Name _____ Class _____ Date _____

Math Skills

Pascal's Principle

After you study each sample problem and solution, work out the practice problems on a separate sheet of paper. Write your answers in the spaces provided.

PROBLEM

A dentist's chair makes use of Pascal's principle to move patients up and down. Together, the chair and a patient exert a downward force of 2,269 N. The chair is attached to a large piston with an area of 1,221 cm^2. To move the chair, a pump applies force to a small piston with an area of 88.12 cm^2. What force must be exerted on the small piston to lift the chair?

SOLUTION

Step 1:   List the given and unknown values.

> **Given:** $F_2 = 2{,}269$ N
>
> $A_1 = 88.12$ cm^2
>
> $A_2 = 1{,}221$ cm^2
>
> **Unknown:** F_1

Step 2:   Write the equations for Pascal's principle and pressure, force, and area.

$$p_1 = p_2$$
$$pressure = \frac{force}{area}$$

Step 3:   Substitute force and area into the first equation, and rearrange for the desired value.

$$p_1 = p_2$$
$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$
$$F_1 = \frac{(F_2)(A_1)}{A_2}$$

Step 4:   Insert the known values into the equation, and solve.

$$F_1 = \frac{(2269 \text{ N})(88.12 \text{ cm}^2)}{1221 \text{ cm}^2}$$
$$F_1 = 163.8 \text{ N}$$

| Math Skills *continued* |

PRACTICE

1. A hydraulic lift office chair has its seat attached to a piston with an area of 11.2 cm^2. The chair is raised by exerting force on another piston, with an area of 4.12 cm^2. If a person sitting on the chair exerts a downward force of 219 N, what force needs to be exerted on the small piston to lift the seat?

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2. In changing a tire, a hydraulic jack lifts 7,468 N on its large piston, which has an area of 28.27 cm^2. How much force must be exerted on the small piston if it has an area of 1.325 cm^2?

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3. An engine shop uses a lift to raise a 1,784 N engine. The lift has a large piston with an area of 76.32 cm^2. To raise the lift, force is exerted on a small piston with an area of 12.56 cm^2. What force must be exerted to raise the lift?

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PROBLEM

An engineering student wants to build a hydraulic pump to lift a 1,815 N crate. The pump will have two pistons connected via a fluid chamber. The student calculates that a force of 442 N will be exerted on the small piston, which will have an area of 50.2 cm^2. What must the area of the large piston be to exert the desired force?

SOLUTION

Step 1: List the given and unknown values.

       Given: $F_1 = 442$ N

                   $A_1 = 50.2$ cm^2

                   $F_2 = 1,815$ N

      Unknown: A_2

Step 2: Write the equations for Pascal's principle and pressure, force, and area.

$$p_1 = p_2$$
$$pressure = \frac{force}{area}$$

Step 3: Substitute force and area into the first equation, and rearrange for the desired value.

$$p_1 = p_2$$
$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$
$$A_2 = \frac{F_2(A_1)}{F_1}$$

| Math Skills *continued*

Step 4: **Insert the known values into the equation, and solve.**

$$A_2 = \frac{(1815 \text{ N})(50.2 \text{ cm}^2)}{442 \text{ N}}$$
$$A_2 = 206 \text{ cm}^2$$

PRACTICE

4. In a newly designed car with a hydraulic braking system, a force of 85 N is applied to one of the master cylinders, which has an area of 8.1 cm^2. The master cylinder is connected to one brake piston, which exerts a force of 296 N. What is the area of the brake piston?

   _____

5. A mechanic uses a hydraulic car jack to lift the front end of a car to change the oil. The jack used exerts 8,915 N of force from the larger piston. To pump the jack, 444 N of force is exerted on the small piston, which has an area of 3.14 cm^2. What is the area of the large piston?

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6. A student in the lunchroom blows into his straw with a force of 0.26 N. The column of air pushing the liquid in the glass has an area of 0.21 cm^2. If the liquid in the glass pushes upward with a force of 79 N, what is the area of the liquid at the surface of the glass?

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PROBLEM

The motor on a construction-grade hydraulic shovel exerts 3.11×10^7 Pa of pressure on a fluid tank. The fluid tank is connected to a piston that has an area of 153 cm^2. How much force does the piston exert?

SOLUTION

Step 1: **List the given and unknown values.**

   Given: $p_1 = 3.11 \times 10^7$ Pa
   $A_2 = 153 \text{ cm}^2$

   Unknown: F_2

Step 2: **Write the equations for Pascal's principle and pressure, force, and area.**

$$p_1 = p_2$$
$$pressure = \frac{force}{area}$$

Math Skills *continued*

Step 3:   Substitute force and area into the first equation, and rearrange for the desired value.

$$p_1 = p_2$$
$$p_1 = \frac{F_2}{A_2}$$
$$F_2 = (p_1)(A_2)$$

Step 4:   Insert the known values into the equation, and solve.

$$F_2 = (3.11 \times 10^7 \text{ Pa})(153 \text{ cm}^2)$$
$$F_2 = \left(\frac{3.11 \times 10^7 \text{ N}}{\text{m}^2}\right)(1.53 \times 10^{-2} \text{ m}^2)$$
$$F_2 = 4.76 \times 10^5 \text{ N}$$

PRACTICE

7. A small crane has a motor that exerts 2.41×10^7 of pressure on a fluid chamber. The chamber is connected by a fluid line to a piston on the crane arm. If the piston has an area of 168 cm^2, how much force does the piston exert?

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8. A bicycle pump uses Pascal's law to operate. The air in the hose acts as a fluid and transfers force and pressure from the piston to the tire. If a pump has a piston with an area of 7.1 cm^2, how much force must be exerted on it to create a pressure of 8.2×10^5 Pa?

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9. A small backyard log splitter has an engine that applies 1.723×10^7 of pressure to a fluid tank. The tank is connected to a piston with an area of 81.07 cm^2. How much force can the piston exert?

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MIXED PRACTICE

10. A force of 38.7 N is applied to the master cylinder of a hydraulic brake system. The cylinder has an area of 7.61 cm^2. The force from the master cylinder is transferred, by brake fluid, to two brake cylinders that have a total area of 49.1 cm^2. How much total force is exerted by the brake cylinders?

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11. A factory lift is used to raise a load of 2,225 N on a piston that has an area of 706.8 cm^2. How much pressure does the lift's engine need to exert on the hydraulic fluid to lift the required load?

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