Supplementary Information (SI) for Journal of Materials Chemistry A.

Omnidirectional Triboelectric Wave Energy Harvester Driven by an Automatic Watch-Inspired Oscillating Weight

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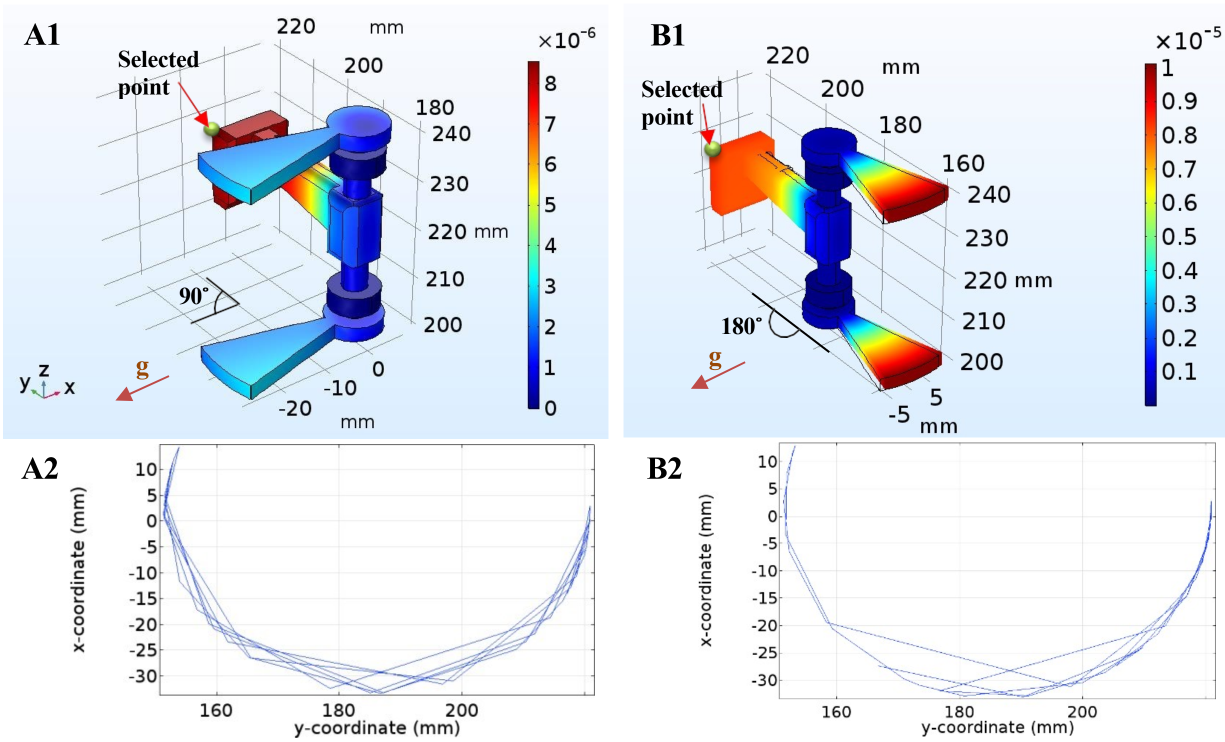
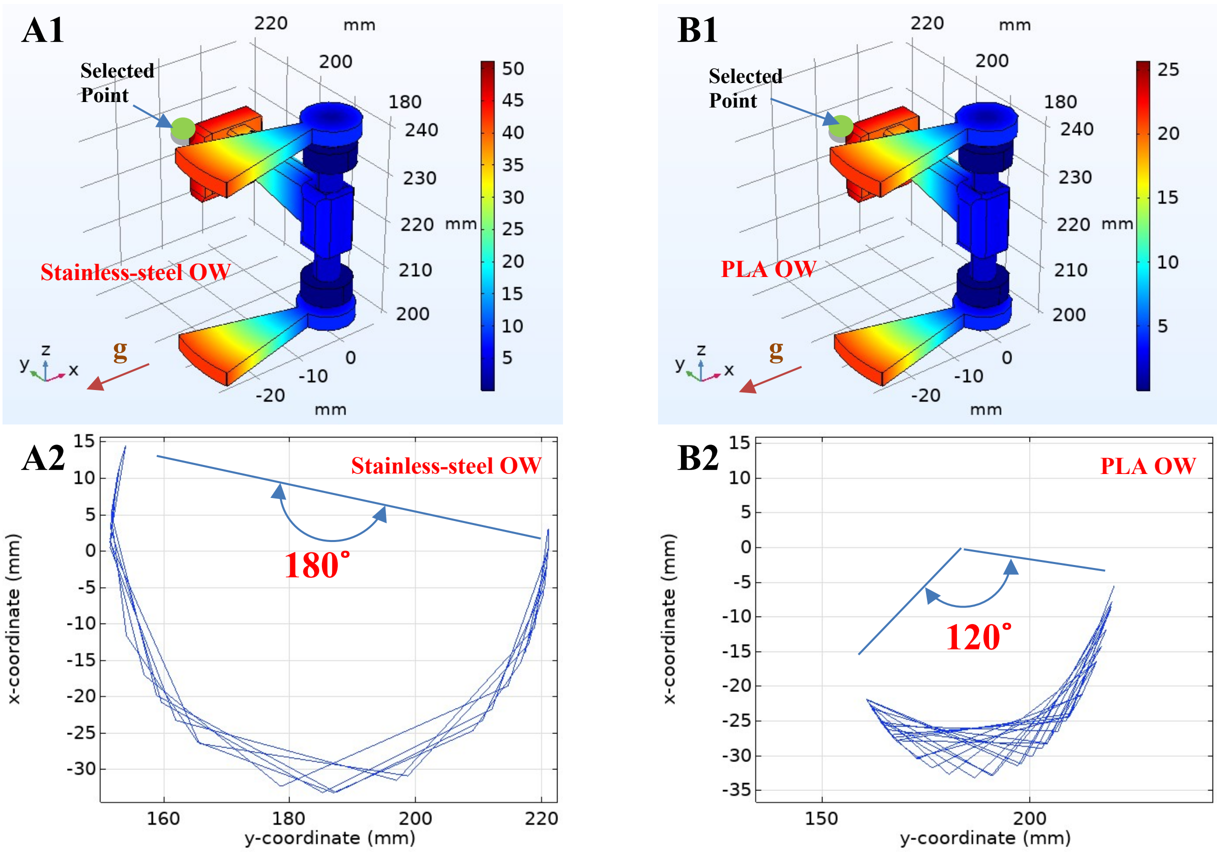


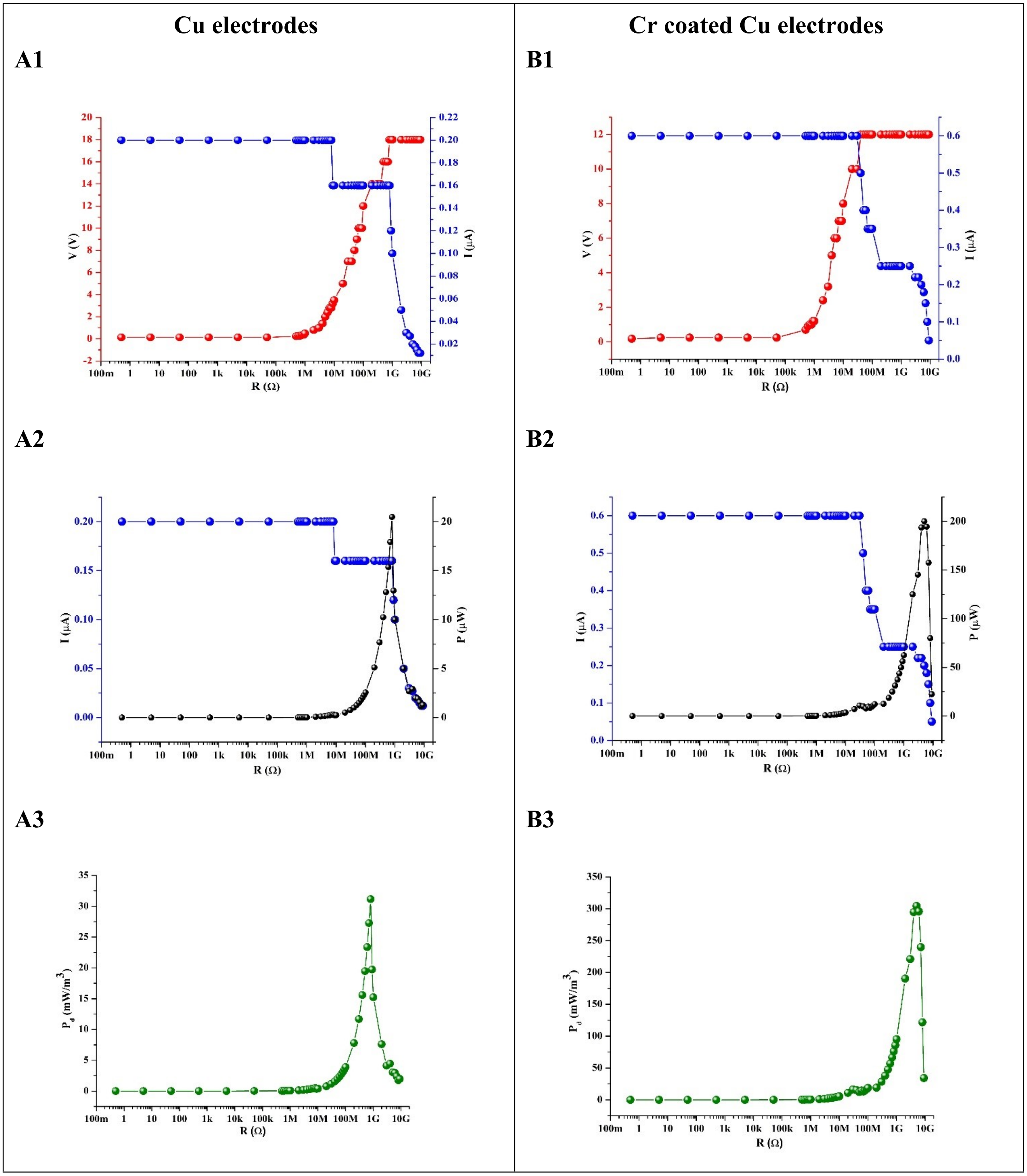
Note S1.

The effectiveness of the WEC's design was confirmed by COMSOL multibody dynamics (MBD) simulation of the oscillating weight and rotors arrangement. Figure A1 shows an isometric view of the rotating/oscillating components design when the angle "θ" between the rotors and oscillating weight is set as 90˚, and Figure B1 shows the components design when θ = 180˚. Tip trajectory plots showing the movement of the selected tip when the oscillating weight is released from the stationary position and allowed to oscillate under the effect of gravity are shown in Figures A2 and B2. Both Figures A2 and B2 show the same oscillation pattern with the start and end of the oscillation x and y coordinates being identical. However, the major difference is in the number of oscillations observed, with θ = 90˚ clearly showing more oscillations than when θ = 180˚. This reaffirms the suitability of the perpendicular arrangement between the oscillating weight and rotors for the purpose kinetic energy harvesting though oscillatory movement.



Note S2.

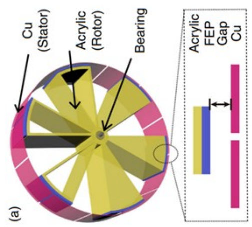
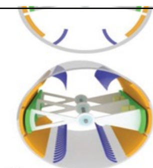
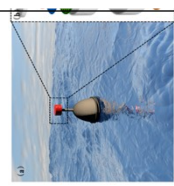
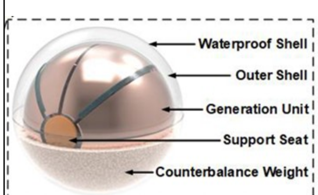
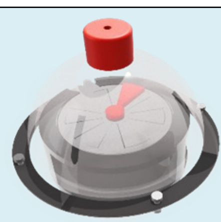
Optimization of the oscillating weight (OW) material type was carried out using COMSOL MBD simulation. From Figures A1 and B1 it could be seen through surface displacement plots that when subject to gravity in the -ve x-direction, the rotating/oscillating component with a stainless-steel oscillating weight has a larger surface displacement of 50 mm than the rotating component with a PLA oscillating weight, which is 25 mm. The tip trajectory plot in Figure A2 also shows smoother oscillations covering 180˚ with the stainless-steel oscillating weight. The PLA oscillating weight showed 120˚ oscillations in Figure B2.



Note S3.

Under simulated water wave conditions in the wave tank, the WEC with Cr coated Cu (Cr/Cu) electrodes showed improved power output compared with Cu electrodes. The motor was set at 25% of its operating capacity with wave frequency of 2 Hz, wave height of 3 cm, and wavelength of 12 cm. Although the output voltage was slightly higher with the Cu electrodes, the Cr/Cu electrodes enhanced the output current by threefold.

Table S1. Comparison of the output and design attributes of this work with previous triboelectric rotational- based wave energy harvesters

Journal (ref no.)	**TENG Type**	**Device Architecture**	**Wave Tank Testing**					**Design Attributes (See Notes)**
			Power Output (μW)	**Power Density (mW/m³)**	**Wave Height (cm)**	**Simulated Wate Wave Frequency (Hz)**	**V_{oc} (V)**	
Applied Physics Reviews (2020)[19]	Cylindrical TENG		18.90	39.80	9.00	0.03	NA	d, e
Advanced Energy Materials (2020)[34]	Cylindrical TENG		93.00	26.30	10.00	1.20	342.00	b, d, g
AIP Advances (2020)[36]	Pendulum TENG		8.01	4.54	NA	1.40	18.00	a
Nano Energy (2020)[37]	Pendulum TENG		15.21*	NA	3.00-7.00	2.00	120.00	b
ACS Nano (2022) (39)	Gyroscopic TENG		600.00*	280.00*	18.00	NA	160.00-730.00*	a, c, d, f, g
This work	Rotational TENG		200.00	304.40	3.00	2.00	12.00	a, b, c, d, e, f, g

* Data obtained from linear motor testing (not from wave tank testing)

Notes:

The WEC design attributes used for comparison include:

a. Omnidirectional wave energy harvesting ability.
b. Demonstrated ability to work in both low frequency and high frequency water wave environments.
c. No seabed mooring system required.
d. WEC works when overturned.
e. Proven scalable by increasing the number of units.
f. Hull design intended for the actual environment with the inner components of WEC waterproofed.
g. Individual WECs in a network can move independently of one another

Video S1

This video shows the result of COMSOL MBD simulation for the oscillating weight and rotors surface displacement (i.e., oscillatory movement) when released from stationary position under the effect of gravity at the -ve x-direction.

Video S2

This video shows a network of 2 x 1 units of the WEC working together in the wave tank with the wave-making motor operating at 2 Hz. The highlight of this video is the movement of the rotors inside each WEC, which move almost randomly in clockwise or counterclockwise directions with the propagating waves.

Video S3

This video shows a single unit of the WEC charging a 0.22 μF capacitor up to 4.45 V in 2 minutes when placed in a wave tank operating with wave frequency of 2 Hz.

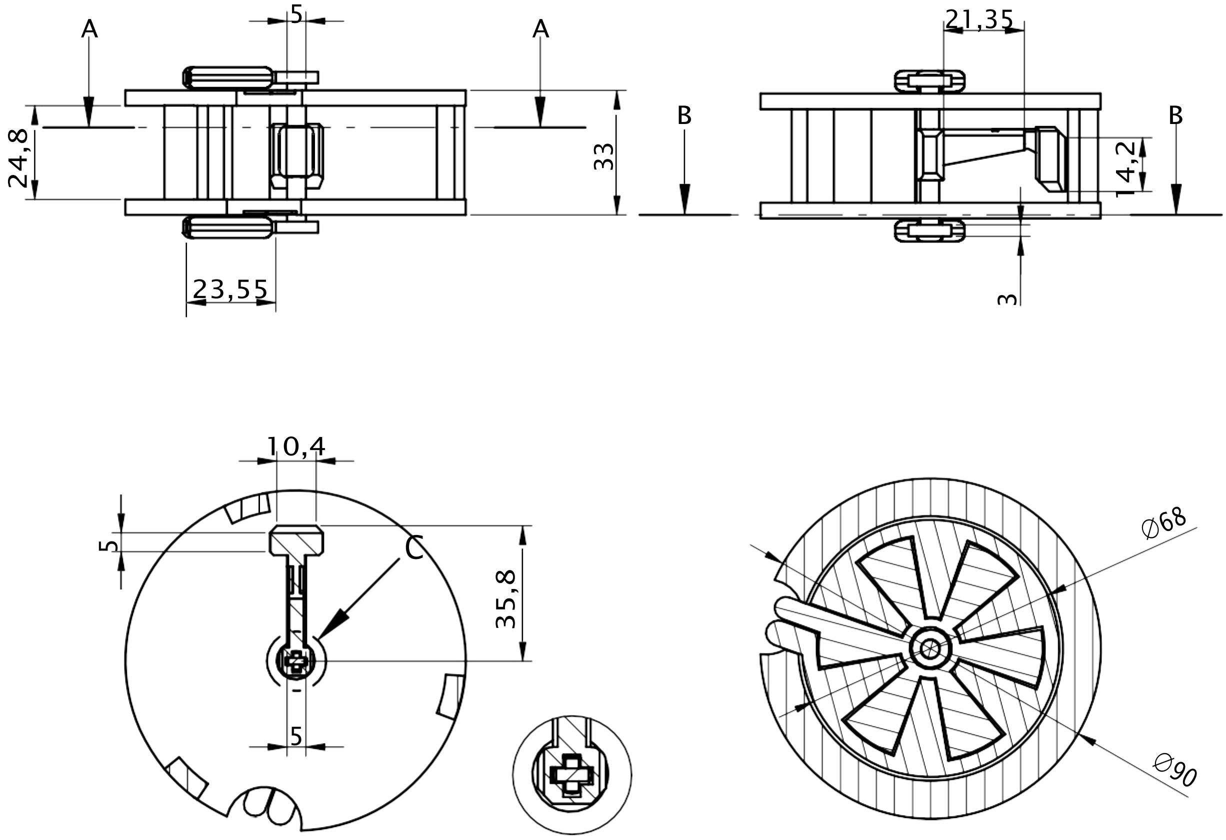
Video S4

This video shows 2 units of the WEC charging a 0.22 μF capacitor up to 5.25 V in 2 minutes when placed in a wave tank operating with wave frequency of 2 Hz.

Video S5

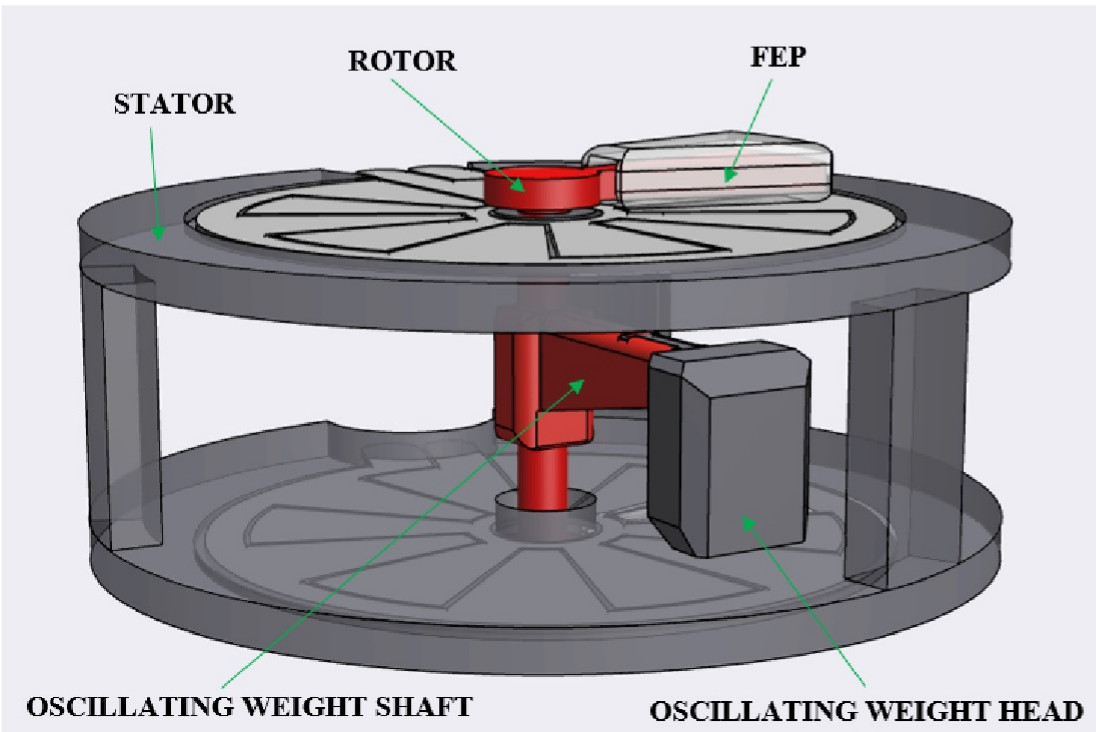
This video shows 1 unit of the WEC charging a 4.7 μF capacitor up to 3.2 V in 33 minutes when placed in a wave tank operating with wave frequency of 2 Hz. The energy stored in the capacitor is used to power up a stopwatch for 2 s.

Main Components of the WEC



A-A C B-B

SCALE 1:1



NOT TO SCALE

TITLE	UNITS	PROJ. ANG.	SIZE	SCALE	LAST UPDATED
Figure S1	mm		A4	1:2	15/05/24

Electrodes of the WEC

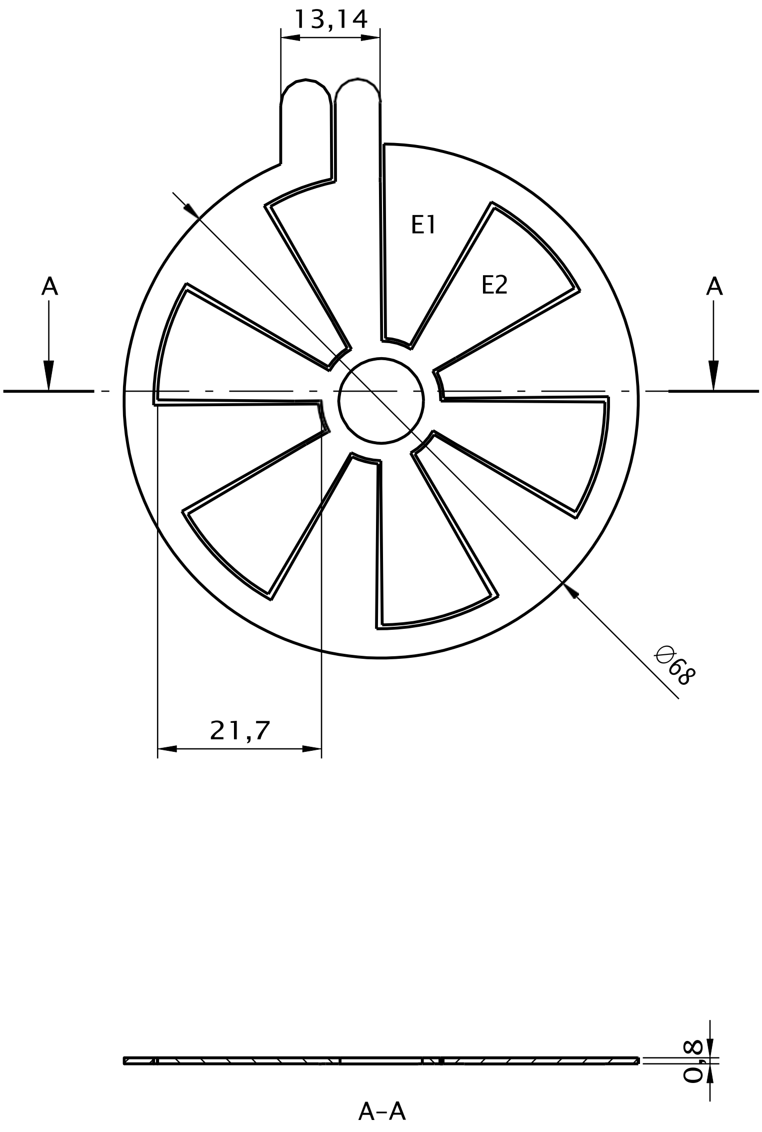


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Figure S2	mm		A4	1:1	15/05/24

Rotating Components of the WEC

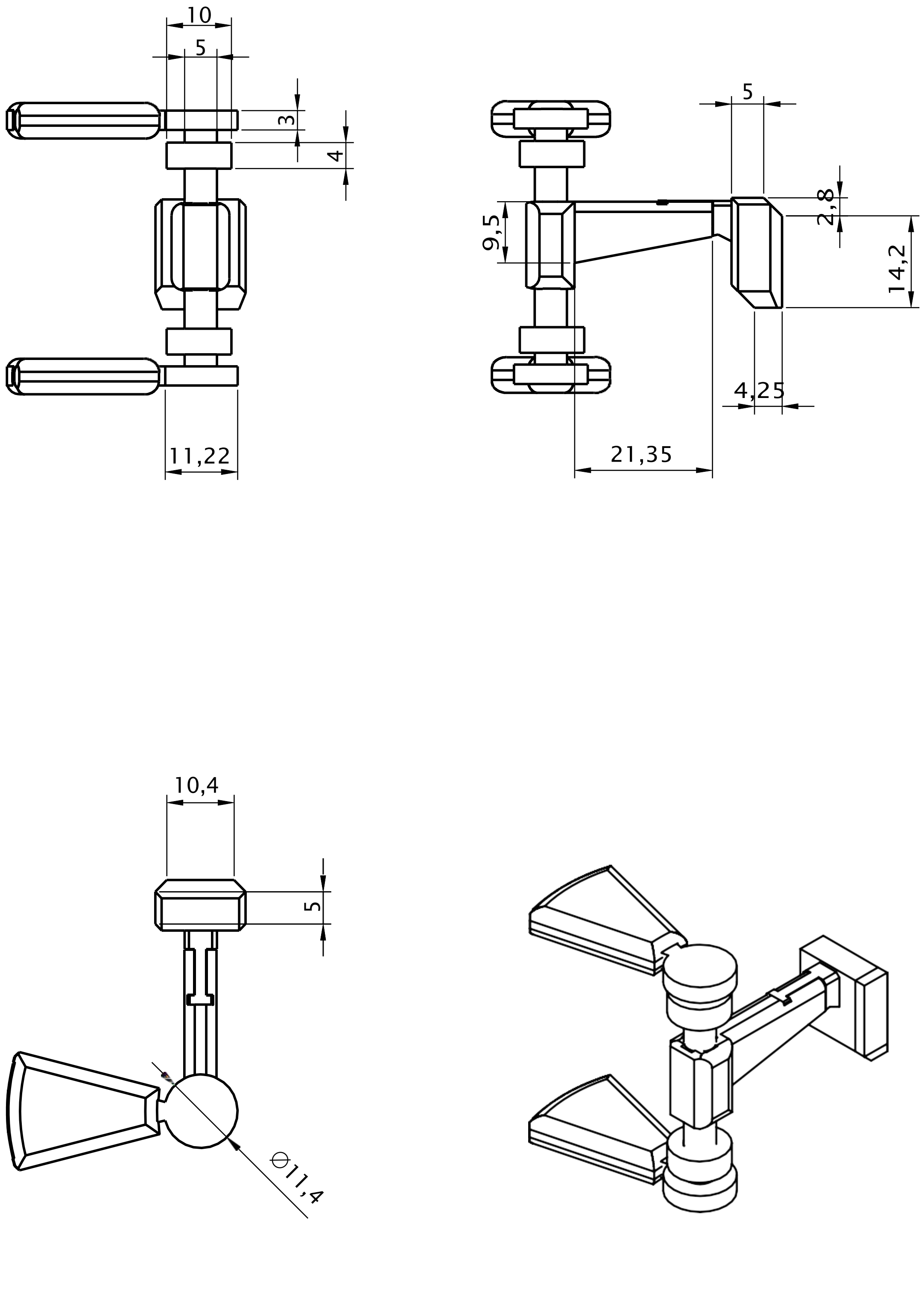

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Figure S3	mm		A4	1:1	15/05/24

Spherical Hull of the WEC

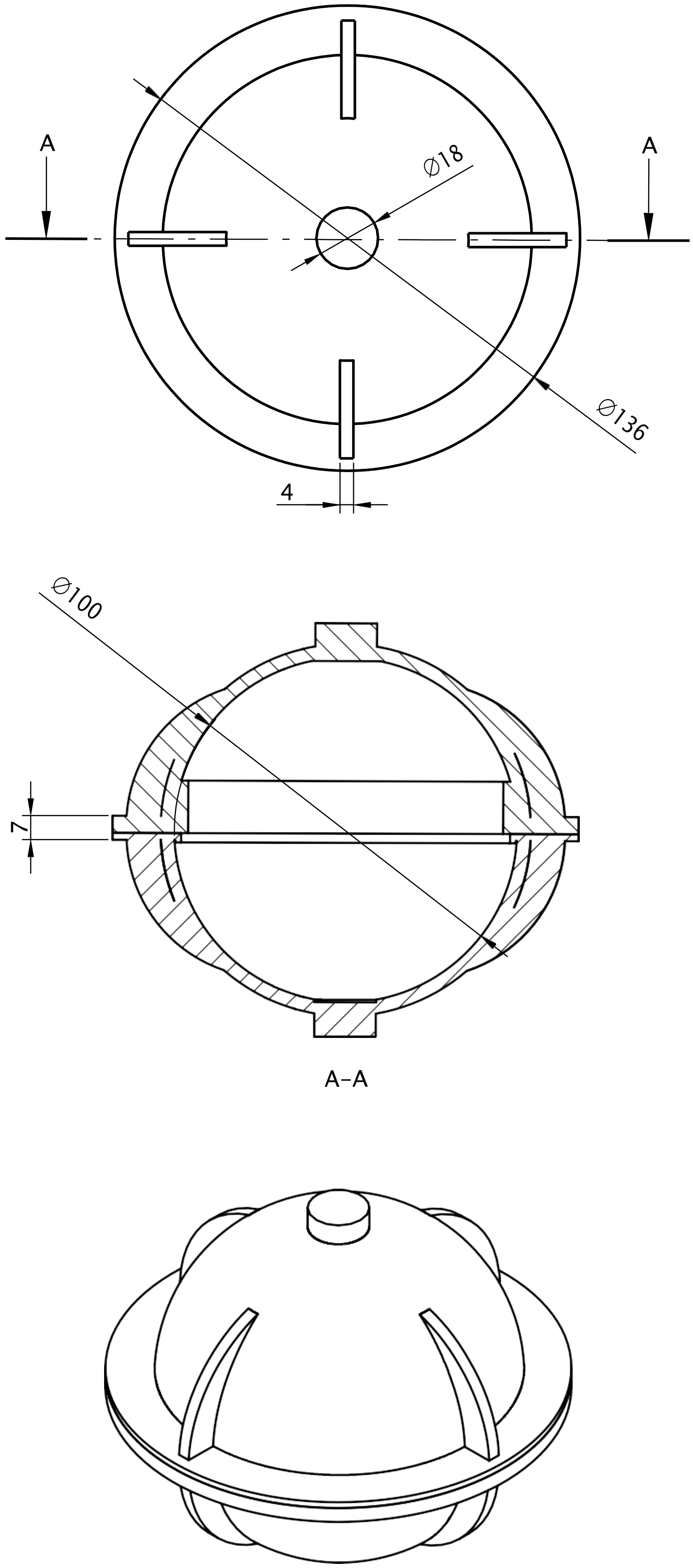

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Figure S4	mm		A4	1:2	15/05/24

Wave Tank Details

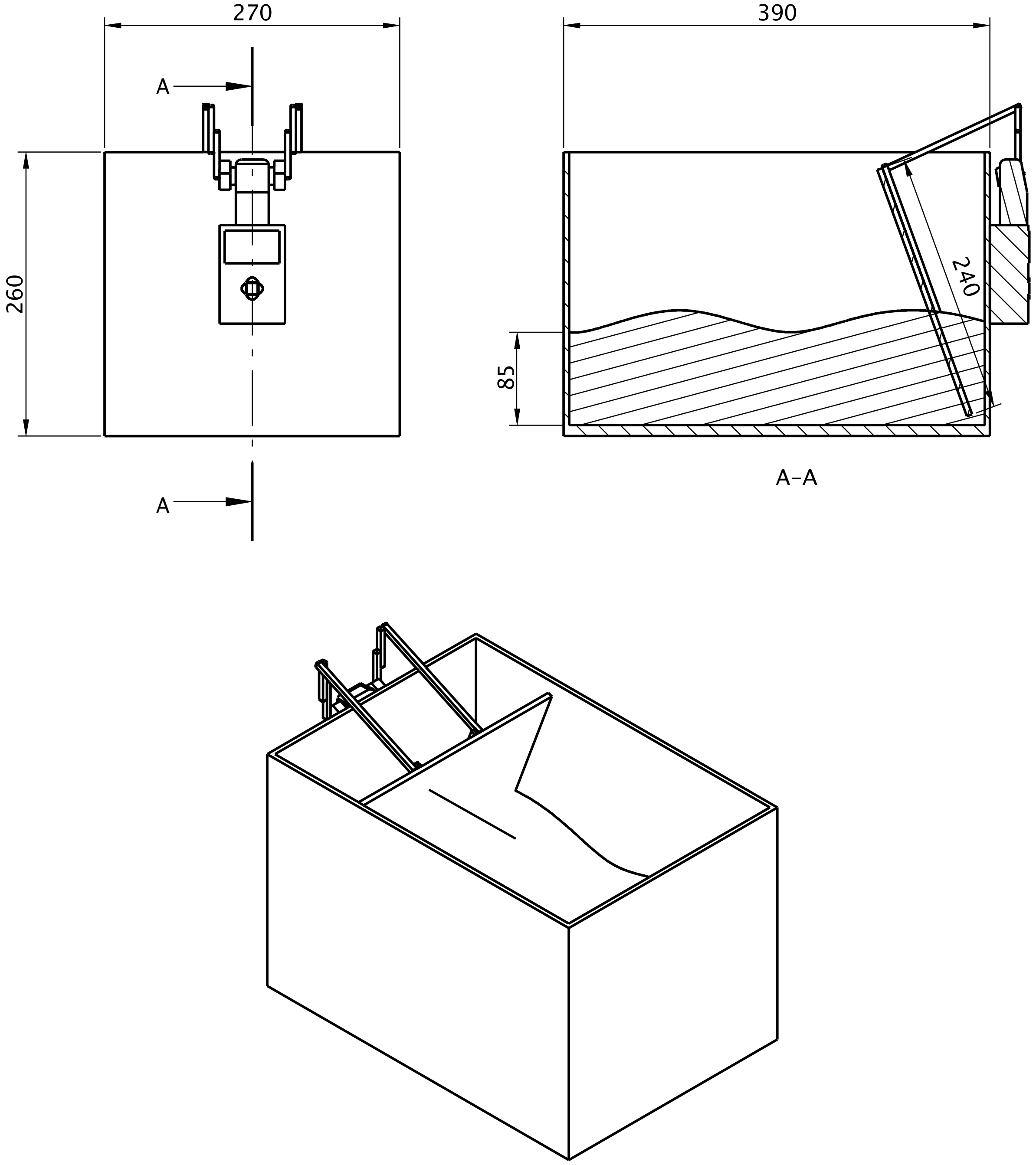

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Figure S5	mm		A4	1:6	15/05/24

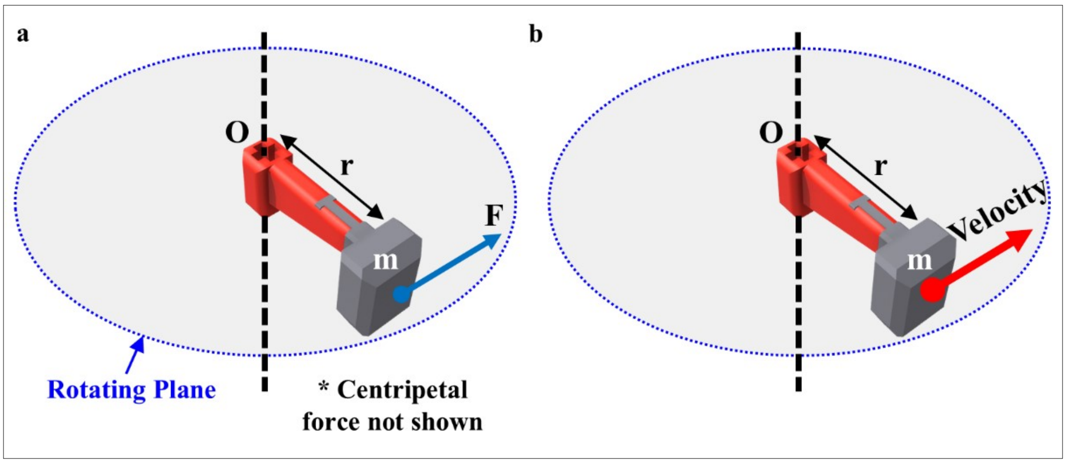

Figure S6. Oscillating weight's force analysis

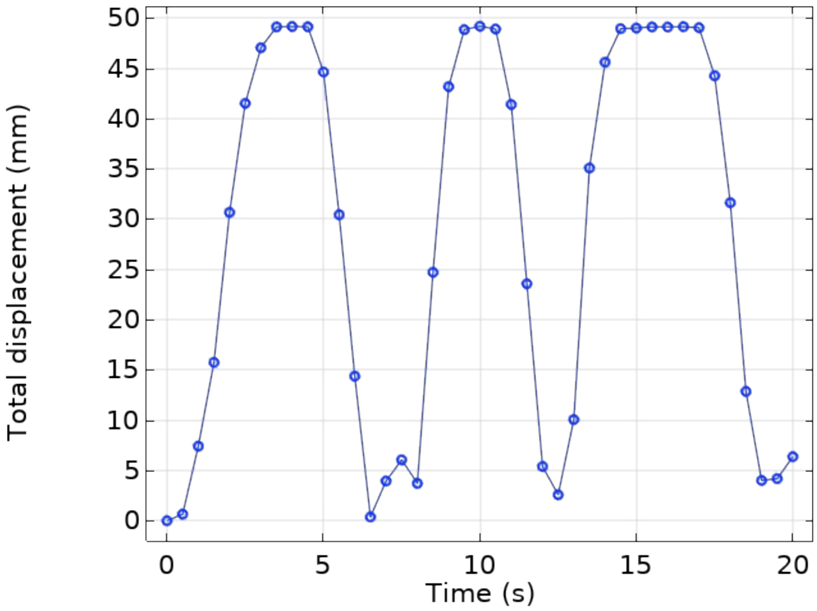

Figure S7. Oscillating weight displacement vs. time.