

I authored the following physics problems for four editions of the Italian Team Physics Competition (2023–2026). Ranging in difficulty from easy to medium-hard, my ultimate goal is to frame each problem within an engaging, cinematic narrative. Additionally, a few of them are specifically designed to be solved using dimensional analysis or numerical estimation. More problems are currently reserved for upcoming contests and are waiting to be added to this file.

The experiments of Baron Munchausen

In one of his amazing adventures, Baron Munchausen finds himself on a lake, aboard his vessel. During a moment of boredom, the Baron devised a new escape protocol in case of boarding, which consists of being launched far away, traveling sitting on a cannonball. To verify its validity, he performs test launches: after each cannon shot, he travels a bit in the air and then falls into the water and is recovered by his assistants. After 1180 launches, he is convinced of the method's reliability and returns below deck. Following the experiment, the water level has dropped by 4 mm. Knowing that the large cannonballs on the Baron's vessel are made of iron, with a density of 7874 kg/m^3 , and have a diameter of 55 cm, what is the surface area of the lake?

Captain Barbosa's Spyglass

Captain Hector Barbosa has a special spyglass made up of two thin converging lenses aligned along the same axis. The peculiarity of his instrument is that the magnification does not depend on the distance from the observed object. If the two lenses are separated by 11 cm and the focal length of the lens closest to the eyes is 1.8 cm, what is the angular magnification of the spyglass?

Descent with infinite friction

In the book *Come Ti Rovino La Fisica*, the scientists of the planet NANA-SANT invent a spray that, if sprayed on solid surfaces, makes their friction coefficient infinite. A homogeneous small sphere of mass 50 g is released from rest from the highest point of an inverted hemispherical bowl, previously sprayed with the spray and fixed to the floor. The sphere immediately starts moving with pure rolling motion, maintained until it detaches from the bowl. Assuming that the gravitational acceleration on the planet's surface is equal to that of Earth, what is the friction force acting on the sphere immediately before the detachment occurs?

Stand up!

A cylindrical container of height 1 m rests on the floor on its lateral surface. A movable partition of mass 3 kg, free to slide without friction, divides the container into two equal compartments, each containing 2×10^{-2} mol of an ideal gas. The container is slowly stood up, so that it rests on one of its bases. Assuming that the room temperature is 23°C and that both the partition and the walls of the container are perfect heat conductors, at what height from the floor does the partition stabilize?

Superman and the straw

Superman tries to drink water from a lake using a straw longer than 2 km, but fails. What is the maximum height above the lake level reached by the water in the straw?

Shrunken planet

A satellite is initially in a circular orbit of radius 4.00×10^8 m around a planet of mass 6.00×10^{24} kg. Suddenly, the mass of the planet decreases by 30%. How far is the farthest point of the satellite's new orbit from the center of the planet?

Orbit change

A particle moves on an elliptical orbit of eccentricity 0.5, under the gravitational attraction exerted by a body located at one of the two foci of the ellipse. When the particle reaches the point of maximum velocity, the attracting body is suddenly transferred to the other focus of the ellipse. What is the eccentricity of the new orbit on which the particle moves?

Relativistic collision

A particle of mass $1.0 \text{ GeV}/c^2$ moves in uniform rectilinear motion with velocity $v = 0.95c$. It collides with a second particle, initially at rest, of mass $2.0 \text{ GeV}/c^2$. The collision is completely inelastic: the two particles "merge" into a single particle. What is the mass of the latter?

Collision between satellites

A satellite moves on a circular orbit around a spherical planet of radius 2×10^3 km, lacking an atmosphere. Another satellite, with identical mass to the first, falls radially towards the planet, starting with zero velocity from a very large distance. The two satellites collide in a completely inelastic manner, merging into a single body, which moves on a new orbit tangent to the planet's surface. What was the radius of the circular orbit of the first satellite?

Gravitational acceleration outside and inside a sphere

A spherical planet of radius R with homogeneous density is located very far from any other celestial body. Given two points located at a height/depth $0 < h < R$ above and below the surface of the planet respectively, what must be the value of $\frac{R}{h}$ so that the gravitational accelerations at the two points are equal in magnitude?

Electron oscillations in a conductor

The free electrons inside a conductor can oscillate collectively with a frequency that depends only on the vacuum permittivity, the elementary charge, the electron mass, and their number density inside the conductor. Given two conductors, such that the electron density in the first is three times that in the second, what is the ratio of the oscillation frequency in the first conductor to that in the second?

Back to the future

Marco has a very peculiar clock: the hour hand rotates counterclockwise, while the minute hand rotates normally. If, at a certain instant, the two hands are perfectly overlapping, after how much time will they realign again?

Tube at the bottom of a lake

At the bottom of a lake 60 m deep, whose surface is exposed to atmospheric pressure, lies horizontally a thin tube containing a certain amount of diatomic gas. One of the two ends of the tube is sealed, while a movable piston prevents the gas from escaping from the other end. The distance between

the sealed base and the movable piston is 10 m. The walls of the tube and the piston are thermal insulators. The tube is slowly rotated and positioned vertically, so that it rests on its sealed base. Assuming the tube is long enough to allow the piston to move without falling out, by how much does the distance between the sealed base and the piston increase?

Note: assume that the gas pressure is uniform inside the tube.

Distance between graphene planes

The graphite contained in pencils consists of (more or less) parallel graphene planes. Each graphene plane is formed by a lattice of regular hexagons with a side length of 1.42×10^{-10} m. At each vertex of the lattice, there is a carbon atom, whose mass number is 12. Knowing that the density of graphite is 2.23 g/cm^3 , what is the distance between two consecutive graphene planes?

Molecules in the atmosphere

Suppose the Earth's atmosphere is composed of N identical molecules, each with a mass equal to 30 times that of a proton. What is the value of $\log_{10} N$?

Escape velocity

A satellite is launched from the Earth's surface in a radial direction, with the minimum velocity necessary to move away indefinitely. How much time is needed for it to cover a distance equal to the Earth's radius?

Note: ignore the effects of Earth's rotation and atmospheric resistance.

Globetrotter

When Lorenzo travels, he usually collects the air from the places he visits using a half-liter bottle, which he brings home for collecting purposes. Last week he was in Giza visiting the pyramids, where the pressure was equal to atmospheric pressure and the temperature was 38°C . Last year he went to Peru to visit Machu Picchu, where the pressure was 0.73 atm and the thermometer read 2°C . What is the ratio between the number of molecules contained in the bottle from the trip to Giza and those contained in the bottle from the trip to Machu Picchu?

Cylinder in a corner

A hollow cylinder of radius 2 cm is initially rotating around its axis with an angular velocity of 70 rad/s . It is gently placed and released in a corner between the floor and the wall, as shown in the figure. If the friction coefficient between the cylinder and each of the two surfaces is 0.4, after how much time will the rotation stop?

Emptying a bucket

A cylindrical bucket, with a base area A , is filled with water to an unknown height h . A hole of cross-section $S \ll A$, also unknown, is made at the bottom of the bucket. Knowing that in 20 s the bucket empties by a fraction $f = 20\%$, how much time remains before it is completely empty?

Equilibrium temperature

Generally, the specific heat of bodies is not constant. In fact, it depends on their temperature. Consider two solid bodies of masses 2 kg and 5 kg, initial temperatures 300 K and 400 K, and specific

heats αT_1^3 and $2\alpha T_2^3$, with $\alpha = 1 \times 10^{-3} \text{ J}/(\text{kg} \cdot \text{K}^4)$ and T_i being the temperature of the i -th body. Both are placed in a single closed container with perfectly insulating walls, such as not to allow any heat exchange with the external environment. What is the equilibrium temperature of the two bodies?

Hot air balloon

An inexperienced explorer is traveling in a hot air balloon, whose total mass (including the explorer) amounts to 350 kg. Some bad decisions lead the balloon to fall downwards with an acceleration of 1.5 m/s^2 . To avoid a hill on the path, the explorer gets rid of some ballast until reaching an upward acceleration of 1 m/s^2 . What is the mass of the ballast?

Gone with the wind

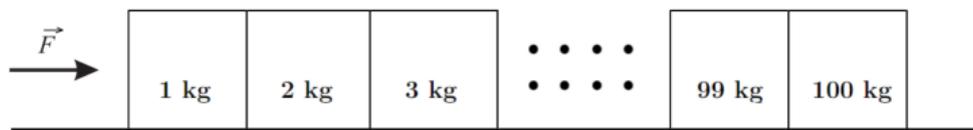
An airliner enters a 7 km long zone where a homogeneously distributed wind is blowing. When the airplane travels parallel to the wind and in the same direction, it takes 29 s at a steady speed to cover the entire stretch. When, instead, it travels in the opposite direction, it takes 35 s. What is the ratio between the speed of the airplane and that of the wind?

Fast and Furious

Fabio and Gimmy are traveling in their respective cars along the same straight road, with constant speeds of 69 km/h and 100 km/h respectively. Daniele travels on another straight road with a speed of 82 km/h, such that the distance separating him from Fabio is always equal to the distance separating him from Gimmy. At what speed does Daniele move relative to Fabio?

Conga train

Consider the system in the figure, formed by 100 boxes resting on a perfectly smooth horizontal plane. The mass of the n -th box, starting from the first on the left, is equal to $n \text{ kg}$. A force of magnitude $F = 1.0 \times 10^3 \text{ N}$ is applied to the first block in the horizontal direction. What is the force that the sixty-ninth box exerts on the seventieth?



Thomas the tank and his cousin

In a railway section, there are two straight and parallel tracks. On them, two trains of lengths 104 m and 240 m travel in opposite directions at speeds of 150 km/h and 230 km/h respectively. An observer, located very far from the tracks, sees the silhouettes of the two trains overlap for a certain amount of time. How much time passes from the moment they see the two silhouettes touch to the moment they see them separate?

Height difference in a U-tube

A U-shaped tube, with two straight vertical branches of cross-section 3 cm^2 , contains a certain amount of water. Into one of the two openings, 0.08 L of oil with a density of 920 kg/m^3 is poured. What is the absolute value of the height difference between the two free liquid surfaces?