UNIVERSITÄT LEIPZIG

FAKULTÄT FÜR PHYSIK UND GEOWISSENSCHAFTEN

EXPERIMENTAL PHYSICS 1

TEST EXAM

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Date of Issue 24 of January 2023

Bonus exercises / Test exam

Name:								
Mat. No.:								
Exercise:	1	2	3	4	5	6	7	8
Points:								
Points total:						47		
Points scored:								

This exercise sheet is a bonus series that will also be a test exam. Each task is relevant to the exam and is recommended to be solved.
The test exam is for practice, you should answer the questions within 180 min. Please write your name and matriculation number on EACH sheet of paper. Use a new sheet of paper for each exercise.
All students who have not yet reached 50% to be admitted to the exam are advised to submit this series. Only the bonus series of these students will be graded. Please check your points on your own.
As always, you will receive the solutions to the bonus series after the deadline.

Useful values:

Gravity of Earth: $g = 9.807\ m \cdot s^{-2}$
Gravitational constant: $G = 6.674 \cdot 10^{-11}\ \mathrm{N} \cdot \mathrm{m}^2 \cdot \mathrm{kg}^{-2}$
Earth radius: $R_E = 6.378 \cdot 10^{6}\ \mathrm{m}$
Earth mass: $M_E = 5.972 \cdot 10^{24}\ kg$

1. General knowledge $\mathbf{1+1+2}$ Points

Give the formula or describe in one short sentence.

a. Name Newton's 3rd law!
b. In which field of physics does the Bernoulli equation find its application?
c. Write down Kepler's 3rd law!

2. Point mass $\mathbf{1+2+3}$ Points

A point mass is located at the place $(0, h)$ at time $t = 0$. The mass is shot with an initial velocity $|\vec{v}_0|$ under the angle α to the x-axis so that it moves in positive x-direction. The gravitational force $\vec{F}_G$ acts in the (-y)-direction (on Earth).

a. Sketch the situation and draw in all the given quantities!
b. Give the velocity $\vec{v}(t)$ and the position vector $\vec{r}(t)$ (vectorial equation)!
c. Derive the formula for the calculation of angle α, under which the mass must be launched, so that the mass with given $|\vec{v}_0|$ and $h = 0$ has covered the maximum distance in x-direction, when it hits the ground $(y = 0)$!

3. Energy and forces $\mathbf{1+3+6}$ Points

The potential energy of an object constrained to the x-axis is given by $U(x) = 3x^2 - 2x^2$, where U is in joules and x is in meters.

a. Determine the force F_x associated with this potential energy function.
b. Assuming no other forces act on the object, at what positions is this object in equilibrium?
c. Which of these equilibrium positions are stable and which are unstable?

4. Orbiting space station $2 + 1 + 3$ Points

A space station with a mass of 100 t is moving around the Earth on a circular orbit at a height of 100 km above the Earth's surface.

a. What is the velocity v (in m·s^{-1}) of the station?
b. How long does the satellite need for one orbit?
c. What is the kinetic, potential and total energy of the station with a reference point for the potential energy at infinity ($E_{pot}(\infty) = 0$)?

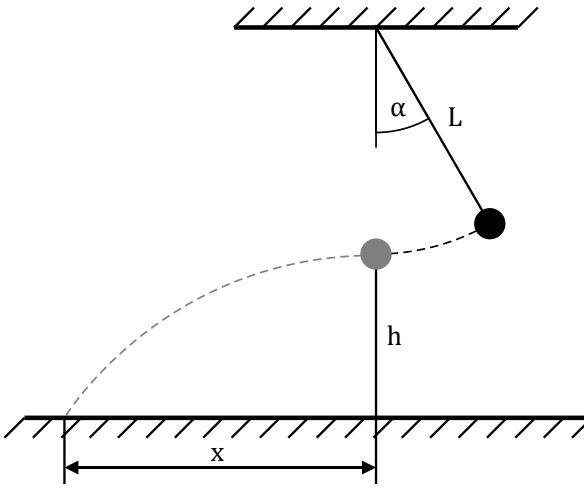
5. Rotating cylinder $1 + 4 + 1$ Points

A solid cylinder with a diameter of 60 cm is rotated by a thread wound around its circumference, from which a 2 kg mass is suspended. 12 seconds after the start of the movement, the mass has passed through a height of fall of 5.3 m and has reached a velocity of 0.88 m·s^{-1}.

a. What is the angular velocity of the cylinder after 12 s?
b. Determine the moment of inertia and the mass of the solid cylinder!
   Hint: Use the law of conservation of energy.
c. What is the angular momentum of the cylinder after 12 s?

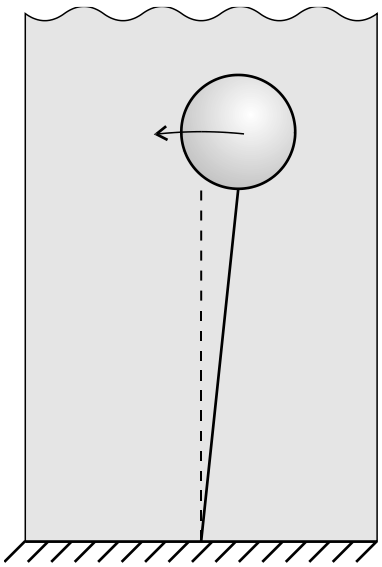
6. Pendulum collision $1 + 2 + 1$ Points

A pendulum with a length L and mass m starts at a time $t = 0$ with a velocity $v = 0$, displaced by an angle α. At the lowest point it hits another mass which sits on a pole, and an elastic collision happens.



a. How much time passes from the beginning of the movement unto the collision?
b. What are the speeds of the pendulum and the mass on the pole before and after the collision?
c. How far does the mass on the pole fly until it hits the ground?

7. Inverted Pendulum $2 + 2 + 2$ Points



An isotropic sphere ($m = 10\text{g}$) is submerged in an aqueous solution at 20°C (e.g. it can be treated as water so its viscosity is $\eta = 10^{-3}\,\frac{\text{kg}}{\text{m·s}}$). Due to buoyancy a lifting force acts on the sphere which is connected to one end of a string. The other end of the string is attached to the bottom. At $t = 0$ the sphere has a speed $v = 0$ and is displaced by an angle of 2°. It then oscillates with a frequency of $f = 0.5\text{Hz}$. After $t_1 = 20\text{s}$ the amplitude is reduced by a factor of 15.

a. What is the radius of the sphere?
b. What is the length of the tether?
c. What would change if the temperature is increased to 37°C. (Describe qualitatively. No calculations necessary.)

Hint: Assume Stokes friction for the sphere, small angles for the amplitude and neglect friction and weight for the string.

8. Spring Oscillator $2 + 1 + 1 + 1$ Points

A massless spring hangs from the ceiling with a small object attached to its lower end. The object is initially held at rest in a position y_i such that the spring is at its rest length. The object is then released from y_i and oscillates up and down, with its lowest position being $10\ \text{cm}$ below y_i.

a. What is the frequency of the oscillation?
b. What is the speed of the object when it is $80\ \text{cm}$ below the initial position?
c. An object of mass $300\ \text{g}$ is attached to the first object, after which the system oscillates with half the original frequency. What is the mass of the first object?
d. How far below y_i is the new equilibrium (rest) position with both objects attached to the spring?

Task to think about:

Is physics fun?