Co-funded by the
Erasmus+ Programme
of the European Union

11. Balls on an Elastic Band

Connect two metal balls with an elastic band, then twist the elastic band and put the balls on a table.
The balls will begin to spin in one direction, then in the other.
Explain this phenomenon and investigate how the behaviour of such a "pendulum" depends on the relevant parameters.

11. Guličky na elastickom páse

Spojte dve kovové guličky elastickým pásom, potom pás zatočte a položte guličky na stôl. Budú sa točiť najskôr do jednej strany a potom do druhej. Vysvetlite tento jav a preskúmajte, ako správanie takéhoto „kyvadla“ závisí od relevantných parametrov.

11. Balls on an Elastic Band

Connect two metal balls with an elastic band, then twist the elastic band and put the balls on a table.
The balls will begin to spin in one direction, then in the other. Explain this phenomenon and investigate how the behaviour of such a "pendulum" depends on the relevant parameters.

two metal balls

elastic band

twist the elastic band

balls on a table

balls will spin in one direction then in the other

11. Balls on an Elastic Band

Connect two metal balls with an elastic band, then twist the elastic band and put the balls on a table.
The balls will begin to spin in one direction, then in the other. Explain this phenomenon and investigate how the behaviour of such a "pendulum" depends on the relevant parameters.

Explain phenomenon

Investigate

how the **behaviour** of a **"pendulum" depends**

on the **relevant parameters**

11. Balls on an Elastic Band

How does it work?

- the twisted and shortened elastic band spins
- the balls are spinning
- the band causes circular motion
- the centrifugal force acts on the balls
- the unwinded bend is elongated
- the band exerts a force until it spins
- due to the inertia of the balls, they wind the band in opposite direction
- twisting takes energy away from the balls until they stop
- the twisted band spins ball again...

11. Balls on an Elastic Band

Basic physics

circular motion

$$F = ma_t$$

$$\omega = \frac{d\varphi}{dt} \qquad \varepsilon = \frac{d\omega}{dt} \qquad a_t = r\varepsilon$$

ω – angular velocity,

ε – angular acceleration

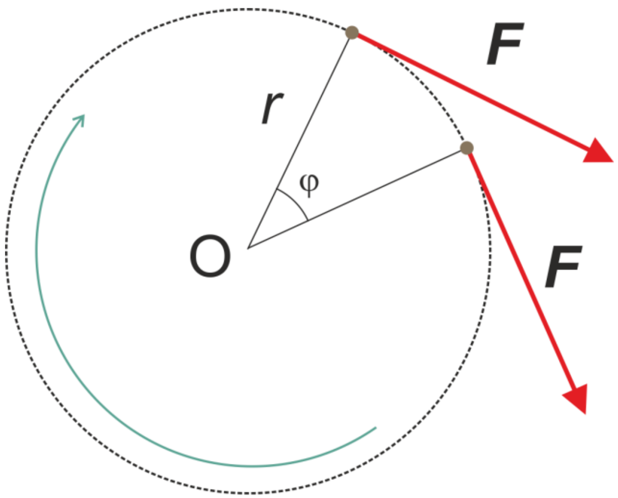
$$Fr = mr^2\varepsilon$$

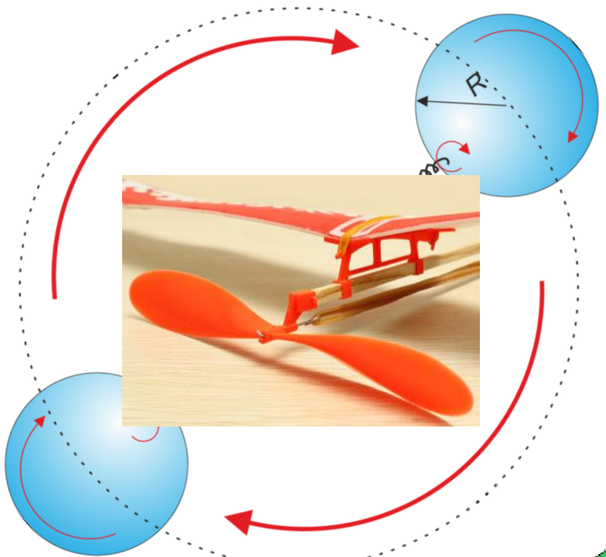
$$I = mr^2 \qquad M = Fr$$

I – moment of inertia, M – torque (moment of force)

$$M = I\varepsilon$$

- **the twisted belt acts with a torque**
  (similar to the rubber drive of the aircraft model)

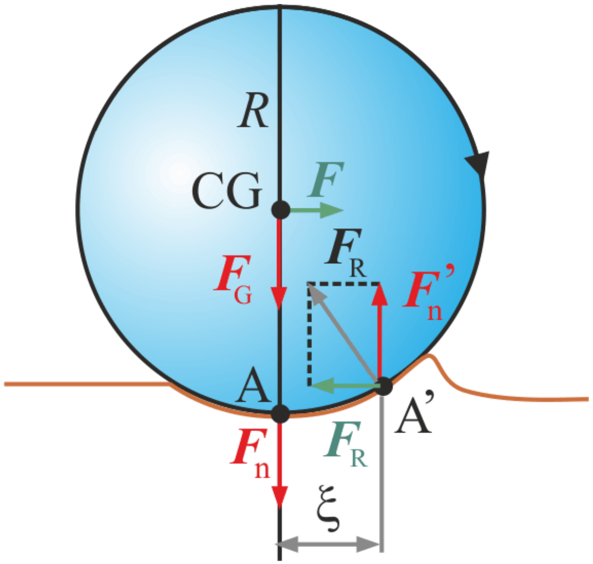




Basic physics

Rolling ball

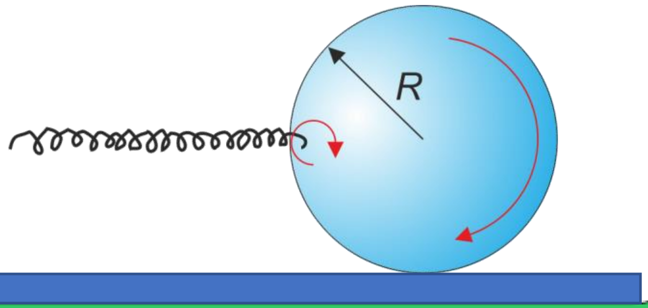
- balls are at the ends of the bend
- action - reaction forces from band
- rolling friction



$$F_R = \frac{\xi F_n}{R}$$

- the ball rolls on the table, without slipping
- static friction prevents slipping

$$F_S = \mu F_n$$



11. Balls on an Elastic Band

Basic physics

moment of inertia

$$I_{CG} = \frac{2}{5} m R^2$$

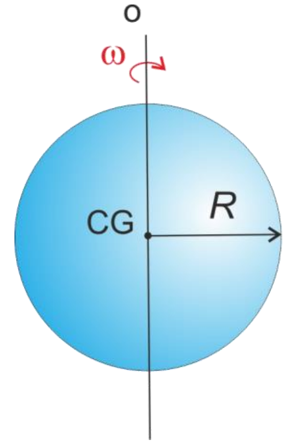
kinetic energy of ball

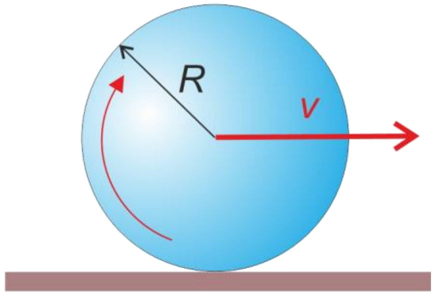
$$E_K = \frac{1}{2} m v_0^2 + \frac{1}{2} I \omega^2$$

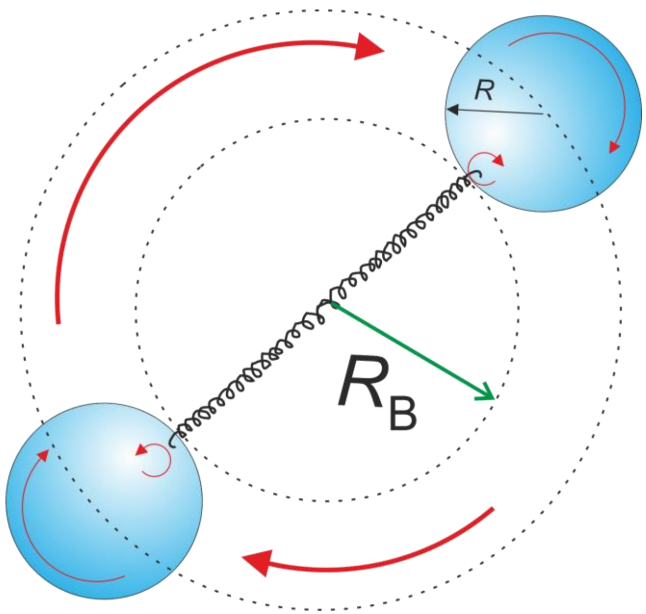
centripetal force, circular motion

$$v = \omega (R_B + R) \qquad F_C = m \frac{v^2}{(R_B + R)}$$

$$F_C = m \omega^2 (R_B + R)$$







11. Balls on an Elastic Band

Basic physics

- rotation of two balls around its center of gravity (flywheel)

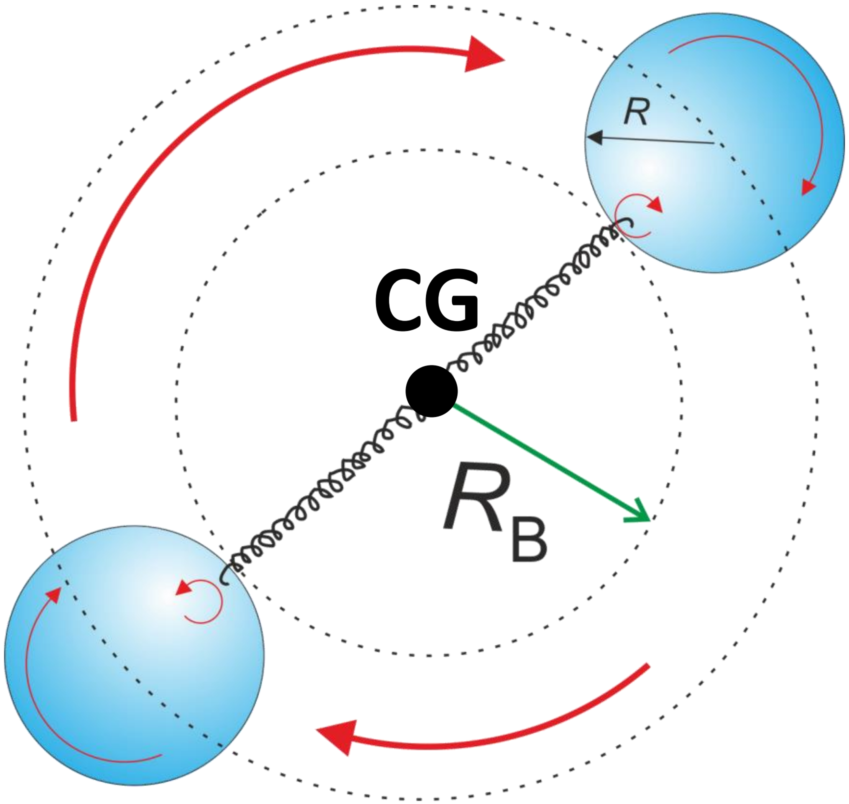
$$E_K = \frac{1}{2} 2m(R_B + R)^2 \omega^2$$

- own balls rotation

$$E_K = \frac{1}{2}\frac{2}{5} 2mR^2 \omega^2$$

- pendulum

$$F = -ky$$



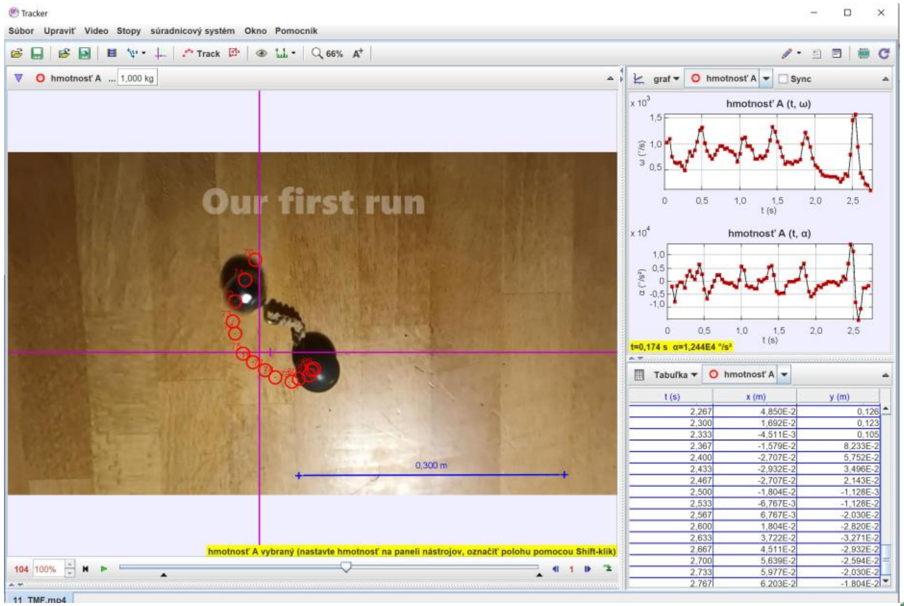
11. Balls on an Elastic Band

Behaviour of pendulum

- time dependence of angular velocity (acceleration)
- changing of band length
- period and frequency of oscillation
- energy and dumping of oscillation
- precesion
- ...

Tracker
Video Analysis and Modeling Tool

https://physlets.org/tracker/

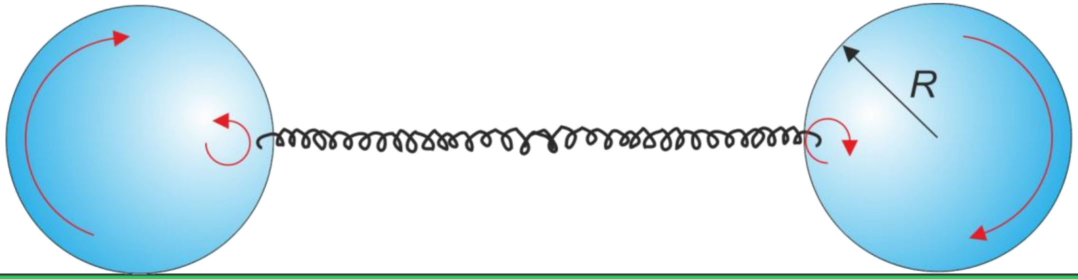


11. Balls on an Elastic Band

„Relevant“ parameters

consider

- different balls (mass, diameter, moment of inertia – hollow/full)
- elastic band (elasticity, length, number of turns)
- surface (coefficient of friction, (not) perfectly horizontal)
- ...



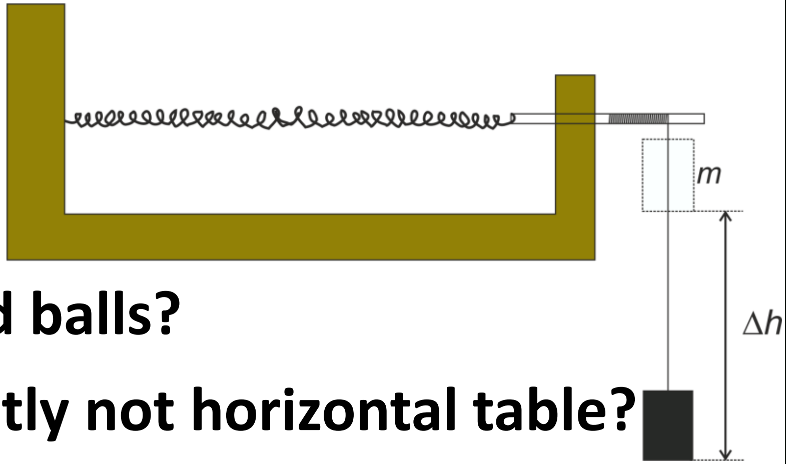
11. Balls on an Elastic Band

Possible approaches to the task

1. How much energy we put into band?
2. How does the band release energy? (IYPT 2014, 14. Rubber motor)
3. Observation and description of different ball oscillations.
4. Explanation of the phenomenon and theoretical model of oscillation.
5. Investigation of the influence of parameters on the pendulum behavior.
6. Comparison of model and experimental results.

11. Balls on an Elastic Band

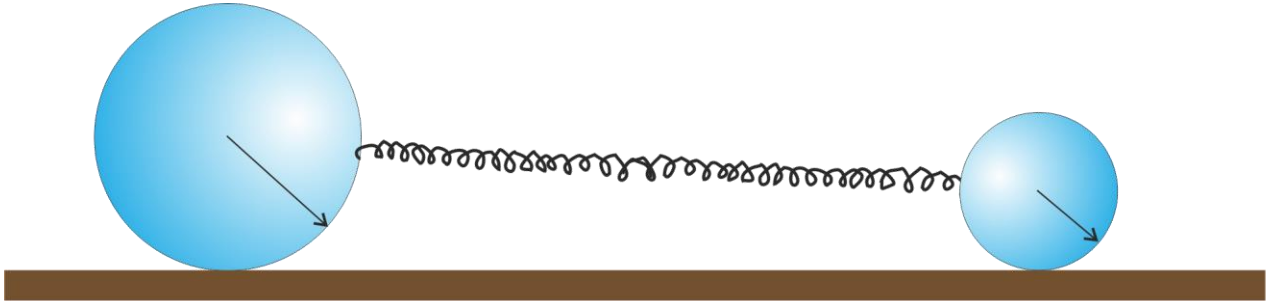
Ideas for experimentation



How much energy we put into band?

How pendulum works with diffent sized balls?

How does a pendulum behave on a gently not horizontal table?



11. Balls on an Elastic Band

Set up

11. Balls on an Elastic Band

Enjoy the fun with the task No 11

Balls on an Elastic Band