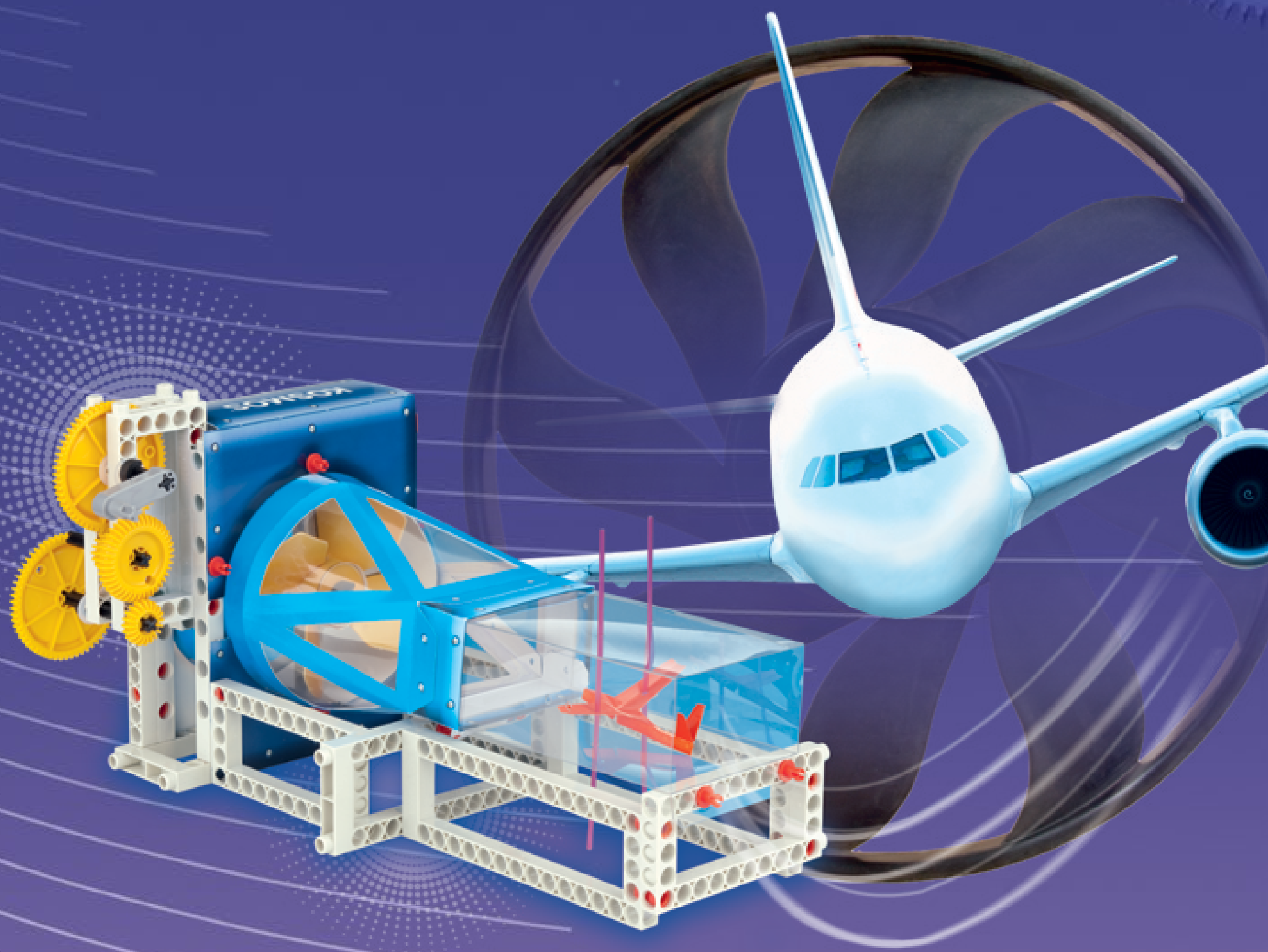
EXPERIMENT MANUAL

Physics Pro



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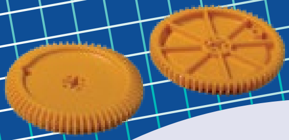

Safety Information for Parents and Adult Supervisors

››› 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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KIT CONTENTS

GOOD TO KNOW! If you are missing any parts, please contact Thames & Kosmos customer service. Any materials not included in the kit are indicated in *italic script* under the "You will need" heading.

The parts in your kit:

✓	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

TABLE OF CONTENTS

GOOD TO KNOW

About solid, liquid, and gaseous bodies

If you pound your fist on a table, you may make an impression on the people around you. You will make little impression, though, on the table itself. Far from being impressed, the table may even hurt your hand a little. If you splash your fist into a pool of water, by contrast, it will squirt to the side, and your hand will quickly be surrounded by water. During immersion, you have briefly sensed a kind of resistance. Now, if you pull your fist energetically into the air, you will sense almost nothing at all.

WHAT IS AIR MADE OF?

The air in our atmosphere is a mixture of various gases. Near the ground, it consists of 78% nitrogen (N or N_2), 21% oxygen (O_2), 0.9% noble gas argon (Ar), as well as very small proportions of other noble gases and carbon dioxide (CO_2). The water vapor content, or relative humidity, of the air fluctuates. Relative humidity is measured as a percentage.

In each of these three examples, your hand would be interacting with a different kind of body, and in each case, you would experience a different kind of resistance. The wooden table top is a fixed or solid body. Water is a fluid body (a liquid), and air is a gaseous body (a gas). A physicist distinguishes all bodies according to these three states: solid, liquid, or gas. That means that every object has characteristic physical properties when forces act upon it. A name for these three states is states of aggregation; they arise through differences in the strength of the forces of attraction acting between individual molecules or atoms in the body.

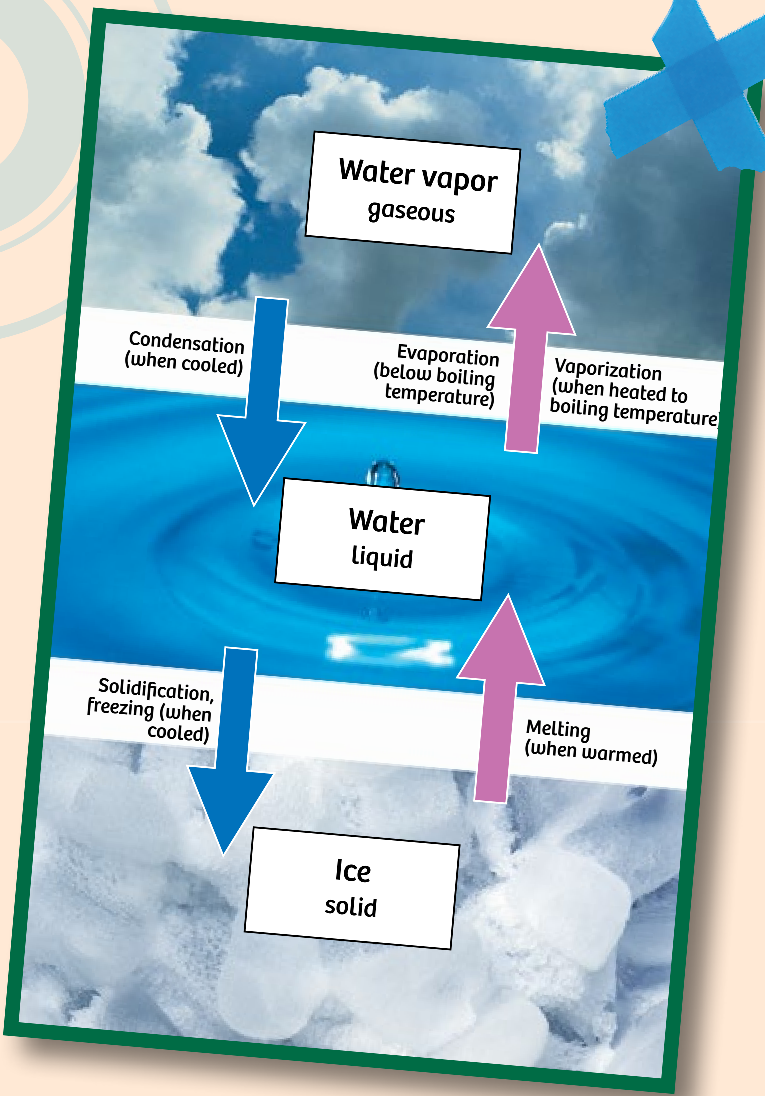
THE THREE STATES OF MATTER

What makes an object a solid, liquid, or gas? All bodies and materials consist of molecules and atoms (or ions). Between them are forces of attraction that hold them together to varying degrees. These forces are called powers of cohesion.

SOLIDS With solid bodies, the cohesion is so strong that they retain a specific form and a specific volume (capacity).

LIQUIDS The molecules of liquids are held together by cohesion too, but they can still move relative to one another. Hence, they have no shape of their own, but take on the shape of their container, whether a drinking glass or the ocean floor. They nevertheless retain their volume as long as no energy is exerted on them.

GASES With gases (e.g. air), there is almost no cohesion at all. Like a liquid, a gas assumes the shape of its container, such as a lung or an air pump. When it does that, the gas always fills the available space completely, regardless of how large that space is. In the process, gases do not retain their volume.



GOOD TO KNOW

Pressure is force per unit of area

At every location of a liquid or a gas — including in water or the air — there is a certain pressure. Let us first define pressure a little imprecisely: There is a prevailing pressure when a force is evenly distributed over a surface area. The larger the surface area, the lower the pressure, and vice-versa.

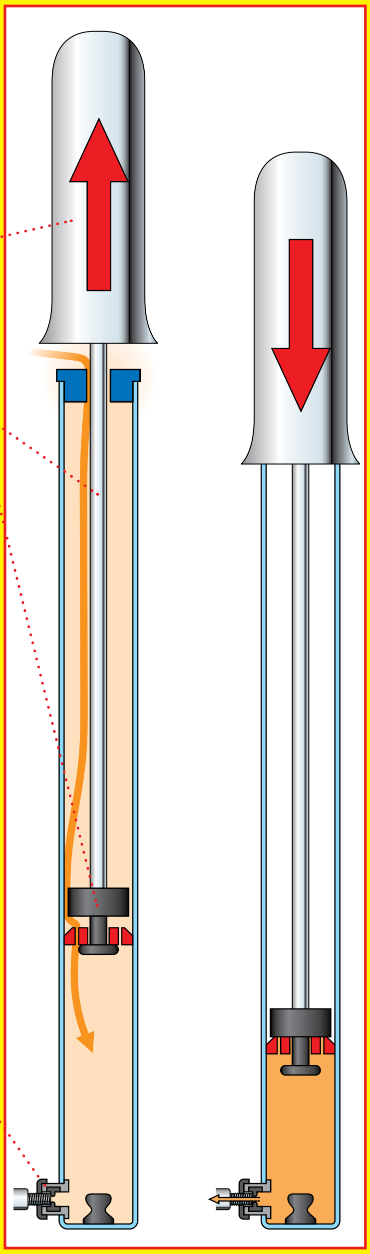
How would a physicist say this more precisely? Pressure is the ratio of a force exerted perpendicularly on a surface to the size of this surface. In other words, force divided by area.

HOW DOES A BICYCLE PUMP WORK?

If you want to pump up a bicycle tire, you grab an air pump. And what does it do? It transfers the force of your arm by way of the pump handle and rod to a piston which compresses the air that had been sucked into the pump's pressure chamber.

The same pressure prevails everywhere in the pressure chamber. This pressure pushes the air out of the pump through a valve into the inner tube (or tubeless tire).

The valve ensures that the air only flows in one direction, into the tube and not back. The tube only gets air if the pressure in the pump is greater than that in the tube, because a liquid or gas always moves from higher to lower pressure. You will notice while you pump that you need more and more force. That is because, as you pump, the pressure in the tire increases.



IMPORTANT FORMULAS

PRESSURE Pressure can be calculated by dividing force by area.

$$P\ (\text{Pressure}) = \frac{F\ (\text{Force})}{A\ (\text{Area})}$$

PASCAL The unit of measure for pressure is 1 pascal (Pa), which is calculated as:

$$1\ \text{Pa} = \frac{1\ \text{N}}{1\ \text{m}^2}$$

For high pressures, the numbers quickly become very long. To save yourself from writing all the zeros, it is easier to write 2,000 hectopascals (hPa) or, even more briefly, 200 kilopascals (kPa). The "h" in the abbreviation stands for "hecto" or hundred-fold, the "k" for "kilo" or thousand-fold.

BAR Many pressure gauges (manometers) also have a different scale with the "bar" pressure unit:

$$1\ \text{bar} = 1{,}000\ \text{hPa}$$

GOOD TO KNOW

Pressure, temperature, and volume are all connected

In practice, it is rare that one is only dealing with two factors with gases. Usually, all three change.

When you pump up your bicycle tire, the pump gets warm, so the temperature of the pump air changes. The pressure simultaneously rises and the air space gets smaller.

In order to be able to do calculations with three changing values, the two laws named before are combined into one, with all three values are factored in. This is the Ideal Gas Law, or the Equation of State of Ideal Gases:

$$\frac{p_1 \cdot V_1}{T_1} = \frac{p_2 \cdot V_2}{T_2} \quad \text{or} \quad \frac{p \cdot V}{T} = \text{constant}$$

So if you change just the temperature or just the pressure or both values, you can figure out how the other parameters will change as well.

HEAT AND TEMPERATURE

Heat, like mechanical energy or electrical energy, is a form of energy. **Temperature** is an indication of a body's heat state.

The greater the weight (or the mass) of a body, the more extra heat (energy) you have to conduct to it in order to raise its temperature by a given amount. It has to "suck up" a quantity of heat corresponding to the quantity by which its temperature is to rise.

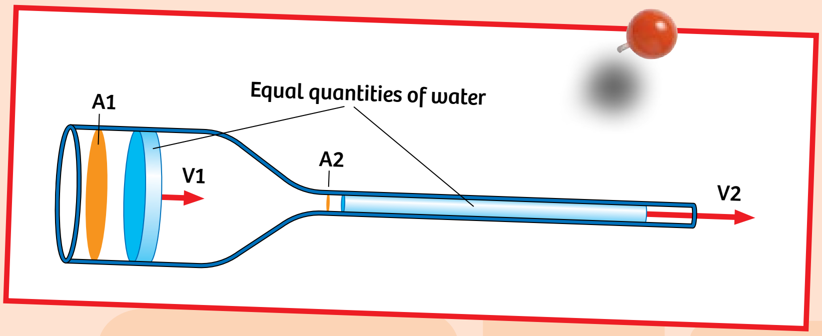
For example, if you want to heat it by 20 °C, it has to absorb twice as much energy as if you wanted to raise its temperature by just 10 °C.

The unit of measurement for energy (and for heat) is the joule (J).

To heat 1 liter (1 kg) of water from 20 °C to 21 °C, you have to apply 4,182 joules of heat energy to it. To heat 1 kg of air, on the other hand, you only need 1,402 J, or about a third.

Like all energy forms, heat obeys the Law of the Conservation of Energy (Energy Conservation Theorem, see page 49). All forms of energy can be converted into one another, albeit not always completely because there are often losses due to friction.

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:

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

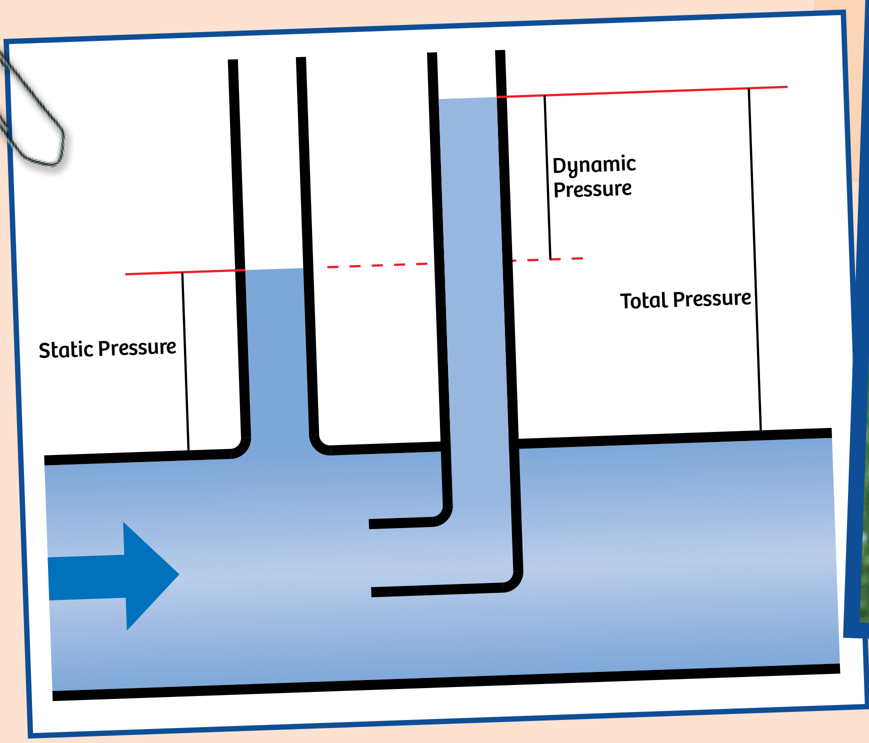
Pressure in currents

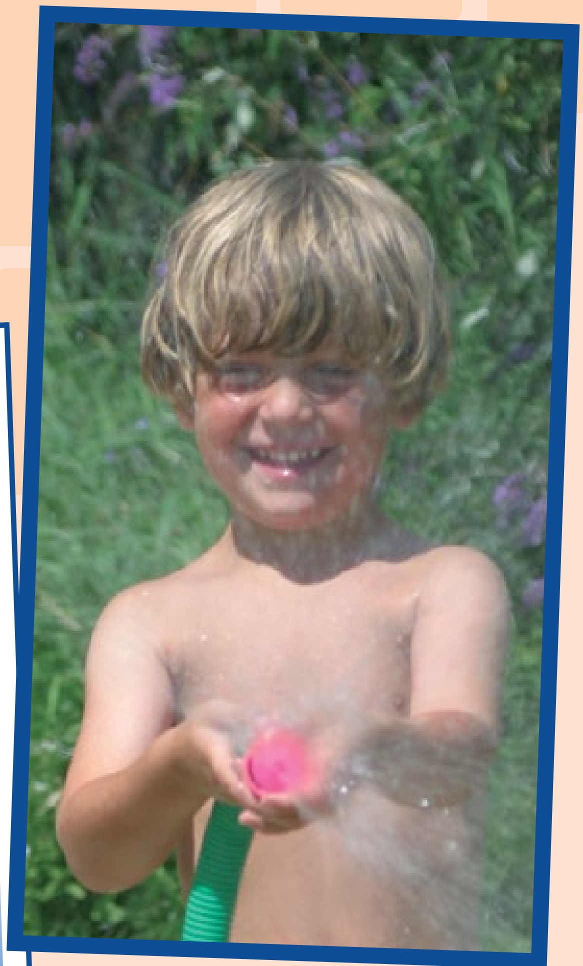
Because the speed of the water increases in the narrow part of a tube, the pressure also increases in the direction of flow. But an increase in pressure also means an increase in force per unit of area and, thus, an increase in the distance the narrower stream of water can shoot.

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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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)