 16:00	Best posters awards	
16:00 – 16:20	Ilya Svetlizky, Technion	***Work hardening in colloidal crystals***
16:20 – 16:40	Victor Yashunsky, Ben Gurion University	***Investigating Topological Defects in Active Nematic Multicellular Systems***
16:40 – 17:00	Yaniv Edery Technion	***Injection-induced deformation in porous media: the coupling between formation heterogeneity, flow, and strain types***
17:00 – 17:20	Herman Haustein Tel Aviv University	***Novel Solutions to Classic Fluid Dynamic Problems: Using Local Linearity and Response Superposition to Resolve Jets, Wakes and Duct Flows***

Titles and abstracts

Mor Mega (Ariel University): *Multi-Directional Laminate: Assessing Mixed Mode Fracture Behavior*

(9:40 - 10:00)

This study aims to determine critical initiation and resistance curves for nearly mode I, nearly mode II, and mixed mode deformations by employing various specimens and criteria. The material considered is a multi-directional (MD) composite laminate manufactured by a wet-layup process. The delamination studied is between a unidirectional (UD) fabric ply with fibers oriented mainly in the 0°- direction and a plain balanced woven ply with tows oriented in the +45°/−45°- directions. Beam type specimens including the double cantilever beam (DCB), calibrated end loaded split (C-ELS), and mixed mode end loaded split (MMELS) specimens and Brazilian disk (BD) specimens, were tested quasi-statically in order to determine initiation failure criteria, as well as fracture resistance curves or R-curves. The BD specimens were tested in various mode mixities to determine the critical initiation energy release rate Gic values as a function of the mode mixty. Based on the results, a failure criterion for Gic as a function of the mode mixity was proposed (Mega and Banks-Sills, 2019). This criterion may be used for the prediction of failure as a function of the mode mixity for this material and interface. In addition, another criterion was obtained using the results of the beam specimens, and the use of the B-K failure curve (Benzeggagh and Kenane, 1996). The results from the beam specimens were also used to determine the amount of energy required for the delamination to propagate GiR as a function of the delamination extension Δa. This data is used to measure the delamination resistance to propagation.

Knowledge of the failure criteria and resistance curves provides critical properties for initiating and propagating delamination along the investigated interface. The results from this investigation may be used to improve the design and safety of a structure fabricated from this laminate and with the interface of the considered material.

Shmuel Rubinstein (Hebrew University): *Predicting Catastrophic Failure in Defect Sensitive Shells*

(10:00 - 10:20)

It is notoriously difficult to systematically study the defect-sensitivity of buckling in shells, as these systems are extremely detail-dependent. Classical linear analysis of cylindrical shells overestimates their buckling loads, which has led to catastrophic failures. In an effort to overcome this challenge, we have developed a fully nonlinear framework inspired by research in turbulent flows. In our research, we chose to focus on commercial soda cans, such as Coke and Beer, as an experimental model because they are widely used in our daily lives and are representative of real industrially relevant shells. We experimentally capture the stability of shells by using lateral probing to measure their stability landscape. This enables unprecedented analysis and predictions of shell stability for shells with defects. We demonstrate the power of this experimental paradigm by accurately predicting the strength of real defective shells using a novel, non-destructive experimental ridge-tracking method.

Haim Diamant (Tel Aviv University): ***Time-dependent viscous flow through channels surrounded by compliant media: Sensitivity to system size***
(10:20 - 10:40)

We revisit the problem of a driven flow of a viscous fluid through a slit or a tube surrounded by an elastic medium. Under a steady pressure difference the flow remains Poissuille's but the elastic strain at the fluid-solid interface diverges with the thickness of the surrounding medium, either linearly (slit) or logarithmically (tube). Under a time-dependent pressure difference the coupling between the two media introduces a similarly divergent contribution to the flow. These anomalies arise from the effectively one-dimensional (slit) or two-dimensional (tube) spread of the elastic stress transverse to the channel axis. The system-size dependence is removed by including a finite sound velocity in the elastic medium but is recovered after the sound wave has reached the boundary. The results can be used to infer the elastic and viscoelastic properties of a material by measuring the flow under a time-dependent pressure gradient through an embedded channel.

Omri Ram (Technion): ***Using refractive index matching to study transient flow phenomena***
(11:00 - 11:20)

Time-resolved Particle Image Velocimetry (PIV) using high-speed cameras has become the most commonly used experimental tool to study transient phenomena in fluid mechanics. Despite its widespread use, PIV, and especially tomographic PIV, depends on optical access, which may lead to lower-quality outcomes when imaging through sharp or highly curved surfaces that cause significant distortions. Additionally, these techniques typically rely on laser illumination, which can cause intense reflections near surfaces that significantly degrade the image quality and measurement accuracy. We use refractive index matching techniques to address these limitations by employing a 63% NaI solution as the working fluid. This method blends the boundaries between the fluid and the solid, eliminating optical distortions and unwanted laser reflections. As a result, we obtain substantial enhancement in the detail and accuracy of velocity measurements. We employ the technique to study high-resolution stereo and high-speed tomographic PIV measurements within suddenly expanding round pipes where sharp corners prohibit optical access and proper velocity measurements. Moreover, it offers the possibility to study the behavior of solids in the flow by introducing acrylic spheres into the flow and tracking their motion and the flow around them. This talk will outline our methodology and initial results, showcasing the benefits of refractive index matching in advancing fluid mechanics research in complex geometries.

Evgeniy Boyko (Technion): ***Contradiction in non-Newtonian fluid mechanics*** **(11:40-12:00)**

Pressure-driven flows of viscoelastic fluids in narrow non-uniform geometries are common in physiological flows and various industrial applications. For such flows, one of the main interests is understanding the relationship between the flow rate q and the pressure drop Δp under steady-state conditions. However, current numerical simulations using continuum-level constitutive models are insufficient to predict experimentally observed flow rate–pressure drop behavior of viscoelastic fluids in contracting geometries. In fact, there is a contradiction

between experiments and simulations: while experiments show the increase in the flow resistance $\Delta p/q$, simulations predict its decrease.
In my talk, I will discuss our theoretical approach to understanding and potentially resolving this contradiction. I will present a theoretical framework for calculating the flow rate–pressure drop relation of viscoelastic fluids in arbitrarily shaped, narrow geometries using the Oldroyd-B constitutive model1.2,3. Since the Oldroyd-B model represents the simplest combination of viscous and elastic stresses, it is important to find the response of the simplest model before investigating more complicated constitutive equations. I will present a theory for low- and high-Deborah numbers, which is in excellent agreement with numerical simulations. I will show that for the flow-rate-controlled situation, the dimensionless pressure drop of the Oldroyd-B fluid in the contraction geometry monotonically decreases with the Deborah number and identify two mechanisms for such pressure drop reduction. These two mechanisms are robust and appear in most constitutive equations for viscoelastic fluids. We believe that our approach is important in providing insight into the cause of the disagreement between experiments and simulations and resolving it by accounting for additional microscopic features of polymer flows.

Aslan Miriyev (Ben Gurion University): *Ionic Electromechanical Systems for Physical AI*

(12:00 – 12:20)

Physical AI (PAI) involves creating nature-like physical systems with the capabilities of intelligent organisms. Ionic electroactive gels (IEGs) show numerous benefits as candidates for use in the field of PAI, owing to their multifunctionality and ability to transform electrical energy into mechanical energy (and vice versa) under low voltages and currents. They can serve as actuators, sensors, and supercapacitors and hold high potential for 3D-printing-mediated fabrication, promising an adaptive electromechanical response. In my talk, I will discuss the exploration and electromechanical behavior of mixed ion-electron conductivity ionogel/single-walled carbon nanotube (ISMC) composites for multisensors, as well as that of ionogel and ionic eutectogel soft wires (i-Wi). The discussed materials are fully 3D-printable, allowing for tailored designs that enable electromechanical performance profiles for specific functional needs. Exploration of the properties of these materials beyond the currently well-studied linear range will enable the creation of soft, autonomous electromechanical systems and pave the way for self-regulating electromechanical behavior through learning-based control methods.

Ilana Nisky (Ben Gurion University): *Kinematic invariances in human movement as signatures of surgical skill*

(12:20 – 12:40)

In robot-assisted minimally invasive surgery (RAMIS), a surgeon manipulates a pair of joysticks that teleoperate instruments inside a patient's body to achieve precise control of movement, tissue manipulation, and perception. Despite many advantages for both the patient and the surgeon, the full potential of RAMIS is yet to be realized. One of the major gaps is understanding how surgeons develop the technical skill needed for RAMIS. I will present recent results of our human behavioral and machine learning studies to uncover the kinematic signatures of human movements while executing surgical tasks with virtual and real objects and how they change across different time scales following adaptation and skill acquisition. I will then discuss how we harness these findings to eventually improve the control of surgical robots, the assessment and advancement of surgical skills, and ultimately, the well-being of patients.

Gil Marom (Tel Aviv University): *Optimizing the functionality and durability of left ventricular expanders for heart failure*

(12:40 – 13:00)

Left ventricular (LV) expanders are spring-like devices that are specifically dedicated for the treatment of heart failure with preserved ejection fraction (HFpEF). They are intended to mechanically facilitate outward ventricular expansion during cardiac relaxation, thus enhancing the LV filling. The aim of this study is to evaluate the effect of such devices implanted inside an in-silico diseased human heart with hypertrophied and stiffened LV myocardium, representing HFpEF. The present study is using the SIMUILIA living heart human model, but modified to include hypertrophy and cardiac stiffening. This generic in-silico model, which represents the morphological and material alteration characterizing HFpEF, was used for the implantation of an LV expander device to optimize the shape, size, and material of the device by testing several configurations. The effect of the various devices on cardiac function was quantified by physiological parameters throughout the cardiac cycle, with a focus on systolic behavior. Finally, fatigue analyses were performed on the optimal design to assess the long-term impact and durability of the device. All expander device designs showed a positive impact on heart function. The results also revealed that cobalt-chromium alloys seem to be more appropriate than nickel-titanium for this type of application. The fatigue analysis, of the most optimized configuration, revealed that the device might not be capable of withstanding 10 years of heart cycles, but it can endure 2.5 years. This study indicates that the use of LV expanders may be used with caution in HFpEF and other diseases of cardiac stiffening. Although the EF and overall systolic function were preserved, the diastolic impact of the device should be more carefully assessed. Interestingly, even devices with a 2.5-year durability may still be beneficial for patients with severe cardiac stiffening, like in HFpEF, who typically have a shorter life expectancy. Further patient-specific analysis is needed to check the device in the context of clinical needs.

Mark Schvartzman (Ben Gurion University): *2D and 3D microstructures for mechanical cell guidance*

(14:10 – 14:30)

It is becoming progressively clear that the cell response is regulated by physical cues, such as the spatial arrangement of signaling molecules, as well as mechanical stiffness and topography of their environment Yet, understanding the role of each cue in cell function is challenged by the fact that in vivo these cues are intermixed, and their effects on cells are often indistinguishable from each other. This challenge can be overcome by ex-vivo platforms for cell stimulation, which are designed to controllably mimic individual physical cues identical to those existing in vivo. Recent nanotechnological advances enable the structuring and positioning of these cues with a precision that reaches the molecular regime.

In the first part of my talk, I will describe a 2D platform that mimics anisotropic spatial distribution of elastic cues. The platform is based on micropatterned soft and stiff lines with sub-cellular width. Two important features of this platform—complete flatness and uniform functionalization with adhesion molecules—ensure that the platform produces neither

topographic nor chemical cues that can direct cell motility. We found that cells seeded on this platform are generally aligned with and move along the lines. However, in contrast to the well-known phenomenon of durotaxis, this movement is not directed by the gradient of environmental elasticity but rather by its anisotropic heterogeneity. We therefore define this new type of cell guidance as “mechanical contact guidance”, similar to contact guidance induced by topographic grooves or lines of adhesive functionalities. In particular, we found that this guidance persists when the lines are above a certain width threshold and discuss possible mechanisms of this threshold. Furthermore, we observed this guidance on the single-cell level and on the level of collective cell migration.
In the second part of my talk, I will describe how we leveraged the insights from the basic studies on mechanostimulation of T cells to engineer a new mechano-topographical T cell platform activation for efficient and controlled CAR T cell therapy. The platform is based on an elastic surface structured with 3D topography of arrays of micropillars. First, we systematically evaluated the effect of various physical parameters of activating surfaces, such as elasticity, pillar geometry, and distribution, on critical T cell functions, including activation, exhaustion, proliferation, and CAR transduction efficiency. By employing multiple discriminant analysis, we identified an optimal set of parameters for surface design, focusing on enhancing memory CAR T cell differentiation. Integration of these optimized surfaces into the standard T cell production protocol resulted in CAR T cells exhibiting superior anti-tumor efficacy compared to those produced using conventional methods. Validation through various assays, including in vitro lysis, ex vivo Cell-Line Derived Xenograft (CDX), ex vivo Patient Derived Xenograft (PDX), and in vivo murine models, confirmed the enhanced potency of CAR T cells produced with the novel surfaces, as compared to those produced by standardly used Dynabeads. Transcriptomic analysis identified that CAR T cells produced by activation with our platform have an increased genetic signature associated with central memory T cells, confirming that differentiation into this T cell subset is key for high immunotherapeutic persistence. These findings signify a groundbreaking advancement in CAR T cell immunotherapy, demonstrating the potential of leveraging surface microstructure and elasticity to bolster therapeutic outcomes.

Eyal Karzbrun (Weizmann Institute): *Tubular morphogenesis in a dish*

(14:30 – 14:50)

During embryonic development, epithelial sheets fold into tubular structures that undergo complex morphogenetic events to form functional organs such as the brain, gut, and lungs. Here, we present a chip-based culture system that enables the self-organization of 2D micropatterned stem cells into three-dimensional tubular tissues with reproducible cell-fate patterns and shapes. We use this system to recreate neural tube folding from human stem cells in a dish. Neural tube formation is a significant event in the embryonic development of the brain and spinal cord. Upon neural induction, the neural ectoderm folds into a millimeter-long neural tube covered with non-neural ectoderm. Folding occurs at 90% fidelity and anatomically resembles the developing human neural tube. We find that the neural and non-neural ectoderm are necessary and sufficient for folding morphogenesis. We identify two mechanisms that drive folding: 1) apical contraction of neural ectoderm, and 2) basal adhesion mediated via extracellular matrix synthesis by non-neural ectoderm. Targeting these two mechanisms using small molecules leads to neural tube folding defects. Finally, we develop a mechanical model that captures neural-tube morphology under all experimental conditions, further highlighting the role of tissue mechanics in organ morphogenesis. Our approach provides a new path to study human organ morphogenesis in health and disease.

Leeya Engel (Technion): *Microfabricated cell culture substrates for cryo-electron tomography*

(14:50 – 15:10)

The ability of living cells to respond to mechanical cues from the microenvironment plays a vital role in physiological processes such as embryonic development and heart function. Over the past decade, the field of mechanobiology has seen major advances catalyzed by increasingly powerful strategies to measure cell-generated forces and to identify mechanosensitive molecules. However, we know comparatively little about the nanometer-scale organization of the cellular components that underly the cell's ability to generate and sense mechanical force. This knowledge gap reflects a lack of tools that can visualize cellular organization at the nanoscale. In this talk, I will present a microfabricated cell culture platform developed to provide programmed physical cues to cells imaged with cryo-electron tomography (cryo-ET), a 3D transmission electron microscopy (TEM) modality that offers the highest resolution structural analysis of cells in a near-native state. The extracellular matrix (ECM) protein micropatterning technology we developed uses maskless photolithography to functionalize TEM supports to shape cells and direct their positioning at high spatial accuracy, solving an important bottleneck in cryo-ET sample preparation. We demonstrated the utility of this technique for structural studies of cardiac and endothelial cells. Over the long term, this technology will elucidate how spatial constraints from the cell microenvironment influence cellular ultrastructure.

Tomer Markovich (Tel Aviv University): *Chiral active fluids are both 'odd' and non-reciprocal*

(15:10 – 15:30)

Active materials are composed of many components that convert energy from the environment into directed mechanical motion, thus locally breaking time reversal symmetry (TRS). Examples of active materials are abundant, from living systems such as bacteria to colloidal rollers. A striking phenomenon of breaking TRS is the possible appearance of odd viscosity. Onsager reciprocal relations require that when TRS holds the viscosity tensor is symmetric for exchanging its first and last pair of indices. However, when TRS is broken, Onsager relations predict an odd viscosity that is both odd under TRS and under the change of indices. Such odd viscosity is non-dissipative and should thus be derivable from a Hamiltonian theory. In this talk I will discuss chiral active fluids in which both parity and TRS are broken at the microscale. This is usually a result of continuous injection of energy and angular momentum through local torques, which are abundant in living systems, and generically result in odd viscosity, even when the constituents are non-interacting. I will show that the mere existence of spin angular momentum density due to the local torques also breaks Onsager's reciprocity relations and leads to non-Hermitian dynamical matrix. When interactions are included phenomenologically, we find regions in in the parameter space in which novel 3D mechanical waves propagate in the bulk, and regions in which they are mechanically unstable. The lines separating these regions are continuous lines of exceptional points, suggesting a non-reciprocal phase transition.

Ilya Svetlizky (Technion): *Work hardening in colloidal crystals*
(16:00 – 16:20)

Colloidal crystals exhibit a rich behavior that is in many ways analogous to their atomic counterparts: they have the same crystal structures; they undergo the same phase transitions; and they possess the same crystallographic defects. In contrast to these structural properties, the mechanical properties of colloidal crystals are quite distinct from those of atomic systems. For example, unlike in atomic systems, the elasticity of hard-sphere colloidal crystals is purely entropic; as a result, they are so soft that they can be melted just by stirring. We use confocal microscopy to show that hard-sphere colloidal crystals exhibit work hardening, where they become stronger when subjected to increasing plastic deformation. Their strength increases with dislocation density, and, remarkably, ultimately follows the classic Taylor scaling behavior for atomic materials, even though hard-sphere interactions lack the complexity of atomic interactions. This striking resemblance between colloidal and atomic crystals, despite the many orders of magnitude difference in particle size and shear modulus, demonstrates the universality of work hardening.

Victor Yashunsky (Ben Gurion University): *Investigating Topological Defects in Active Nematic Multicellular Systems*
(16:20 – 16:40)

Multicellular systems, including tissues and bacterial colonies, manifest as dynamic assemblages of self-propelled entities exhibiting collective behaviors, resulting in complex biological functionalities. These systems, comprising elongated particles known as "nematic," intricately intertwine their dynamics with spatial organization described by the director field. Topological defects emerge as inherent local features within the director field, profoundly influencing its structure and evolution. Interactions among these defects including attraction and repulsion play a pivotal role in system reorganization. I will present experimental results across different multicellular systems delving into flow patterns surrounding nematic defects, the organization of defects within boundary-constrained environments, and interactions between defect pairs during annihilation and nucleation.

Yaniv Edery (Technion): *Injection-induced deformation in porous media: the coupling between formation heterogeneity, flow, and strain types.*
(16:40-17:00)

The injection of pressurized fluids into the underground, commonly utilized in industrial processes such as carbon storage, geothermal energy production, and hydraulic fracturing, can induce seismic activity and deform the porous structure of the underground rocks. While pore pressure typically induces expansion, experimental studies suggest that under confined conditions—relevant to many injection operations into aquifers—fluid injection may lead to compaction of the porous medium. However, the coupling of flow and deformation exhibits a rich, dynamic range for the deformation type that has not been previously explored in porous structures, ranging from localized compaction to dilation and fracturing. This study investigates injection-induced compaction localizations in a granular porous medium by tracking both the global and local deformation and monitoring the applied pressure and flux. For that, we devel oped a method to chemically sintere Poly(methyl methacrylate) (PMMA) grains so to simulate rock-like conditions. We employ refractive index-matching fluids to track the deformation by fluorescent imaging of fluorescently labeled beads that are embedded in the porous structure during the pressurized flow. The results demonstrate continuous elasto-plastic compaction at the global scale, which follows the mean effective stress. Surprisingly, this global compaction is punctuated by abrupt strain localizations that couple compaction and shear. These localizations are triggered by sudden pore collapses, followed by the shearing and rearrangement of adjacent regions, primarily upstream, due to stress gradients imposed by fluid flow. This shear-induced rearrangement temporarily reduces stiffness, driving further compaction and stiffness recovery over time. Furthermore, while the flow condition should induce 1D compaction, we observe considerable dilation transverse to the flow, which moderates the measured permeability reduction, producing a discrepancy between the stress-strain hysteresis and the stress-permeability hysteresis. We also show that under radial conditions, these compaction-dilation events may result in tensile fractures. Our findings underscore the complexity and rich physical dynamics of injection-induced compaction localization, revealing the emergence of non-axial strains in what initially appears to be a one-dimensional problem.

Herman Haustein (Tel Aviv University): ***Novel Solutions to Classic Fluid Dynamic Problems: Using Local Linearity and Response Superposition to Resolve Jets, Wakes and Duct Flows***

(17:00 – 17:20)

The talk presents recent advances gained in the understanding, description and prediction of several classical fluid dynamic problems. Several known methodologies were employed in an original way to solve or approximate the most common flow configurations, including bounded, unbounded and semi-bounded flows. A common example of the former is duct flows, which are very wide-spread. At the microscale these develop slowly (laminar conditions), raising several major questions: must developing pipe flow be simulated or can it be captured by a few explicit equations? How important is the entrance condition? How far downstream does its affect fade? How do the dynamics change in annular/rectangular ducts? These matters have been addressed by a new approximate description, derived from superposition of the flow's (first-order) response to the sudden change in boundary condition upon entering the duct (Haustein & Kashi, 2019; Hecht & Haustein, 2024). Previous such analysis of the inverse response (no-shear), successfully captured the evolution of another canonical configuration: the free-surface jet (e.g. water in air, Haustein et al., 2017). The approximate analysis was able to capture the influences of issuing profile (nozzle), gravity (orientation), surface tension (at low We) and dissipation (at low Re).
Similarly, submerged jet flow (e.g. air in air) is commonly used in cooling, cleaning and drying applications. Until recently, only the mostly irrelevant, far-field (self-similar) solution had been obtained for axisymmetric or 2D conditions (Schlichting, 1933; Bickley, 1939, accordingly; see Schlichting, 1967). In a recent study, the authors used asymptotic analysis, enabling local linearization to reduce the Navier-Stokes equation to a convection-diffusion (heat) equation. Resulting in a series-solution (or error function) for the axisymmetric (or 2D) near-field free jet evolution (Kashi et al., 2018; Oved & Haustein, 2024). This solution has been instrumental at identifying the dissipation downscaling-limit of micro-jets (Kashi & Haustein, 2019), along with stability analysis revealing the conditions required for jet-edge vortex roll-up (Mogilevsky & Haustein, 2024). The new analytic solution unlocked subsequent jet-impingement flow and heat transfer analysis for both the submerged and free-surface configurations (Kashi & Haustein, 2020, 2025; Oved et al., 2024; Harnik & Haustein, 2025a, Mogilevsky & Haustein, 2025). This analysis elucidated the conditions for the occurrence of the off-center heat transfer peak, tying them to the shape of the jet velocity profile arriving at the wall (Kashi & Haustein,

2025; Harnik & Haustein, 2025b). Moreover, it provided for the first time an Excel-level design and optimization tool for jet-impingement applications, currently considered for funding of custom gpu-based data center cooling solutions.
Finally, it has recently been shown that the same analysis methodology can be applied to wakes. Despite the similarity between jets and wakes, which can be viewed as a positive velocity wave or velocity-deficit wave, accordingly. The entrainment has a very differing effect, whereas jet's conserve positive momentum, wakes do not conserve the negative equivalent, and accounting for the momentum entrainment is needed. The adapted solution is shown to be both simple and accurate, capturing again the near-body solution and not just the far-body self-similar one (Tollmien, 1931; Goldstein, 1933). Moreover, this new solution is shown to also be valid for bluff-body wakes, prior to vortex shedding. The new solution reveals that such bodies have a two-tier wake (separated by a velocity maxima), wherein the inner-wake's entrainment (negative) is exactly balanced by the outer-wake's (positive). Thus, the bluff-body's wake has a net-zero entrainment effect, prior to vortex shedding. These new findings have significant implications to wake stability analysis and other mixing layers (Haustein & Mogilevsky, 2025).