Team of Russia

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Problem №15 «Slow Descent»:

Design and make a device, using one sheet of A4 80 gram per m² paper that will take the longest possible time to fall to the ground through a vertical distance of 2.5m. A small amount of glue may be used. Investigate the influence of the relevant parameters.

Plan of solution

1. Short analysis
2. Methods of solution definition
3. Perfection of a devices
4. Physical model
5. Creation of devices, that meet demands of model
6. Comparison of theoretical results with practical
7. Conclusion

Short analysis

- Translational motion:

$$E_p = E_{k\ trans.} + W_{drag}$$

Methods of problem's solution

decline of velocity's vertical component

Short analysis

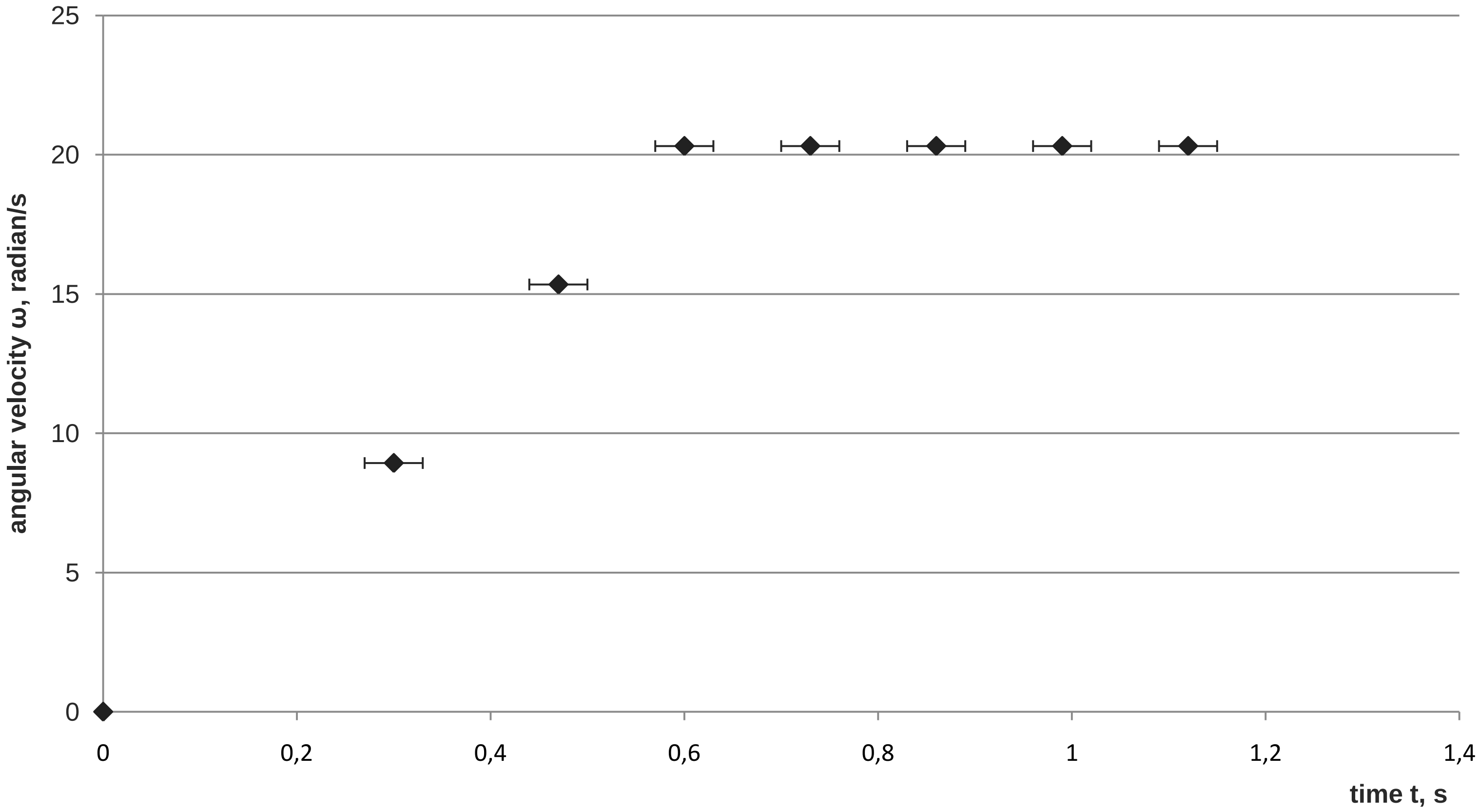
- Translational and rotational motion:

$$E_p = E_{k\ trans.} + W_{drag\ trans} + E_{k\ rotat.} + W_{drag\ rotat.}$$

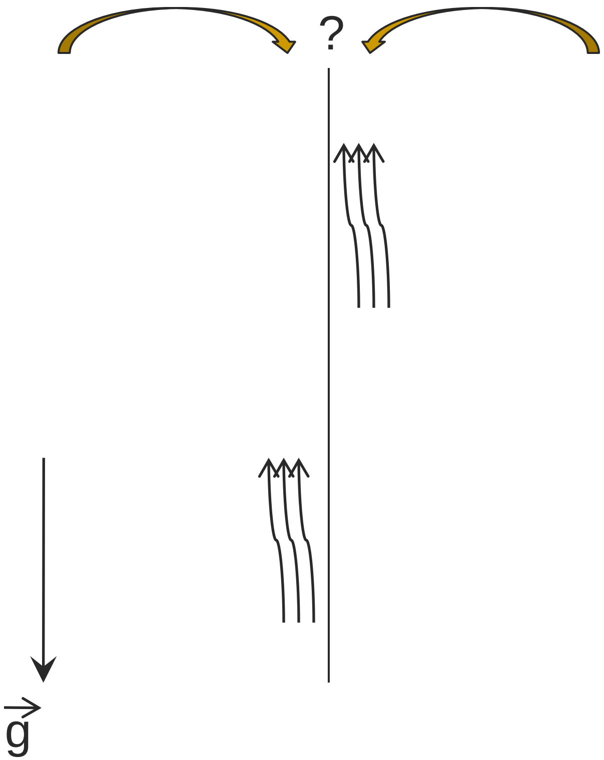
Methods of problem's solution

- decline of velocity's vertical component
- Rotation around an axis

Dependence ω(t)

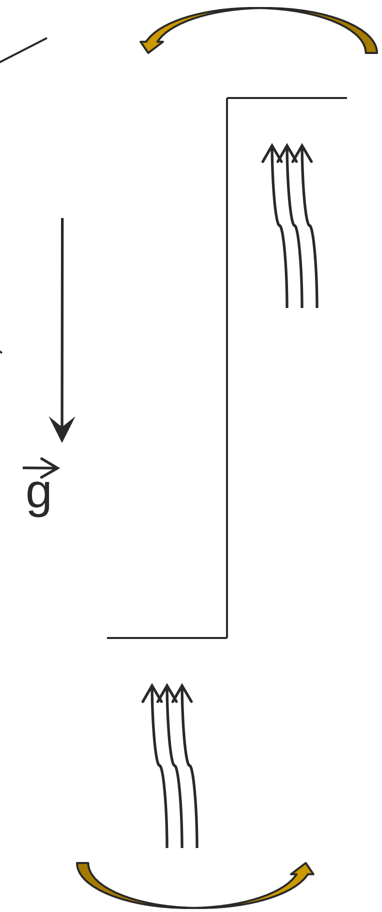


Physical model

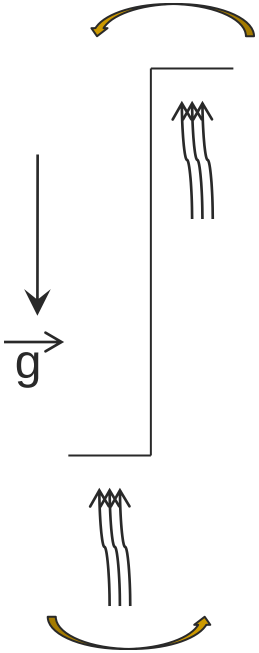


Weaknesses:

- instability
- fuzzy concept
- governed by chance

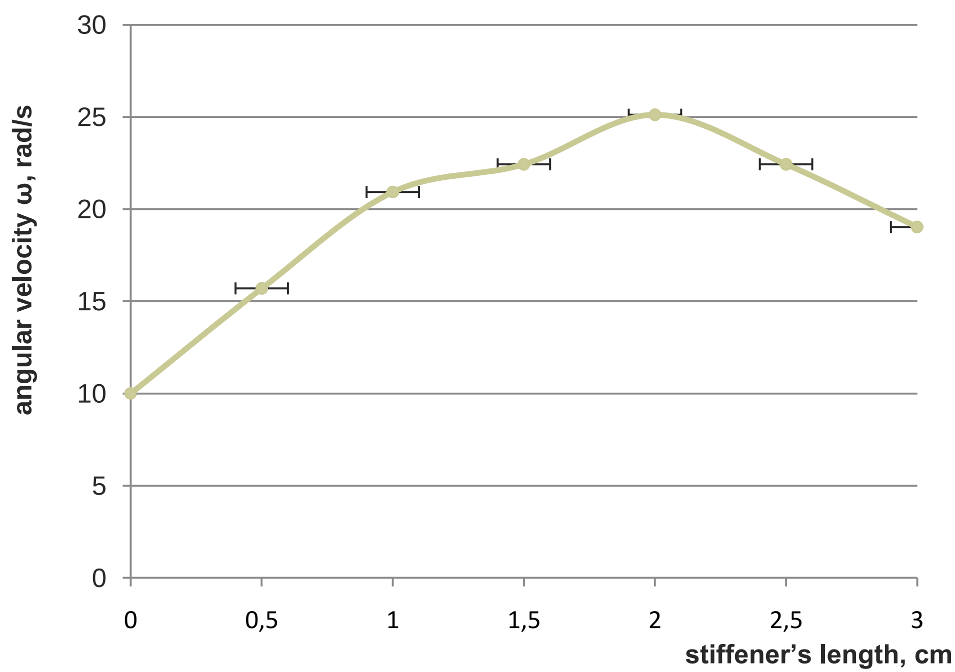


Physical model



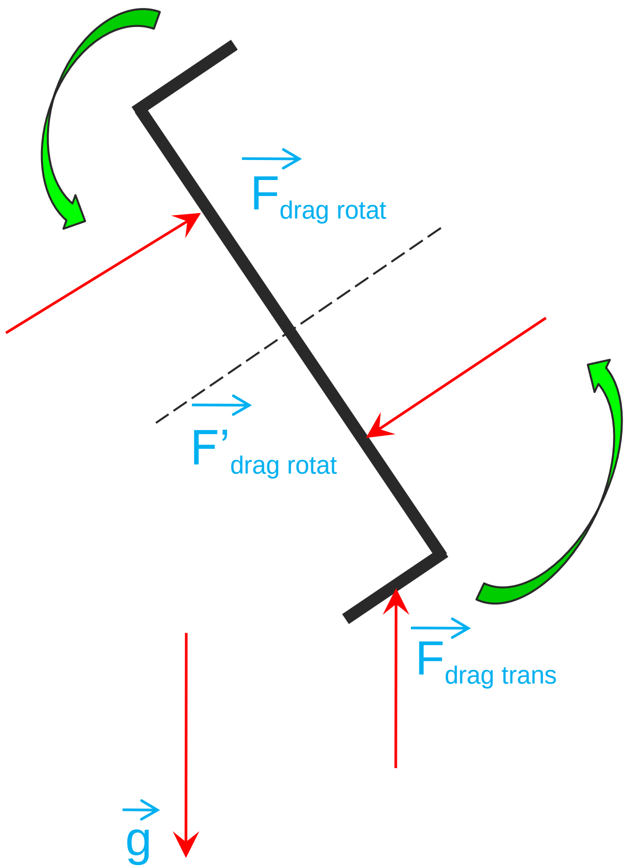
Dependence ω on length of stiffener

2 pieces; landscape	Length of stiffeners, cm	ω, rad/s
	0	10
	0,5	15,7
	1	20,93
	1,5	22,43
	2	25,12
	2,5	22,43
	3	19,03



2 pieces; landscape	Time using stiffeners	Time
	6,1	2,7
	6,2	2,9
	5,9	3,4
	5,7	3,2
	5,8	3,6
Average time	5,94 ± 0,3	3,16 ± 0,6

Physical model



Energy balance:

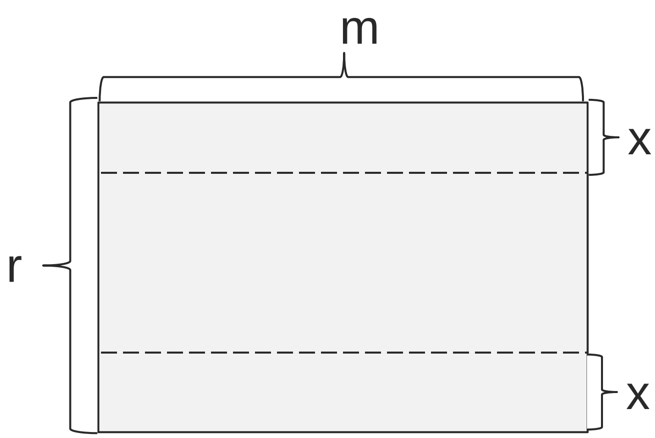
$$E_p = E_{k1} + E_{k2} + W_{drag1} + W_{drag2}$$

After some transformations:

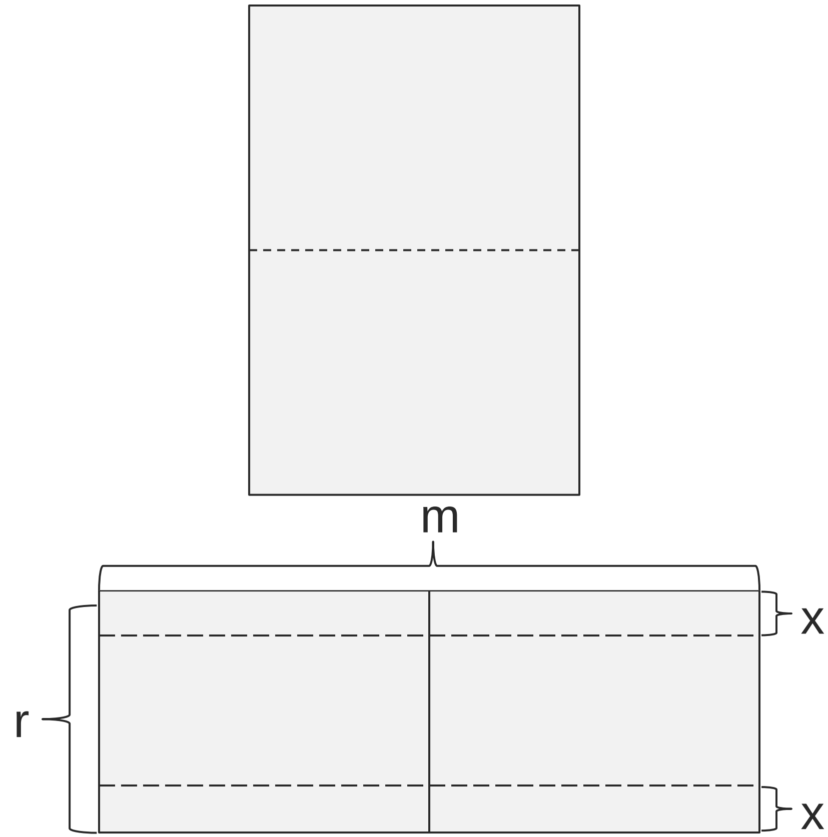
$$mgh = \frac{mv^2}{2} + \frac{m(r\omega)^2}{24} + \alpha * v^2 * S * l + \beta * (r\omega)^2 * r/4 * 2\pi * N$$

$$v = \sqrt{\frac{mgh - \beta * (r * \omega)^2 * r/4 * 2\pi * N}{m/2 + \alpha * l * S}}$$

Devices which were used and their size

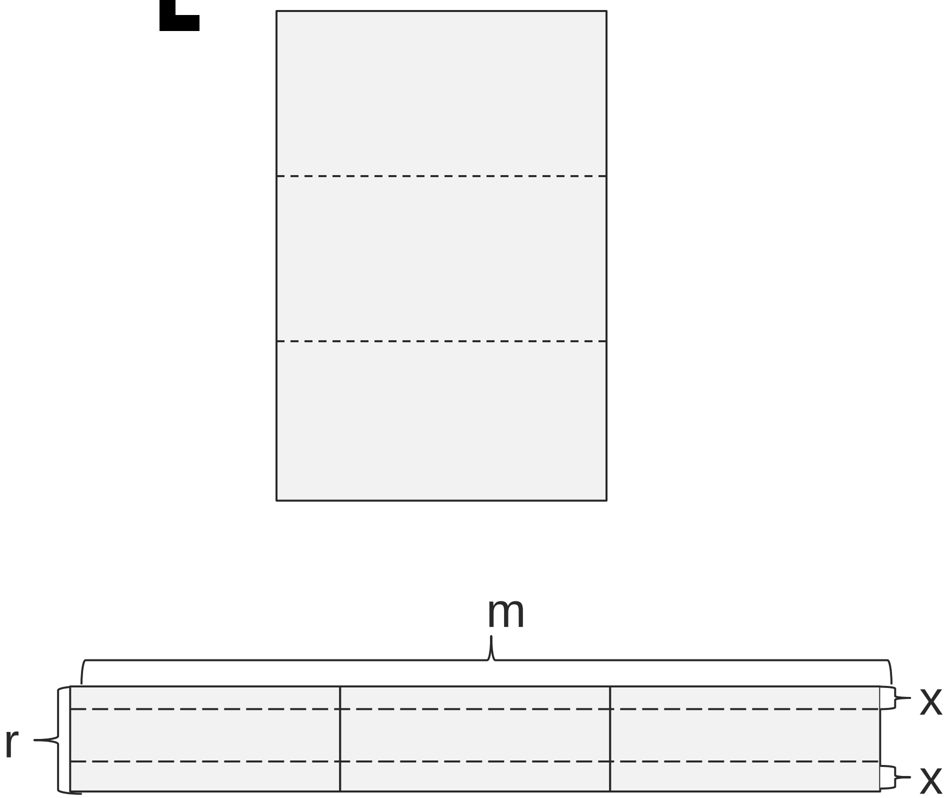


format	r, m	m, m	x cm	(ω*r)^2
A4	0,21	0,3	4	3,65

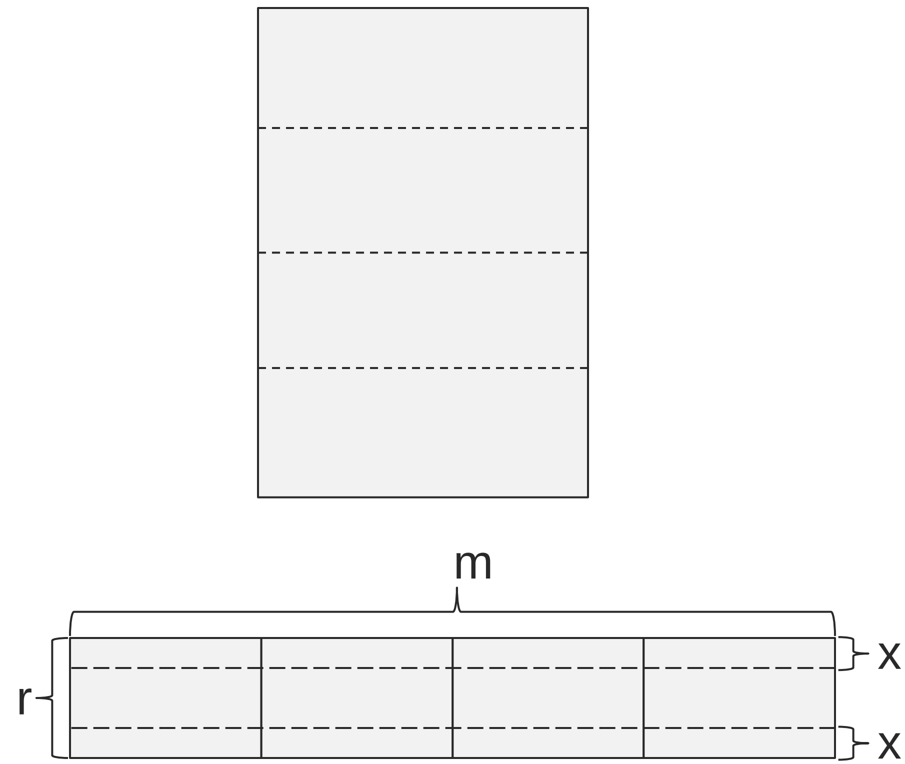


format	r m	m, m	x cm	(ω*r)^2
2 p. portrait	0,15	0,42	3	18,07

Devices which were used and their size

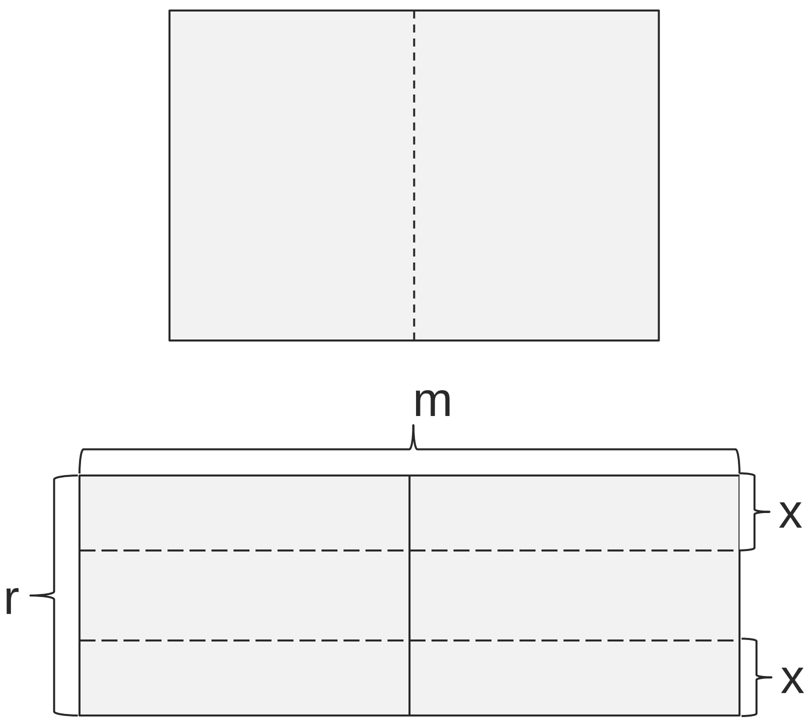


format	r m	m, m	x cm	(ω*r)^2
3 p. portrait	0,1	0,63	2	5,41

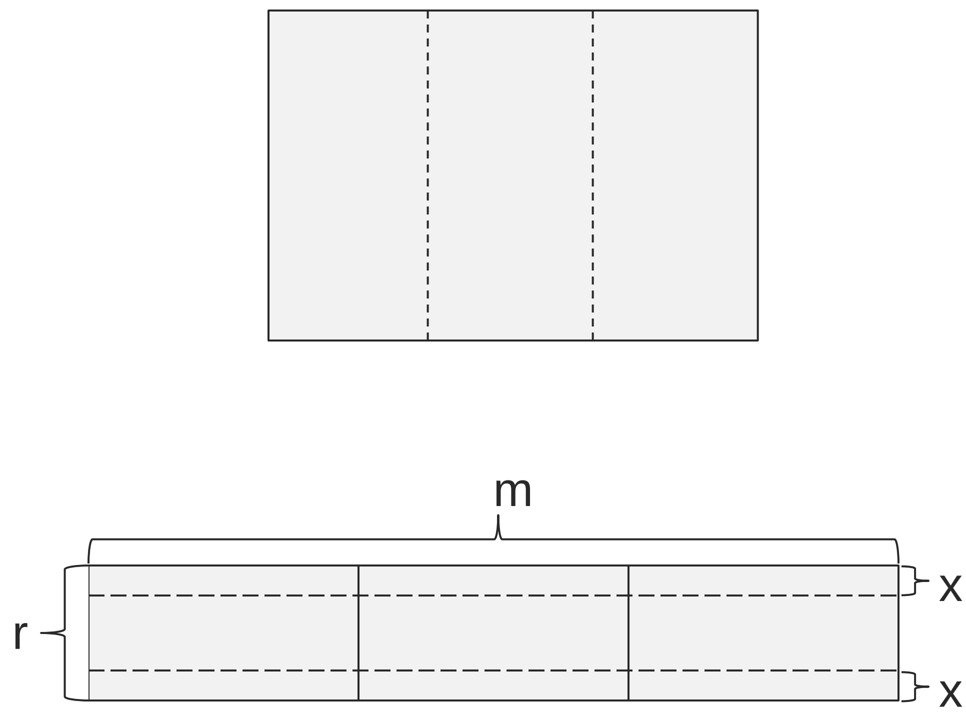


format	r m	m, m	x cm	(ω*r)^2
4 p. portrait	0,075	0,85	1,5	7,68

Devices which were used and their size

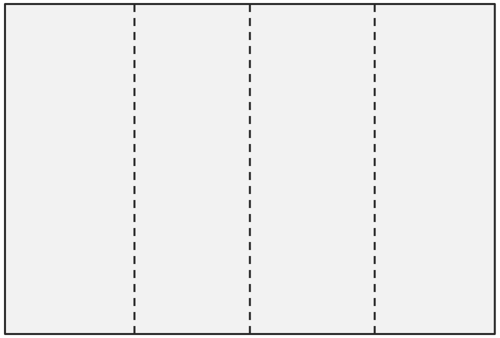


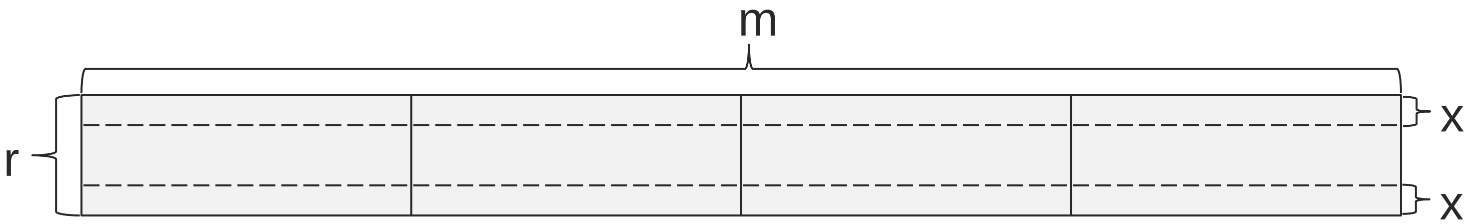
format	r m	m, m	x cm	(ω*r)^2
2 p. landsc.	0,105	0,6	2	6,96



format	r m	m, m	x cm	(ω*r)^2
3 p. landsc.	0,07	0,9	1,5	5,96

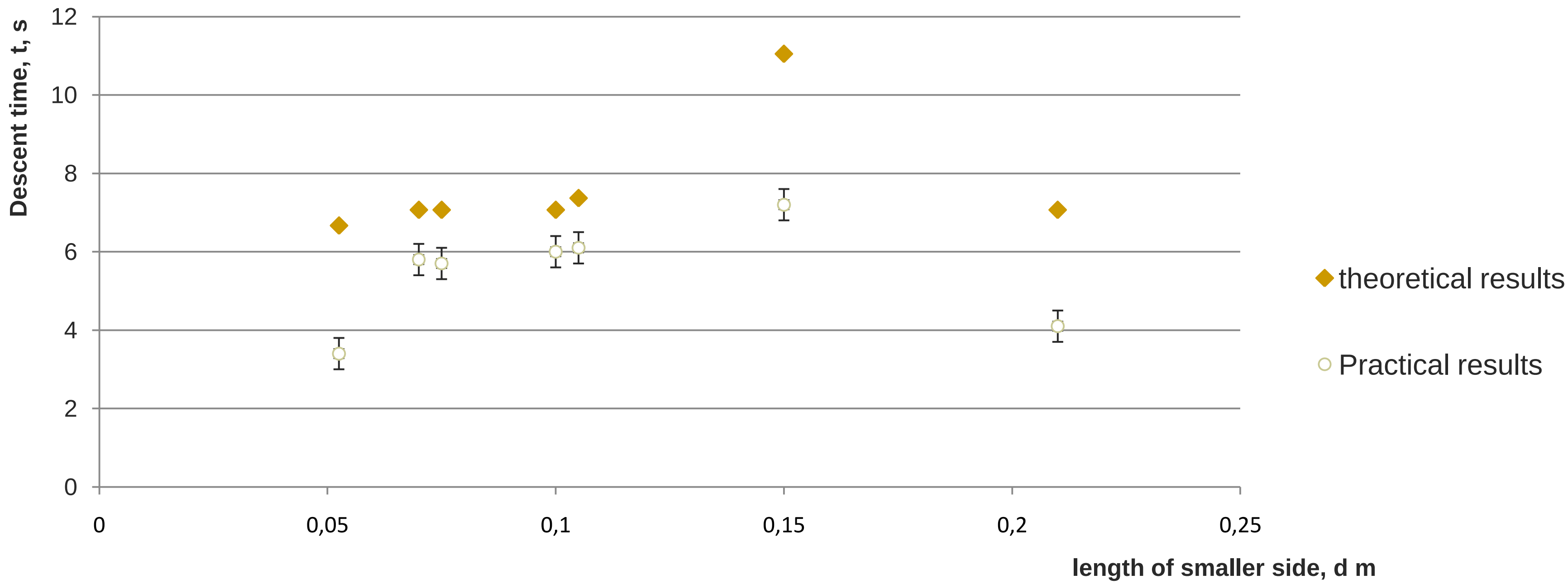
Devices which were used and their size





format	r m	m, m	x cm	(ω*r)^2
4 p. landsc.	0,0525	1,2	1	0,07

Comparison of theoretical results with practical ones



$$t = l \,/\, \sqrt{\frac{mgh - \beta * (r * \omega)^2 * r/4 * 2\pi * N}{m/2 + \alpha * l * S}}$$

Conclusion

Parameters of the device which take the longest possible time to fall to the ground through a vertical distance of 2.5m:

- length of sides 15x42 cm.
- length of stiffener 3 cm

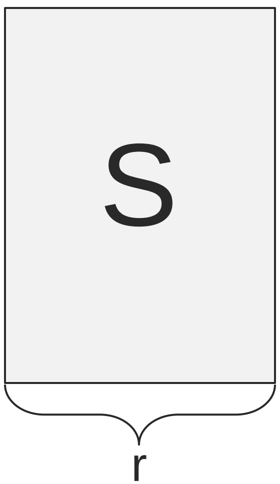
The relevant parameters:

- stiffeners
- format of device

Hidden slide

Action of $W_{F_{drag}}$

$$mgh = \frac{mv^2}{2} + \frac{I\omega^2}{2} + W_{drag\ trans} + W_{drag\ rotat}$$



$$I = \frac{mr^2}{12}$$

$$W_{f_{drag\ trans.}} = \alpha * v^2 * S * d$$

d is the distance which object has get over
v is a linear velocity of a device
S is a contact area between air and device

$$W_{drag\ rotat.} = M_f * \varphi =$$
$$= \beta * (r\omega)^2 * r/4 * 2\pi * N$$

r is a length of a smaller side
ω is an angular velocity of a device
N is a number of complete turns at full time of descent

$$mgh = \frac{mv^2}{2} + \frac{m(r\omega)^2}{24} + \alpha * v^2 * S * l + \beta * (r\omega)^2 * r/4 * 2\pi * N$$

$$v = \sqrt{\frac{mgh - \beta * (r * \omega)^2 * r/4 * 2\pi * N}{m/2 + \alpha * l * S}}$$