



Unit 8 • Pressure: Pascal's law and hydraulic machines

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. thrust
2. pressure
3. pascal
4. fluids
5. depth
6. incompressible
7. transmitted
8. multiplier

K • 4

Each carries 0.5 mark.

2 Label the diagram

1. ram (large piston)
2. pumping piston (small)
3. upper valve
4. lower valve
5. release valve
6. oil reservoir

K • 3

Each carries 0.5 mark.

3 Multiple choice

- i. b. the one in high heels, because her weight is spread over a smaller area

U • 1

The force (their weight) is the same, but $P = F/A$: a smaller area means a bigger pressure. The heels press on a tiny area, so the pressure under them is many times bigger. Equal weights are tempting, but pressure depends on the area too.

- ii. b. the pressure made by your fingers is transmitted through the paste to the nozzle

U • 1

The paste, like a liquid, can hardly be compressed, so the pressure you make at the bottom is passed on through all of it, and the only way out is the nozzle.

- iii. b. $W_1 = 5 \text{ N}$, $W_2 = 10 \text{ N}$

A • 1

$W_2 = W_1 \times \frac{A_2}{A_1} = 2W_1$. Only 5 N and 10 N fit. The other three have the bigger weight on the smaller piston, the wrong way round.

- iv. c. 1,500 N

A • 1

$F_2 = F_1 \times \frac{A_2}{A_1} = 50 \times 30 = 1500 \text{ N}$. (80 N comes from adding instead of multiplying; 1.67 N from dividing the wrong way.)

- v. c. air can be compressed, so the push would squeeze the air instead of moving the large piston

U • 1

A gas gets squeezed into a smaller volume before it passes on much of the push, so most of your effort would be wasted. A liquid can't be compressed, so it passes on the pressure at once and fully.

4 Very short answers

- a. MARKING SCHEME

K • 1

✓ A force acting at right angles (perpendicular) to a surface.



- b. MARKING SCHEME K · 1
 ✓ Pressure applied at any point of a liquid in a closed container is transmitted equally in all directions throughout the liquid, at right angles to the walls.
- c. MARKING SCHEME K · 1
 ✓ Any two of: hydraulic brakes, hydraulic jack, hydraulic lift, hydraulic press, excavator arms.

5 Short answers

- a. MARKING SCHEME U · 2
 ✓ Pressure = thrust ÷ area: the same load on a larger area gives a smaller pressure.
 ✓ A wide namlo spreads the load, so it presses less on the head and hurts less.
- b. MARKING SCHEME U · 2
 ✓ The pressure of water increases with depth ($P = h\rho g$).
 ✓ The water pushes hardest on the bottom of the wall, so it must be strongest there.
- c. MARKING SCHEME U · 2
 ✓ The brake fluid must be a liquid that can't be compressed, so it passes the pressure from the pedal to the brakes fully and at once.
 ✓ It must also have a high boiling point (and a low freezing point) and not damage the rubber seals, which ordinary oil or water can't do.

6 Long answer

ANSWER

A · 4

Suggestion: put the stone on the larger piston and push on the smaller piston. The way it is now, the machine works backwards: to lift 500 N on the small piston, the push on the large piston must be $500 \text{ N} \times A_2/A_1$, many times the stone's weight.

How the force is increased (figure: two cylinders, small area A_1 and large area A_2 , joined and filled with oil, F_1 pushing down on the small piston, F_2 pushing up the load): a force F_1 on the small piston makes a pressure $P = F_1/A_1$ in the liquid. By Pascal's law this pressure is transmitted equally to the large piston, where it makes a force $F_2 = P \times A_2 = F_1 \times A_2/A_1$. Since $A_2 > A_1$, $F_2 > F_1$. If A_2 is 10 times A_1 , a push of 50 N lifts the 500 N stone.

MARKING SCHEME

- ✓ Suggestion: put the stone on the larger piston and push on the smaller piston.
- ✓ A labeled figure: two cylinders of areas A_1 (small) and A_2 (large) joined and filled with liquid, with F_1 and F_2 marked.
- ✓ A force F_1 on the small piston makes a pressure $P = F_1/A_1$, which is transmitted equally to the large piston (Pascal's law).
- ✓ On the large piston it makes $F_2 = P \times A_2 = F_1 \times A_2/A_1$, which is larger than F_1 because $A_2 > A_1$.

7 Numerical problems

- a. ANSWER A · 2
 $P = h\rho g = 2 \text{ m} \times 1000 \text{ kg/m}^3 \times 9.8 \text{ m/s}^2 = 19,600 \text{ Pa}.$
 MARKING SCHEME
 ✓ $P = h\rho g$ with $h = 2 \text{ m}$, $\rho = 1000 \text{ kg/m}^3$ and $g = 9.8 \text{ m/s}^2$ put in.
 ✓ $P = 19,600 \text{ Pa}.$
- b. ANSWER A · 2
 $F_1/A_1 = F_2/A_2$ (1 for piston A, 2 for piston B), so $F_2 = F_1 \times A_2/A_1 = 20 \text{ N} \times 5/0.5 = 200 \text{ N}.$
 MARKING SCHEME
 ✓ $F_1/A_1 = F_2/A_2$ (Pascal's law), with the values put in.
 ✓ $F_2 = 200 \text{ N}$ on piston B.



c. ANSWER

A • 4

- a. $W = mg = 1000 \text{ kg} \times 9.8 \text{ m/s}^2 = 9800 \text{ N}$.
b. $A_2 = 200 \text{ cm}^2 = 0.02 \text{ m}^2$, so $P = F_2/A_2 = 9800 \text{ N} \div 0.02 \text{ m}^2 = 490,000 \text{ Pa}$.
c. $A_1 = 4 \text{ cm}^2 = 0.0004 \text{ m}^2$, so $F_1 = P \times A_1 = 490,000 \text{ Pa} \times 0.0004 \text{ m}^2 = 196 \text{ N}$ (or $F_1 = 9800 \times 4/200 = 196 \text{ N}$).

MARKING SCHEME

- ✓ $W = mg = 9800 \text{ N}$.
- ✓ Areas in m^2 (0.02 m^2 and 0.0004 m^2) and $P = F_2/A_2$.
- ✓ $P = 490,000 \text{ Pa}$.
- ✓ $F_1 = P \times A_1 = 196 \text{ N}$.

8 Think**MARKING SCHEME**

HA • 2

- ✓ The pressure of a liquid depends only on its depth ($P = h\rho g$), not on how much liquid there is.
- ✓ 10 m of water makes about 98,000 Pa, and this pressure is transmitted to every part of the barrel's walls, a huge force on their large area.

9 Activity: A hydraulic machine from two syringes (Activity 8.3)

(not marked)

WHAT STUDENTS SHOULD FIND

A small weight on the small piston balances a much bigger weight on the large piston: if the large piston has 4 times the area, it balances 4 times the weight (friction makes the numbers a little off). The large piston moves much less than the small one, only a quarter as far in this case: the force is multiplied, not the work.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	10	9	14	2	35





Unit 8 • Pressure: upthrust, Archimedes' principle and flotation

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. upthrust
2. apparent weight
3. Archimedes
4. displaced
5. density
6. flotation
7. hydrometer
8. ballast tanks

K • 4

Each carries 0.5 mark.

2 Label the diagram

1. upthrust = the difference
2. small push down on the top
3. sideways pushes cancel

4. bigger push up on the bottom (it is deeper)

U • 2

Each carries 0.5 mark.

3 Multiple choice

- i. b. Archimedes' principle

K • 1

A lactometer floats, and how deep it sinks depends on the upthrust, which by Archimedes' principle (and the law of flotation that follows from it) depends on the density of the milk.

- ii. d. weight of the balloon < weight of air displaced

U • 1

The weight of the air displaced is the upthrust. The balloon rises when the upthrust is greater than its weight. (When they are equal, it floats at one height; and a weight can't be equal to a volume.)

- iii. c. $W_3 < W_2 < W_1$

A • 1

Glycerine (about $1,260 \text{ kg/m}^3$) is denser than water, which is far denser than air. The denser the fluid, the bigger the upthrust, and the smaller the reading. So glycerine gives the smallest reading and air the largest.

- iv. b. the density of seawater is higher than that of river water

U • 1

The ship must displace its own weight of water. River water is less dense, so a bigger volume of it is needed, and the ship sits deeper.

- v. c. volume

U • 1

In the same liquid, $U = V\rho g$ depends only on the volume displaced. The same upthrust means the same volume under water, so cubes held completely under water have equal volumes. (If all three were floating instead, the same upthrust would mean the same **weight**, since a floating object's upthrust equals its weight. The question means cubes that are completely under water.)

4 Very short answers

- a. MARKING SCHEME

K • 1

- ✓ When an object is partly or completely immersed in a fluid, the upthrust on it equals the weight of the fluid it displaces.



- b. MARKING SCHEME K · 1
✓ The upward force of a fluid on an object partly or completely immersed in it.
- c. MARKING SCHEME K · 1
✓ A floating object displaces liquid whose weight equals its own weight.

5 Short answers

- a. MARKING SCHEME U · 2
✓ Steel pin: small and solid, it displaces only a little water, so the upthrust is less than its weight and it sinks.
✓ Steel plate (dish-shaped): its wide shape displaces much more water, enough for an upthrust equal to its weight, so it floats.
- b. MARKING SCHEME U · 2
✓ The water gives an upthrust equal to the weight of water we displace.
✓ While floating, the upthrust equals our whole weight, so our apparent weight is almost zero.
- c. MARKING SCHEME U · 2
✓ Extra passengers make the boat sink deeper, displacing more water, until the water reaches its top edge.
✓ Then it can't displace more, so the upthrust can't grow to match the extra weight; water comes in and the boat sinks.

6 Long answer

ANSWER

A · 4

No. It is true for a **solid lump** of the substance, but not for an object **shaped** to hold air. Iron ($7,800 \text{ kg/m}^3$) is much denser than water, yet a ship made of iron floats; aluminium foil ($2,700 \text{ kg/m}^3$) sinks as a crumpled ball but floats as a tray. A hollow, wide shape displaces a large volume of water, enough to give an upthrust equal to its weight. What decides floating is the **average density of the whole object**, including the air inside it, compared with the density of the liquid.

MARKING SCHEME

- ✓ No: it is true only for a solid lump of the substance.
- ✓ Example: iron is much denser than water, yet a ship made of iron floats (or aluminium foil sinks as a ball but floats as a tray).
- ✓ A hollow, wide shape displaces a large volume of water, enough to give an upthrust equal to its weight.
- ✓ What decides floating is the average density of the whole object, including the air inside it.

7 Numerical problems

- a. ANSWER A · 2
Partly under: $U = W_1 - W_2 = 20 \text{ N} - 14 \text{ N} = 6 \text{ N}$. Completely under: $U = 20 \text{ N} - 10 \text{ N} = 10 \text{ N}$.
- MARKING SCHEME
- ✓ Partly under: $U = 20 - 14 = 6 \text{ N}$.
 - ✓ Completely under: $U = 20 - 10 = 10 \text{ N}$.



b. ANSWER

A • 4

- a. $U = W_1 - W_2 = 6 \text{ N} - 3.6 \text{ N} = 2.4 \text{ N}$.
b. $U = V\rho g$, so $V = U \div (\rho g) = 2.4 \div (1000 \times 9.8) = 0.000245 \text{ m}^3$ (245 cm³).
c. Relative density = $W_1 \div (W_1 - W_2) = 6 \div 2.4 = 2.5$.
d. Density = $2.5 \times 1000 \text{ kg/m}^3 = 2500 \text{ kg/m}^3$.

MARKING SCHEME

- ✓ $U = 6 - 3.6 = 2.4 \text{ N}$.
✓ $V = U/(\rho g) = 0.000245 \text{ m}^3$.
✓ Relative density = $6 \div 2.4 = 2.5$.
✓ Density = 2500 kg/m^3 .

c. ANSWER

A • 2

Weight of the block: $W = V\rho g = 0.02 \times 700 \times 9.8 = 137.2 \text{ N}$. By the law of flotation, the water displaced also weighs 137.2 N, so its volume is $137.2 \div (1000 \times 9.8) = 0.014 \text{ m}^3$ under water.

MARKING SCHEME

- ✓ Weight of the block = 137.2 N = weight of water displaced (law of flotation).
✓ Volume under water = $137.2 \div 9800 = 0.014 \text{ m}^3$.

8 Think**ANSWER**

HA • 2

It rises, and then floats with part of it above the surface, higher as more salt is dissolved. The salt makes the water denser, so the upthrust on the object ($V\rho g$) becomes greater than its weight. It comes to rest when only enough of it is under the surface to displace its own weight of the denser water.

MARKING SCHEME

- ✓ The object rises and floats with part of it above the surface, higher as more salt is added.
✓ Salt makes the water denser, so the upthrust becomes greater than the object's weight (less of it needs to be under to displace its own weight).

9 Activity: Checking Archimedes' principle (Activity 8.5)

(not marked)

WHAT STUDENTS SHOULD FIND

The upthrust ($W_1 - W_2$) comes out equal to the weight of the water that overflowed ($W_4 - W_3$), for every object, as Archimedes' principle says.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **The Rock That Floats** (exhibit): Pumice floats: so full of gas bubbles, it's less dense than the water it sits on.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	8	11	13	2	34

