EXPERIMENT MANUAL

Physics Pro

THAMES & KOSMOS

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››› WARNING! Only for use by children aged 10 years and older. Instructions for parents or other supervising adults are included and have to be observed.

››› WARNING! Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Strangulation hazard — long cords may become wrapped around the neck.

››› This kit contains functional sharp-pointed corners and sharp edges. Do not injure yourself!

››› Flying Wing Glider: Warning! Do not aim at eyes or face.

››› Keep the experimental kit out of reach of small children.

››› Keep the packaging and instructions as they contain important information.

3rd Edition 2012

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Photos: Werthdesign, Horb-Betra; Prof. Dr. E. Reuschel, Leipzig/FH Potsdam <www.ki-smile.de> (p. 17); Gardena AG, Ulm (p. 20); MTU Friedrichshafen (p. 20); <www.amical.de>/Ralf Dujmovits, Bühlertal (p. 27); Otto-Lilienthal-Museum/Bildarchiv, Anklam (p. 34); Research Institute for Kraftfahrtwesen and Fahrzeugbau/FKFS, Stuttgart (p. 36); Lufthansa AG/Bildarchiv, Frankfurt/Main (p. 43 t./assembly); Picture Alliance dpa (p. 48); MAFELL AG, Oberndorf a. N. (p. 48); <www.extrem-motorsport.de> (p. 51); Landesfeuerwehrschule Schleswig-Holstein (p. 57); Voith AG, Heidenheim (p. 71); Sächsische Dampfschifffahrt, Dresden (p. 75); N. Fasching, Gärtringen (p. 86); DaimlerChrysler AG, Stuttgart (p. 89), all others: Medien Kommunikation, Unna
Layout and Typesetting: Medien-Kommunikation, Unna
Packaging Design Concept (and Layout): Peter Schmidt Group GmbH, Hamburg
Packaging Photos: Andreas Klingberg, Hamburg; Thames & Kosmos

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Distributed in North America by Thames & Kosmos, LLC. Providence, RI 02903
Phone: 800-587-2872; Email: support@thamesandkosmos.com

Distributed in United Kingdom by Thames & Kosmos UK LP. Cranbrook, Kent TN17 3HE
Phone: 01580 713000; Web: www.thamesandkosmos.co.uk

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KIT CONTENTS

✔	No.	Description	Count	Item No.
❍	1	Anchor pin	40	702527
❍	2	Joint pin	12	702524
❍	3	Shaft plug	30	702525
❍	4	Shaft pin	2	702526
❍	5	Axle lock	12	702813
❍	6	Washer	12	703242
❍	7	Long frame	4	703239
❍	8	Short frame	6	703232
❍	9	Long rod	6	703235
❍	10	Short rod	6	703233
❍	11	Long axle	4	703234
❍	12	Medium axle	5	703238
❍	13	Short axle	1	703236
❍	14	Medium pulley wheel	4	702518
❍	15	Small pulley wheel	4	702519
❍	16	Large gear wheel (60 teeth)	2	702506
❍	17	Medium gear wheel (40 teeth)	4	702505
❍	18	Small gear wheel (20 teeth)	7	702504
❍	19	Baseplate	2	703237
❍	20	Crankshaft	2	702599
❍	21	XL (extra long) axle	1	703518
❍	22	Connector bridge	2	703231
❍	23	Turbine blade	16	702815

✔	No.	Description	Count	Item No.
❍	24	Rubber band (long)	1	703241
❍	25	Rubber band (medium)	1	703374
❍	26	Cotton cord (white)	1	703244
❍	28	Wheel	2	703230
❍	29	Tire ring (medium pulley wheel)	2	703251
❍	30	Anchor pin lever (Part separator tool)	1	702590
❍	31	Crank	2	703377
❍	32	Straw (red)	2	703513
❍	33	Digging shovel	1	703514
❍	34	Experiment book (not shown)	1	703510
❍	35	Measuring cup	1	703532
❍	36	Plastic strip for spring motor	1	703240
❍	37	Film for cutouts	1	703380
❍	38	Boat hull	1	703519
❍	39	Die-cut cardboard sheets	1	703522
❍	40	Hydraulic pump	1	703515
❍	41	Hydraulic switch	1	703516
❍	42	Hydraulic cylinder	4	703378
❍	43	Narrow tubing	1	703500
❍	44	Thick tubing	1	703511

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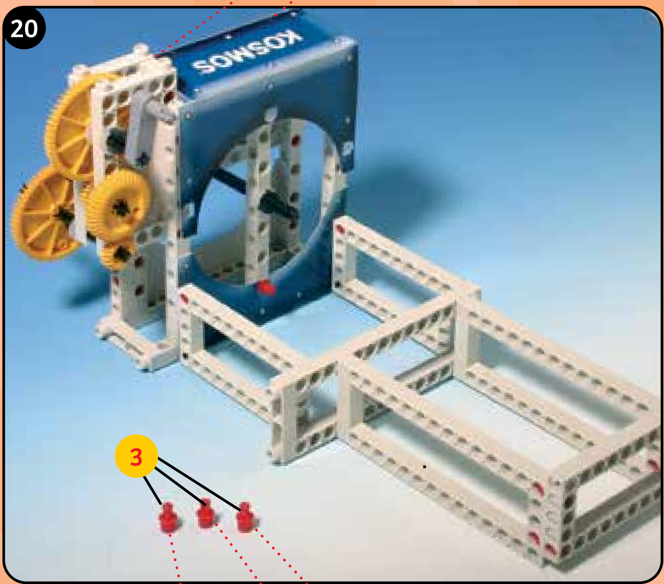
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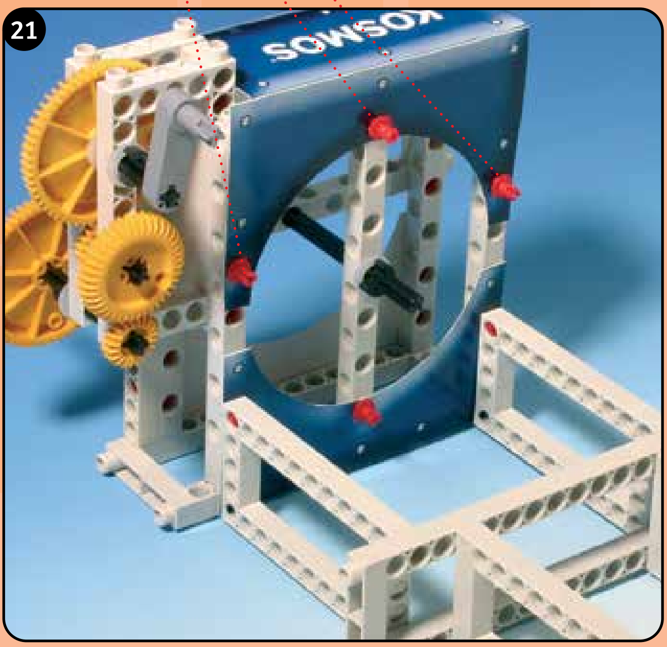
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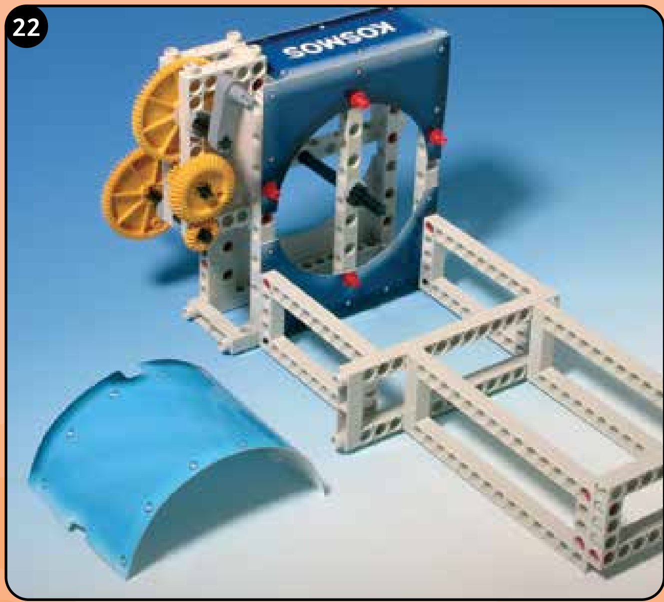
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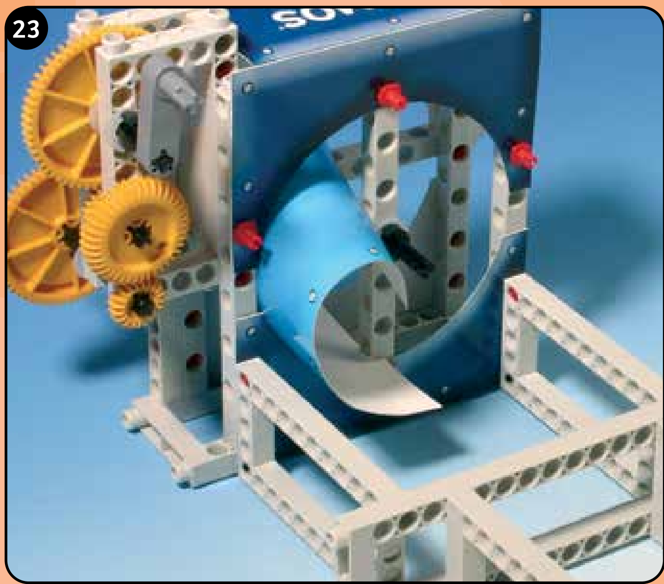
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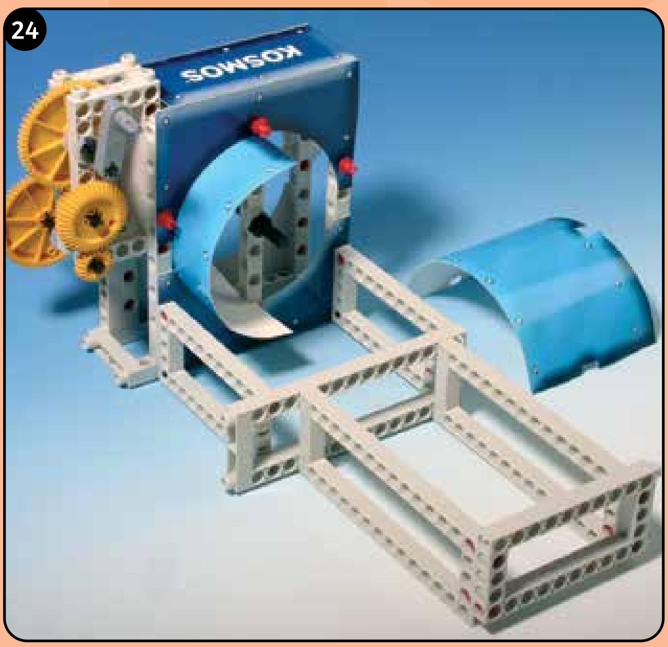
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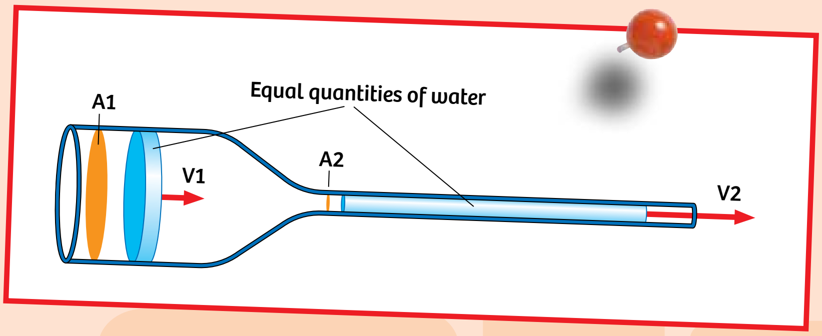
GOOD TO KNOW



THE FLOW EQUATION

If you multiply the large cross-sectional area (A_1) by the corresponding velocity (v_1), the product is the same as when you multiply the small cross-sectional area (A_2) by the velocity there (v_2).

This equation is called the flow rate equation or continuity equation:

$$A_1 \cdot v_1 = A_2 \cdot v_2$$

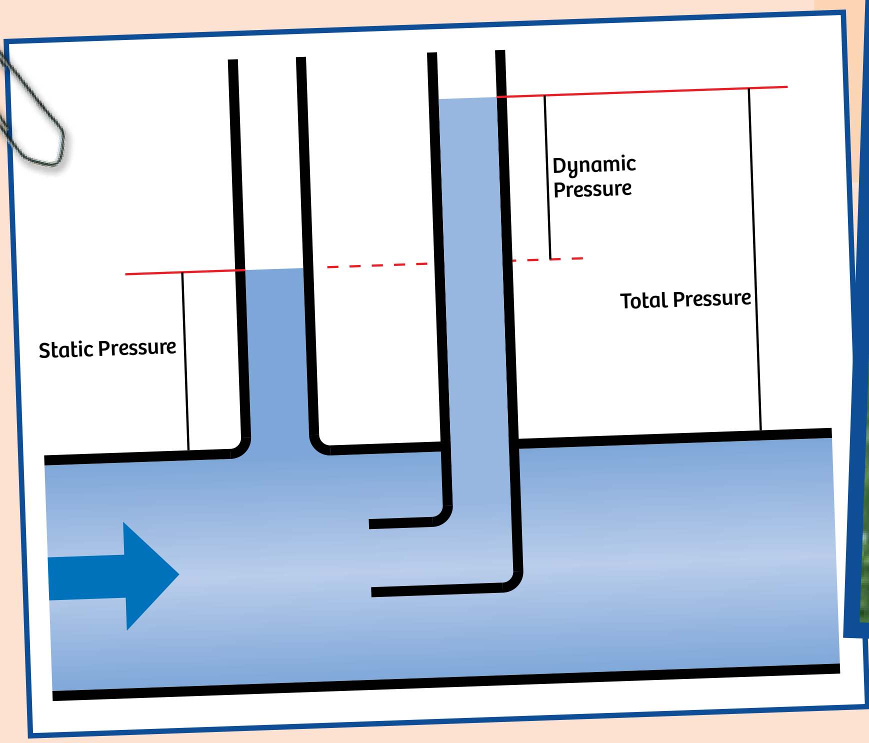
Pressure in currents

Because the speed of the water increases in the narrow part of a tube, the pressure also increases in the direction of flow. But an increase in pressure also means an increase in force per unit of area and, thus, an increase in the distance the narrower stream of water can shoot.

The pressure in the direction of flow is also called dynamic pressure, because it arises with dynamics, or the force of movement. In tubes, there is always also something called static (resting) pressure, which is a product of the difference in pressure between the entrance to and exit from the tube.

Dynamic pressure is measured against the stream, static pressure in the stream. When the liquid is resting, there is only static pressure, and the dynamic pressure is equal to zero. When movement starts, dynamic pressure rises and static pressure simultaneously drops.

That also applies in reverse. In a uniform current, in any case, the sum of the two pressures is always the same.



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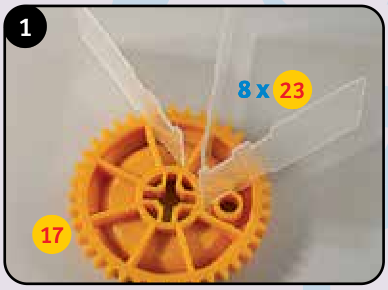
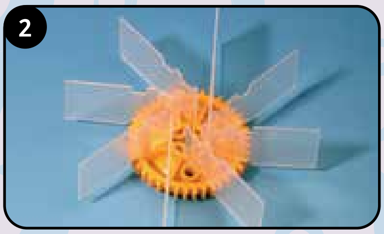
Compressed air

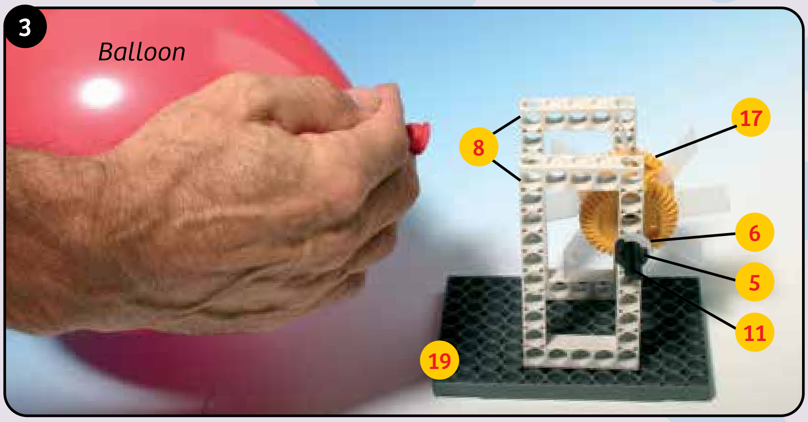
The air-filled balloon has potential energy too. You can drive a paddle wheel turbine with it.

YOU WILL NEED

- 1 Axle lock 5
- 1 Washer 6
- 2 Short frames 8
- 1 Long axle 11
- 2 Medium gear wheels 17
- 1 Baseplate 19
- 8 Turbine blades 23
- *1 Balloon*







Power is work divided by time

Work is measured independent of the time it takes to do the work. If you do the same amount of work in less time, then you exert more power doing it — whether its raising your hand in school or biking.

When you calculate power, time becomes a factor. Power is the relationship of the work performed to the time needed to do it:

$$P\ (\text{Leistung}) = \frac{W\ (\text{Arbeit})}{t\ (\text{Zeit})}$$

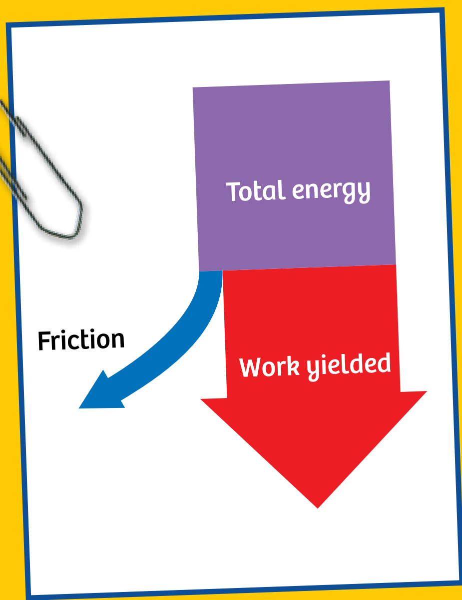
The unit of measure for power P is the watt (W):

$$1\ W = \frac{1\ J}{1\ s}$$

In addition to watts, kilowatts (1 kW = 1,000 W) and megawatts (1 mW = 1,000,000 W) are also used as units of power. The engine of a mid-sized car handles about 60 kW. A human can perform about 200 watts of physical work over a long period of time, while a cyclist with a bicycle can get to 1,500 watts fairly quickly.

CONSERVATION OF ENERGY

Not all of the potential energy of the water is converted into hammer beats in our gravity hammer experiment. Part of it is used up by friction in the axle seats, the pulley wheels, and the hammer shaft. In this process, it is only lost as far as the hammering is concerned. If you add up the work from the friction and the hammering, it equals the energy you started with.



In other words, **the conservation of energy law** applies:

In a closed mechanical system, no energy is lost. Energy can be neither created nor destroyed. It can only be converted. The sum of the mechanical energy remains the same (constant).

CAR WITH HYDRAULIC BRAKES

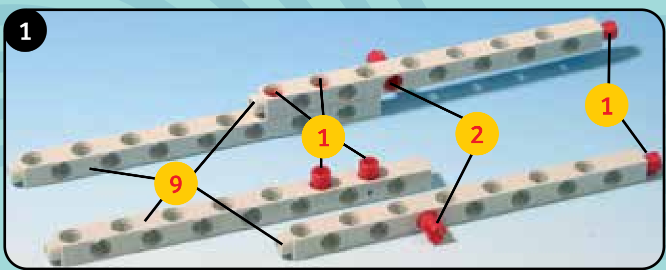
Every vehicle should be able to brake. As their main braking device, passenger cars have a hydraulically activated foot brake. Its hydraulic mechanism consists of a cylinder that transfers force from the brake pedal to the main cylinder. From there, the braking force is transferred equally by separate pathways to the braking cylinders on the wheels. Big and heavy vehicles, e.g. a tour bus or dredger, have so-called servo brakes, which amplify the braking force through a pump.

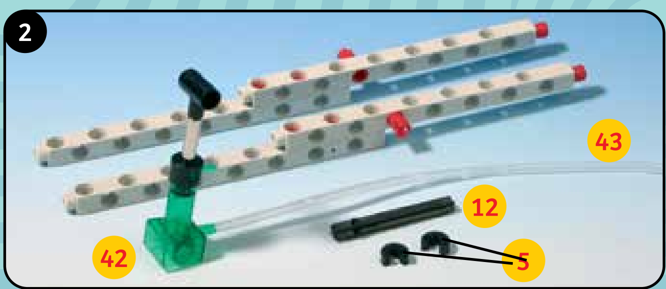
This model is like the racing car model (page 89) — but without the drive spring. Test the hydraulic brake by pushing against the car's brake pedal (the front pair of rods). Push the pedal down to activate the brake. That pulls the rear pair of rods down onto the tires. Water will serve as the hydraulic fluid. You will see in Experiments 1 and 2 (on pages 10 and 11) how to fill it without air bubbles.

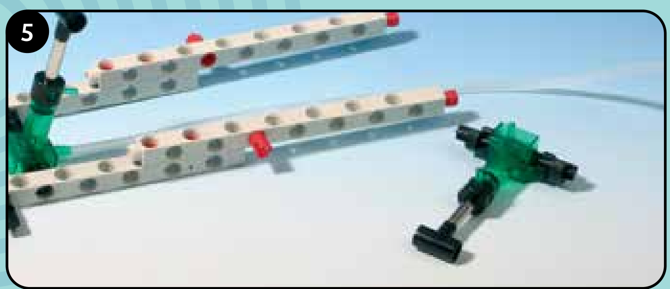
> See Pages 10-11 and 20-22

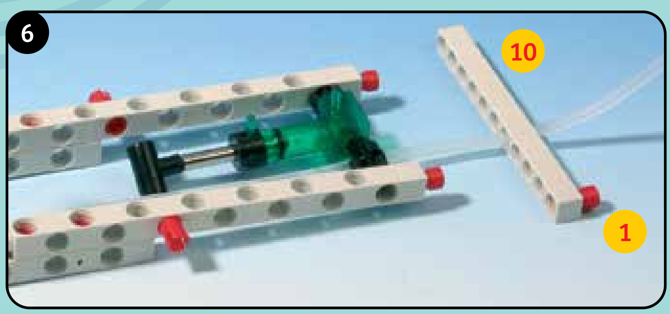
YOU WILL NEED

- 8 Anchor pins 1
- 4 Joint pins 2
- 2 Shaft plugs 3
- 10 Axle locks 5
- 8 Washers 6
- 1 Short frame 8
- 4 Long rods 9
- 6 Short rods 10
- 4 Long axles 11
- 3 Medium axles 12
- 2 Medium pulleys 14
- 2 Large gear wheels 16
- 2 Small gear wheels 18
- 1 XL (extra long) axle 21
- 1 Rubber band (medium) 25
- 2 Wheels 28
- 2 Tire rings for pulleys 29
- 2 Hydraulic cylinders 42
- 1 Piece of narrow tubing 43









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Solutions to the Quiz:

Question 1 Answer B is right. The balloon retained its weight. The mass (the quantity of molecules) of the enclosed air did not change. The balloon's rubber also weighs the same as before.

Question 2 Answer B is right. The weight of the board and Max's weight total 72 kg, distributed over a surface area of 0.6 m x 1.8 m = 1.08 m^2. Since pressure equals force divided by area and the unit for pressure, 1 Pa, equals N/m^2, Max and the board press down with a weight of 72 x 9.81 = 709 N on a surface area of 1.08 m^2; so everywhere in the air mattress, including the inlet, they produce a pressure of 706 / 1.08 = 653 Pa. You are countering this pressure with 4,000 Pa: So you can lift everything up quite easily by blowing — even if only by fractions of a millimeter with each breath!

Question 3 Answer C is right. With the same hull shape and the same ship weight, both hulls submerge equally far and displace the same amount of water. Therefore, their buoyancy is also equal.

Question 4 Answer A is right. By the flow rate equation, the same quantity of water has to flow through the hose and the nozzle per second. Since the nozzle's cross-sectional area is four times as small as the cross-sectional area of the hose, the water has to flow four times as fast, i.e. 16 m/s, through the nozzle as through the hose.

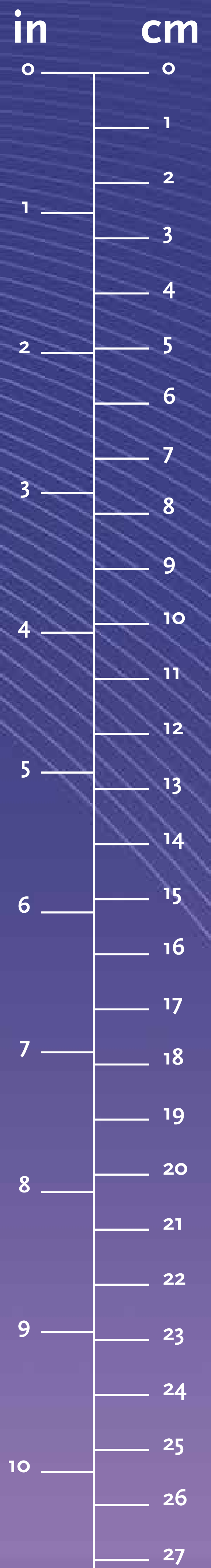
Question 5 We will use the formula $F_d = C_d \cdot A \cdot r \cdot v^2$ and insert values:
$C_d = 0.3$; $A = 0.2\ m^2$; $r = 1{,}000\ kg/m^3$; $v = 3\ m/s$
$F_d = 0.3 \cdot 0.2 \cdot 1{,}000 \cdot 9 = 540\ N$

Question 6 Answer B is right. The equation is as follows:
mass (m) · acceleration due to gravity (9.81 m/s^2) x distance (d) = work (w)
45 · 9.81 · 30 = 13,243.5 J (or newton meters Nm)

Question 7 Answer C is right. Let's calculate:

$$\text{Power (P) [watts]} = \frac{\text{distance (s) [in meters]} \cdot \text{mass (m) [in kilograms]} \cdot \text{weight (9.81 N)}}{\text{time (t) [seconds]}}$$

$$P = \frac{3 \cdot 50 \cdot 9.81}{12} = 123 \text{ watts}$$ (the exact value is: 122.625 W)



Important Units of Measure in Physics

The unit for length is the meter [1 m].
1 meter = 1,000 millimeters [mm] = 100 centimeters [cm]
1,000 meters = 1 kilometer [km]

The unit for volume is the cubic meter [1 m^3].
That corresponds to a cube with sides 1 m in length.
1 m^3 = 1,000 liters
1 liter = 1 cubic decimeter [dm^3] = 1,000 milliliter [ml] or 1,000 cubic centimeters [cm^3]

The unit for time is the second [s].
1 hour [h] = 60 minutes [min] = 3,600 seconds [s]

The unit for mass is the kilogram [kg].
1 kilogram = 1,000 grams [g] = 1,000,000 milligrams [mg]

The unit for speed is meters per second [m/s].
Speed is also measured in kilometers per hour [km/h].
This unit indicates the distance covered in a certain time.

The unit for force is the newton [N].
1 N is the force needed to accelerate a mass of 1 kg by 1 m/s per second.

The unit for weight is likewise the newton [N].
In everyday situations we use the kilogram. The weight acting on a mass of 1 kg equals 9.81 N on the Earth's surface.

The units for work and energy are the same: both are indicated in joules [J]. The energy of one joule [J] corresponds to the work performed when the point of contact of a force of 1 N is moved a distance of 1 m in the direction of this force.
1 joule [J] = 1 newton meter = 1 watt second [Ws]

The unit for power is the watt [W].
1 watt is the power produced by 1 joule [J] of work performed within 1 second [s], or with which 1 J of energy is realized in 1 s.

The unit for temperature is the degree Celsius [°C]. For thermodynamic (absolute) temperature, the unit Kelvin [K] is used.
Zero Kelvin [K] = minus 273.15 degrees Celsius [°C] = absolute zero (starting point of the thermodynamic temperature scale)
Zero degrees Celsius [°C] = freezing point of water

The unit for pressure is the pascal [Pa].
The pressure of 1 pascal [Pa] arises when the force of 1 newton [N] is exerted on a surface area of 1 m^2. The older unit bar [bar] is easy to convert into pascals:
1 pascal [Pa] = 0.01 millibar [mbar] = 0.00001 bar
1 bar = 1,000 hectopascals [hPa] = 100 kilopascals [kPa] = 100,000 pascals [Pa]

The unit for density* is kilogram divided by cubic meter [kg/m^3].
1 kg/m^3 corresponds to the density of a homogeneous body with a mass of 1 kilogram [kg] and that takes up a volume of 1 cubic meter [m^3].
1,000 kg/m^3 = 1 g/cm^3 = 1 kg/dm^3 = 1,000 g/l

*There is also something known as relative density, which is dimensionless, meaning that it is indicated without any unit of measure. It generally corresponds to a temperature of 4°C and a pressure of 101,325 Pa.

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