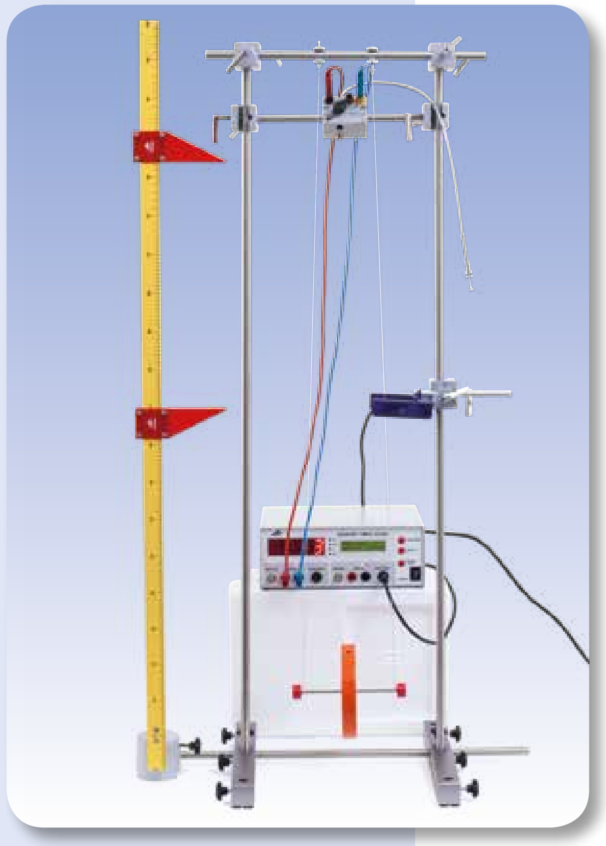
UE1040320

MAXWELL'S WHEEL



OBJECTIVE

Confirm the conservation of energy with the help of Maxwell's wheel

SUMMARY

Maxwell's wheel is suspended from threads at both ends of its axle in such a way that it can roll along the threads. In the course of its motion, potential energy is converted into kinetic energy and back again. The process of rolling up and down is repeated until the potential energy derived from the initial height of the wheel is entirely lost due to reflection losses and friction. In this experiment a photo-electric light barrier is set up at various different heights in such a way that the axle of Maxwell's wheel repeatedly breaks the beam. From the times between these interruptions of the beam it is possible to establish the instantaneous speed of the wheel and thereby to calculate its kinetic energy.

EXPERIMENT PROCEDURE

- **Plot a graph of displacement against time and another of speed against time for the first downward roll.**
- **Determine the acceleration and the moment of inertia.**
- **Determine the kinetic energy and potential energy during upward and downward motions.**
- **Confirm the conservation of energy taking into account losses due to reflection and friction.**

You can find technical information about the equipment at 3bscientific.com

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REQUIRED APPARATUS

Quantity	Description	Number
1	Maxwell's Wheel	1000790
1	Trigger Device for Maxwell's Wheel	1018075
1	Digital Counter with Interface (230 V, 50/60 Hz)	1003123 or
	Digital Counter with Interface (115 V, 50/60 Hz)	1003122
1	Photo Gate	1000563
1	Stand with H-Shaped Base	1018874
2	Stainless Steel Rod 1000 mm	1002936
5	Universal Clamp	1002830
1	Stainless Steel Rod, 400 mm, 10 mm diam.	1012847
1	Pair of Safety Experimental Leads, 75 cm, red/blue	1017718
Additionally recommended		
1	Electronic Scale 5000 g	1003434
1	Callipers, 150 mm	1002601

BASIC PRINCIPLES

Maxwell's wheel is suspended from threads at both ends of its axle in such a way that it can roll along the threads. As it moves, potential energy is increasingly converted into kinetic energy of the spinning wheel. Once the threads are fully wound out, though, they then start to wind up the opposite way round and the wheel rises, whereby the kinetic energy is converted back into potential energy until all of it is reconverted. The wheel then keeps rolling down and back up again until the potential energy derived from the initial height of the wheel is entirely lost due to reflection losses and friction.

As it rolls up and down, the wheel moves at a velocity v. The velocity obeys the following fixed relationship to the angular velocity ω with which the wheel rotates about its axle:

(1) $v = \omega \cdot r$ where r = radius of axle.

The total energy is therefore given by

(2)
$$E = m \cdot g \cdot h + \frac{1}{2} \cdot I \cdot \omega^2 + \frac{1}{2} \cdot m \cdot v^2$$
$$= m \cdot g \cdot h + \frac{1}{2} \cdot m \cdot \left(\frac{I}{m \cdot r^2} + 1\right) \cdot v^2$$

m: mass, I: moment of inertia,
h: height above lower point of reversal, g: acceleration due to gravity

This describes a translational motion with an acceleration downwards given by

(3)
$$\dot{v} = a = \frac{g}{\frac{I}{m \cdot r^2} + 1}.$$

This acceleration is determined in the experiment from the distance covered in time t

(4)
$$s = \frac{1}{2} \cdot a \cdot t^2.$$

It can also be determined from the instantaneous speed attained after a time t

(5)
$$v = a \cdot t.$$

The measurement involves setting up a photo-electric light barrier at various heights h, whereby the light beam is repeatedly broken by the axle of the wheel as it rolls up and down (see Fig. 1). A digital counter measures the time between interruptions of the beam Δt and the time t it takes the wheel to descend in its initial downward roll.

EVALUATION

If the mass of the wheel m and the radius of its axle r are known, the moment of inertia can be determined from the acceleration a. From equation (3), the following must be true:

$$I = m \cdot r^2 \cdot \left(\frac{g}{a} - 1\right).$$

The instantaneous speeds v and kinetic energies E_{kin} are calculated from the intervals between interruptions Δt as follows:

$$v = \frac{2 \cdot r}{\Delta t} \quad \text{and} \quad E_{kin} = \frac{1}{2} \cdot m \cdot \left(\frac{I}{m \cdot r^2} + 1\right) \cdot v^2.$$

The potential energy is given by

$$E_{pot} = m \cdot g \cdot h.$$

The energy losses which are clearly apparent from Fig. 4 are described quite well by assuming a constant force of friction acting in opposition to the direction of motion and an appreciable loss of energy when the direction changes at the bottom of the motion.

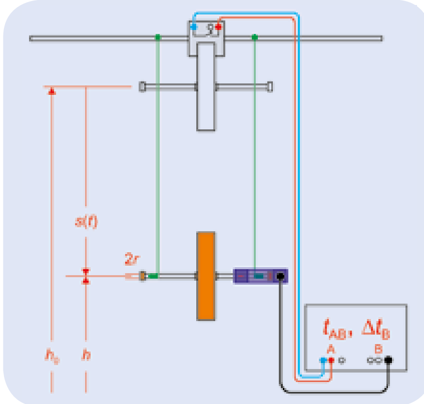

Fig. 1: Schematic of experiment set-up

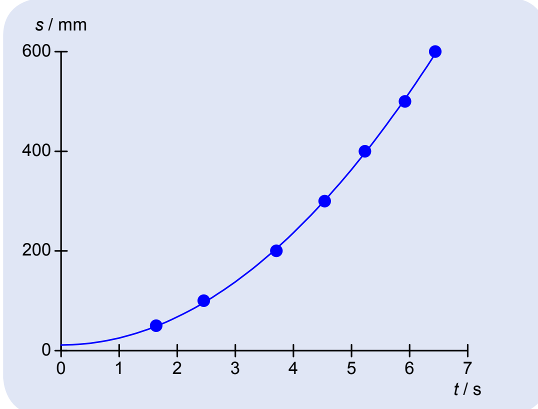

Fig. 2: Graph of displacement against time for initial downward motion

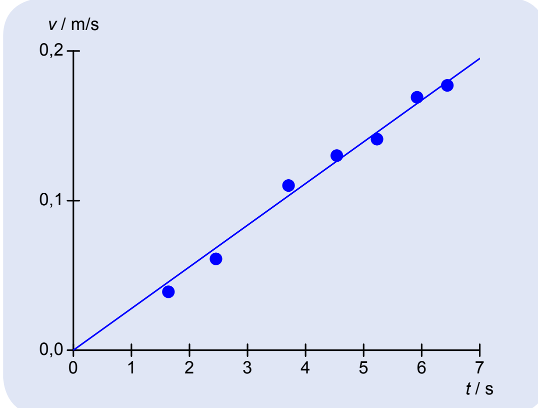

Fig. 3: Graph of speed against time for initial downward motion

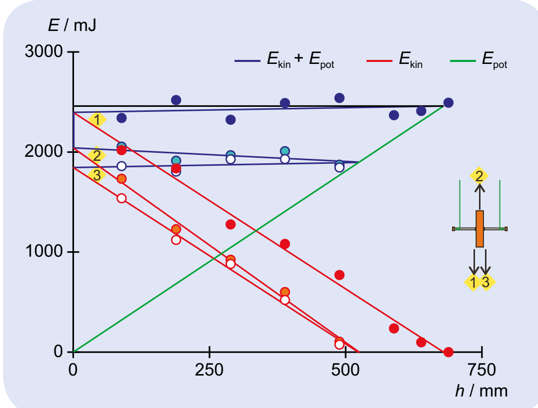

Fig. 4: Energy distribution as a function of height h

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