Formative Practice 2.1 [Pressure In Liquid]

1. State three factors that affect the pressure in a liquid.

2. What is the water pressure at a depth of 24 m in a lake?
[Density of water, ρ = 1 000 kg m^{-3} and gravitational acceleration, g = 9.81 m s^{-2}]

3. A diver dives to a depth of 35 m in the sea. What is the actual pressure acting on his body?

Formative Practice 2.2 [Atmospheric Pressure]

1. Explain the existence of atmospheric pressure.

2. The height of the mercury column in a barometer is 756 mm Hg on a cloudy day. Calculate the atmospheric pressure at that time in pascal.
[Density of mercury, ρ = 13 600 kg m^{-3} and gravitational acceleration, g = 9.81 m s^{-2}]

3. What is the actual pressure at a depth of 125 m in a dam? State your answer in m H_2O and pascal.
[Atmospheric pressure = 10.3 m H_2O, density of water, ρ = 1 000 kg m^{-3} and gravitational acceleration, g = 9.81 m s^{-2}]

Formative Practice 2.3 [Gas Pressure]

1. Figure 2.21 shows a water manometer connected to a flask containing gas.
   (a) Compare the gas pressure in the flask with the atmospheric pressure.
   (b) State the difference between the gas pressure and the atmospheric pressure in m H_2O.
   (c) Calculate the gas pressure in pascal.
   [Density of water, ρ = 1 000 kg m^{-3}
   gravitational acceleration, g = 9.81 m s^{-2} and
   atmospheric pressure = 10.3 m H_2O]

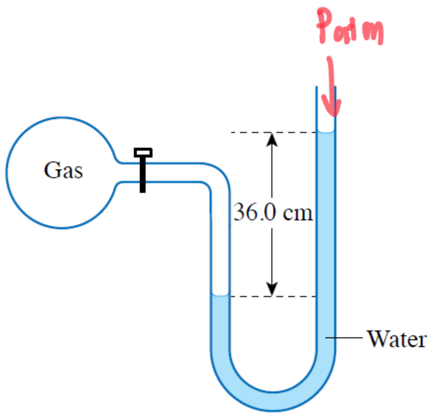


Figure 2.21

2. What are the advantages of using a mercury manometer compared to a water manometer?

3. A mercury manometer is connected to a steel cylinder containing compressed gas. The pressure of the compressed gas and the atmospheric pressure are 180 kPa and 101 kPa respectively. Calculate the difference in height between the two mercury columns in the manometer.
[Density of Hg, ρ = 13 600 kg m^{-3} and gravitational acceleration, g = 9.81 m s^{-2}]

<u>Formative Practice 2.4 [Pascal's Principle]</u>

1. State Pascal's principle.

2. Describe how a hydraulic machine can achieve force multiplication by applying Pascal's principle.

3. In a hydraulic system, an input force of 4.0 N acts on a piston with surface area 0.50 cm^2. Calculate the output force produced on a piston with surface area 6.4 cm^2.

4. A pupil has a small syringe with a piston of diameter 1.5 cm. The pupil intends to construct a hydraulic system that can multiply force from 6 N to 72 N. What is the diameter of a large syringe that is required for this hydraulic system?

Formative Practice 2.5 [Archimedes' Principle]

1. State Archimedes' principle.

2. A small boat displaces 3.8×10^{-2} m^3 of sea water. Calculate the buoyant force acting on the boat.
[Density of sea water, ρ = 1 050 kg m^{-3} and gravitational acceleration, g = 9.81 m s^{-2}]

3. Figure 2.42 shows a block of mass 0.48 kg and volume 5.0×10^{-4} m^3 being held in water. The density of water is 1 000 kg m^{-3}. Determine the movement of the block when it is released.
[Density of water, ρ = 1 000 kg m^{-3} and gravitational acceleration, g = 9.81 m s^{-2}]

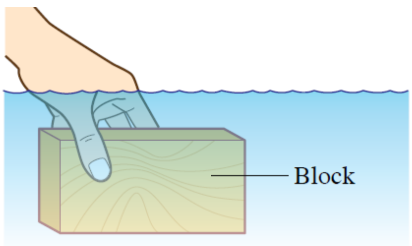


Figure 2.42

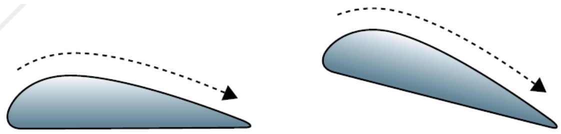
Formative Practice 2.6 [Bernoulli's Principle]

1. State Bernoulli's principle.

2. Explain three ways of using a piece of A4 paper to demonstrate Bernoulli's principle.

3. Figure 2.53 shows the cross section of the wing of an aeroplane when the aeroplane is accelerating along the runway and when it begins to take off from the runway.

With the aid of labelled diagrams, explain how the lift force is produced when the aeroplane takes off.



(a) Accelerating along the runway (b) Taking off from the runway

<u>Summative Practice</u>

1. (a) Derive the formula for pressure at depth h in a liquid with density ρ.
   (b) Calculate the pressure at depth of 24 m in a lake that contains water with a density of 1 120 kg m^{-3}.

2. Figure 1 shows the apparatus for comparing the densities of two types of liquid after some air is sucked out of the apparatus.
   (a) Explain why the pressure at point *A* is equal to the pressure at point *B*.
   (b) Calculate the density of liquid *X*.
   [Density of water, ρ = 1 000 kg m^{-3}]

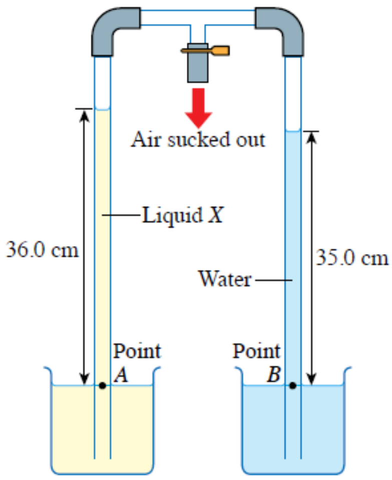


Figure 1

3. Compare and contrast the existence of pressure in the liquids and the atmospheric pressure.

	Pressure In Liquid	Atmospheric Pressure
Similarities		
Difference		

4. Figure 2 shows a U-tube containing mercury.
   (a) What is the pressure acting on point X and point Y on the surface of mercury?
   (b) By comparing the pressure at point X and point Z, explain why the height of the mercury column, h is a measure of atmospheric pressure.
   (c) Determine the atmospheric pressure in Pa.
   [Density of mercury, ρ = 13 600 kg m^{-3} and gravitational acceleration, g = 9.81 m s^{-2}]

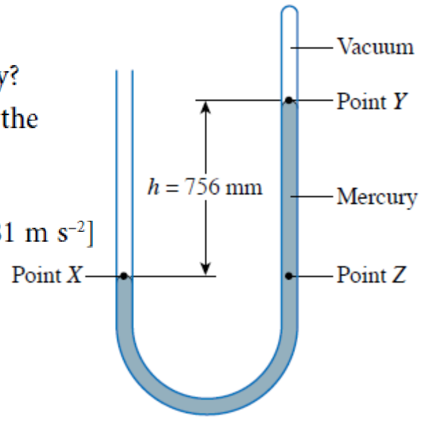


Figure 2

5. A mercury manometer is connected to a cylinder containing gas. The gas pressure in the cylinder and the atmospheric pressure are 180 kPa and 103 kPa respectively.
   Sketch a diagram of the manometer connected to the gas cylinder. Determine the height of the mercury column in your sketch.
   [Density of mercury, ρ = 13 600 kg m^{-3} and gravitational acceleration, g = 9.81 m s^{-2}]

6. In a hydraulic brake system, the driver of the vehicle applies a force of 80 N on the brake pedal. This force is multiplied by the mechanical lever system to be a 400 N input force on the hydraulic liquid in the master cylinder. The diameter of the master cylinder and the diameter of the slave cylinder are 0.8 cm and 2.5 cm respectively.

(a) Calculate the pressure on the hydraulic liquid in the master cylinder.

(b) State the principle that enables pressure to be transmitted from the master cylinder to the slave cylinder.

(c) What is the braking force produced at the slave cylinder to stop the rotation of the wheel?

7. A wooden block with volume 3.24×10^{-3} m^3 is released in a tank of water. By doing the relevant calculations, sketch the state of buoyancy of the wooden block in the tank.
[Density of wood, $\rho = 920$ kg m^{-3}, density of water, $\rho = 1\ 000$ kg m^{-3} and gravitational acceleration, $g = 9.81$ m s^{-2}]

8. Figure 3 shows two designs of a hydraulic jack, *X* and *Y* which were suggested by a technician.

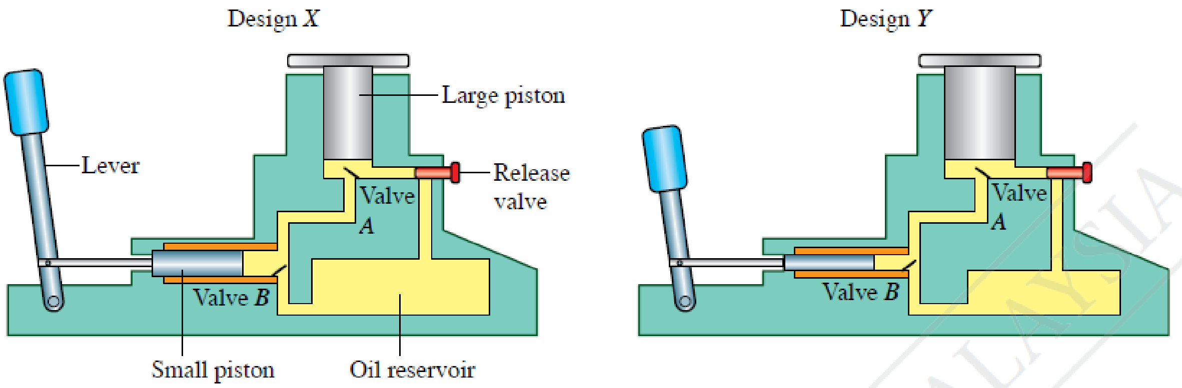


Figure 3

(a) By referring to design *X*, describe the operation of the hydraulic jack.

(b) Study design *X* and design *Y*. Compare the advantages and disadvantages of design *X* and design *Y*.

(c) Based on your answer in 8(b), suggest a design of hydraulic jack that can produce a larger output force and lift a load to a greater height.

9. A hot air balloon is in a stationary position in the air.

(a) State Archimedes' principle.

(b) Explain the relationship between the weight of the balloon and the weight of air displaced.

(c) When the flame of the burner is extinguished and the parachute valve is opened, the balloon begins to descend. Explain how this action enables the balloon to descend to the ground.

10. Figure 4 and Figure 5 show the same metal blocks of mass 0.050 kg hanging from a spring balance, immersed in water and cooking oil respectively.

(a) Compare the pressure at point *A* and point *B* in Figure 4. Explain your answer.

(b) Explain how the difference in pressure in 10(a) exerts a buoyant force on the metal block.

(c) Calculate the density of cooking oil if the density of water is 1 000 kg m^{-3}.
[Gravitational acceleration, g = 9.81 m s^{-2}]

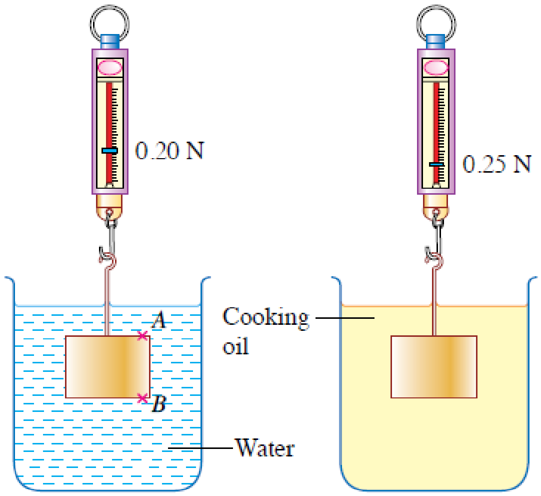


Figure 4 ***Figure 5***

11. Photograph 1 shows a racing car that is stabilised by downforce while being driven at high speed.

Photograph 1

Explain the production of the downforce due to the air flowing past the:
(a) inverted aerofoil-shaped spoiler
(b) top and bottom sections of the car

21st Century Challenge

12. Figure 6 shows part of the hydraulic brake system of a car. A driver finds that the brake has to be pressed harder and further in to stop the car.

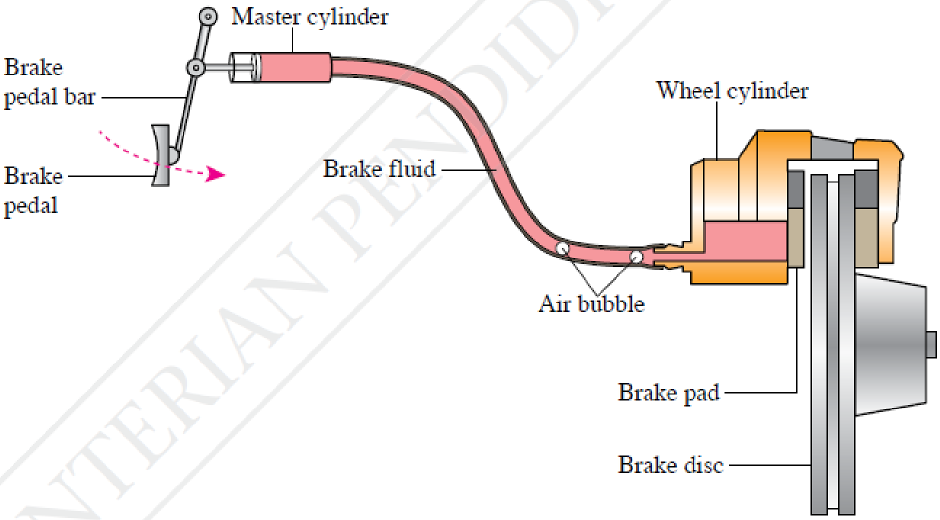


Figure 6

(a) Identify the weaknesses in the hydraulic brake system of the car.

(b) By using suitable physics concepts, suggest modifications to the brake system so that the car can be stopped more effectively. Your answer should include the following aspects:

(i) characteristics of the brake fluid
(ii) cross-sectional area of the master cylinder
(iii) cross-sectional area of the wheel cylinder
(iv) length of the brake pedal bar
(v) other suitable designs

Aspect	Characteristic	Explanation
Characteristics of brake fluid		
Cross-sectional area of master cylinder		
Cross-sectional area of wheel cylinder		
Length of brake pedal bar		
Additional design		

ANSWER

Formative Practice 2.1

1. Depth, density of liquid, gravitational acceleration
2. Water pressure $= h\rho g$
   $= 24 \times 1\,000 \times 9.81$
   $= 2.35 \times 10^5$ Pa
3. Water pressure $= h\rho g$
   $= 35 \times 1\,060 \times 9.81$
   $= 363\,951$ Pa
   $= 364$ kPa

   Actual pressure $= 364 + 100$
   $= 464$ kPa

Formative Practice 2.2

1. Atmospheric pressure is the pressure due to the weight of the layer of air acting on the surface of the earth.
2. Atmospheric pressure = 756 mm Hg = 0.756 m Hg
   Atmospheric pressure $= h\rho g$
   $= 0.756 \times 13\,600 \times 9.81$
   $= 100\,862$ Pa
3. Actual pressure = water pressure + atmospheric pressure
   $= 125 + 10.3$
   $= 135.3$ m H_2O
   Actual pressure $= 135.3 \times 1\,000 \times 9.81$
   $= 1\,327\,293$ Pa
   $= 1.33 \times 10^6$ Pa

Formative Practice 2.3

1. (a) The gas pressure is higher than the atmospheric pressure.
   (b) Pressure difference = 36.0 cm H_2O
   = 0.36 m H_2O
   (c) Gas pressure = (0.36 + 10.3) m H_2O
   = 10.66 m H_2O
   Gas pressure $= 10.66 \times 1\,000 \times 9.81$
   $= 104\,575$ Pa
2. • Can measure higher pressure because mercury is a denser liquid
   • Does not need a very long tube
   • Rate of evaporation of mercury is lower than rate of evaporation of water
3. Difference in pressure between the compressed gas and atmospheric pressure = 180 – 101
   = 79 kPa
   = 79 000 Pa

   $h\rho g = 79\,000$
   $h \times 13600 \times 9.81 = 79\,000$
   $h = 0.592$ m
   $h = 59.2$ cm

   Difference in height of the two mercury columns in the manometer = 59.2 cm

Formative Practice 2.4

1. Pascal's principle states that the pressure applied on an enclosed fluid is transmitted uniformly in all directions in the fluid.
2. A small force, F_1 exerts pressure on the liquid below the small piston.

   Pressure $= \dfrac{F_1}{A_1}$

   A_1 = cross-sectional area of the small piston
   According to Pascal's principle, this pressure is transmitted uniformly throughout the liquid.
   This pressure exerts a force on the large piston.
   Force on the large piston, F_2 = pressure × cross-sectional area of the large piston.

   $F_2 = \dfrac{F_1}{A_1} \times A_2$

   A_2 = cross-sectional area of the large piston

   Force on the large piston, $F_2 = \dfrac{A_2}{A_1} \times F_1$

   Since $A_2 > A_1$, $F_2 > F_1$

   Therefore, a small input force on the small piston is multiplied to become a larger output force on the large piston.
3. $F_2 = \dfrac{6.4}{0.50} \times 4.0$
   $F_2 = 51.2$ N
4. $\dfrac{F_1}{A_1} = \dfrac{F_2}{A_2}$

   $\dfrac{A_2}{A_1} = \dfrac{F_2}{F_1}$

   $\dfrac{A_2}{A_1} = \dfrac{72}{6} = 12$

   $A_2 = 12\,A_1$

   $\dfrac{\pi d_2^{\,2}}{4} = 12\dfrac{\pi d_1^{\,2}}{4}$

   $d_2^{\,2} = 12 \times 1.5^2$
   $d_2 = 5.20$ cm
   Diameter of large piston = 5.20 cm

Formative Practice 2.5

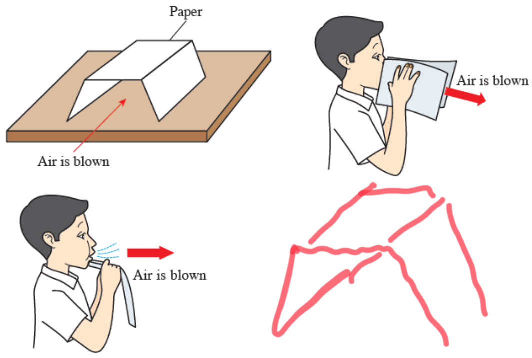
1. Archimedes' principle states that an object which is partially or fully immersed in a fluid will experience a buoyant force equal to the weight of fluid displaced.
2. Buoyant force, $F_B = \rho V g$
   $= 1\,050 \times 3.8 \times 10^{-2} \times 9.81$
   $= 391.4$ N
3. Weight of block $= mg$
   $= 0.48 \times 9.81$
   $= 4.71$ N

   Buoyant force, $F_B = \rho V g$
   $= 1\,000 \times 5.0 \times 10^{-4} \times 9.81$
   $= 4.91$ N

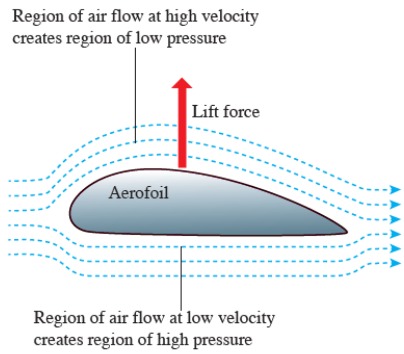
   Buoyant force > Weight of block
   The block will move up with an acceleration.

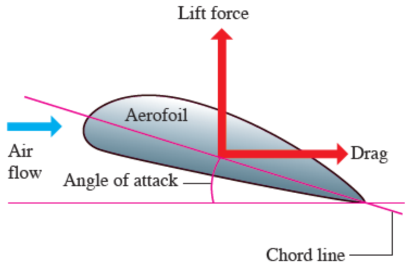
Formative Practice 2.6

1. Bernoulli's principle states that when the velocity of the flow of a fluid increases, the pressure in the fluid decreases.
2.



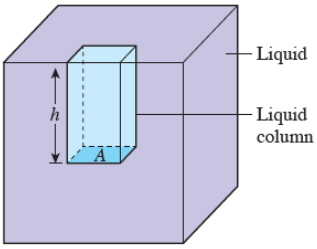
3. The shape of the aerofoil causes air to flow:
   – at high velocity above the upper section of the wing of the aircraft
   – at lower velocity below the lower section of the wing of the aircraft
   According to Bernoulli's principle:
   – above the upper section of the wing is a region of low air pressure
   – below the lower section of the wing is a region of high pressure
   – this difference in air pressure produces a resultant force upwards to lift the aircraft into the air
   The wing is inclined to produce an angle of attack:
   – the flow of air below the wing experiences an action force and is deflected
   – the wing experiences a reaction force that contributes to the lift force





Summative Practice

1. (a) Consider a liquid column in a container
Height of liquid column = h
Area of the base of liquid column = A
Density of liquid = ρ



Pressure on the base of the liquid column is due to the weight of the liquid column.
Volume of liquid column, $V = Ah$
Mass of liquid column, $m = Ah\rho$
Weight of liquid column, $W = Ah\rho g$

Pressure on the base of liquid column, $P = \dfrac{\text{Weight of liquid column}}{\text{Surface area}}$

$$P = \frac{Ah\rho g}{A}$$
$$P = h\rho g$$

(b) $P = h\rho g$
$= 24 \times 1\ 120 \times 9.81$
$= 2.64 \times 10^5$ Pa

2. (a) A and B are at the same level in a stationary liquid.
(b) Density of liquid $X = \rho$
Pressure at A = pressure at B
$36.0 \times \rho \times g = 35.0 \times 1\ 000 \times g$
$\rho = 972$ kg m^{-3}

3.

	Pressure in liquid	Atmospheric pressure
Similarities	Due to the weight of the fluid column acting on the surface below it.	
	Acts in all directions	
	Does not depend on surface area	
	Depends on density	
	Depends on gravitational acceleration	
Difference	Increases with depth	Decreases with altitude

4. (a) Pressure at point X = atmospheric pressure
Pressure at point Y = 0
(b) Since point X and point Z are at the same level,
Pressure at point X = pressure at point Z
Pressure at point X = atmospheric pressure, and
Pressure at point Z = pressure due to mercury column + 0
Atmospheric pressure = pressure due to mercury column
Therefore, the height of the mercury column, h is a measure of atmospheric pressure.
(c) Atmospheric pressure = 756 mm Hg = 0.756 m Hg
Atmospheric pressure = $0.756 \times 13\ 600 \times 9.81$
= 100 862 Pa

5. Difference between the pressure of the compressed air and atmospheric pressure = 180 – 103
= 77 kPa
= 77 000 Pa

$h\rho g = 77\ 000$
$h \times 13\ 600 \times 9.81 = 77\ 000$
$h = 0.577$ m
$h = 57.7$ cm

Difference in height between the two mercury columns in the manometer = 57.7 cm

12. (a) Weaknesses of the braking system of the car
– Brake pedal bar that is short and almost vertical
Does not produce a large input force on the brake fluid in the master cylinder
– Air bubbles in the brake fluid
Air can be compressed. The movement of the piston in the master cylinder produces a very small
movement of the piston in the wheel cylinder
– The cross-sectional area of the wheel cylinder is almost the same as the cross-sectional area of the master cylinder.
The multiplying factor is small. A large braking force cannot be produced.

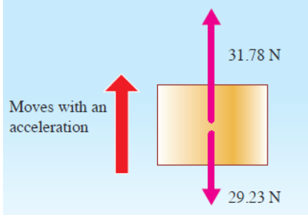
(b) Suggested modifications:

Aspect	Suggestion	Explanation
(i) Characteristics of brake fluid	– Liquid with high boiling point – Low density – Liquid without rusting effect	Low rate of evaporation. Does not produce bubbles or vapour Can flow smoothly in the brake fluid lines Does not cause rusting of the brake fluid lines
(ii) Cross-sectional area of master cylinder	Smaller cross-sectional area	Produces a larger multiplying factor, and therefore a larger braking force
(iii) Cross-sectional area of wheel cylinder	Larger cross-sectional area	Produces a larger multiplying factor, and therefore a larger braking force
(iv) Length of brake pedal bar	Longer brake pedal bar	Produces a larger input force
(v) Additional design	A mechanical system or compressed air system between the brake pedal and master cylinder	Multiplies the force exerted by the foot of the driver so that a larger input force acts in the master cylinder

6. (a) Diameter of master cylinder = 0.8 cm
Cross-sectional area of master cylinder $= \dfrac{\pi \times 0.8^2}{4}$
$= 0.50$ cm^2

Pressure $= \dfrac{400}{0.50}$
$= 800$ N cm^{-2}
(b) Pascal's principle
(c) Cross-sectional area of slave cylinder $= \dfrac{\pi \times 2.5^2}{4}$
$= 4.91$ cm^2
Braking force = pressure × surface area
$= 800 \times 4.91$
$= 3\ 928$ N

7. Mass of wooden block $= 3.24 \times 10^{-3} \times 920 = 2.98$ kg
Weight of wooden block $= 2.98 \times 9.81 = 29.23$ N
Buoyant force $= 3.24 \times 10^{-3} \times 1\ 000 \times 9.81$
$= 31.78$ N
Buoyant force > weight of block
There is a resultant force upwards
The block moves up with an acceleration



8. (a) The handle of the lever is pulled to the right.
An input force acts on the small piston.
The input force produces a pressure on the hydraulic oil.
Valve A opens, valve B closes.
Pressure is transmitted to the large piston.
A larger output force moves the large piston upwards.

The handle of the lever is pulled to the left.
Valve A closes, valve B opens.
The large piston stays at the same position.
Hydraulic oil flows from the reservoir into the small cylinder.

This process is repeated so that the large piston is moved a little at a time.
(b) • Lever: Design X is better than design Y.
A longer lever enables a larger input force to be exerted on the small piston.
• Cross-sectional area of small piston and large piston: Design Y is better than design X.
Output force, $F_2 = \dfrac{A_2}{A_1} \times F_1$
A_2 = cross-sectional area of large piston
A_1 = cross-sectional area of small piston
F_1 = input force
Design Y has larger A_2 and a smaller A_1 to give a larger multiplying factor $\dfrac{A_2}{A_1}$
• Volume of oil reservoir: Design X is better than design Y
Design X has a larger volume of oil. More oil can be moved from the small cylinder to the large cylinder.
(c) Suggested design:
• Longer lever
• Smaller cross-sectional area for the small piston
• Larger cross-sectional area for the large piston
• Oil reservoir with a larger volume

9. (a) Archimedes' principle states that an object which is partially or fully immersed in a fluid will experience a buoyant force equal to the weight of fluid displaced.
(b) The balloon is stationary, that is the forces acting on the balloon are in equilibrium.
Resultant force on the balloon = 0.
Weight of balloon = buoyant force
According to Archimedes' principle, buoyant force = weight of air displaced
Therefore, weight of balloon = weight of air displaced
(c) When the flame of the burner is extinguished and the parachute valve is opened:
• part of the hot air in the balloon flows out through the valve
• temperature of the air in the balloon decreases
• cooler surrounding air flows into the balloon
• density of the balloon increases
• weight of the balloon increases
Since the weight of the balloon > buoyant force, there is a resultant force downwards
The balloon moves down until it reaches the ground.

10. (a) Pressure at point A < pressure at point B
because the depth of A is lower than B
(b) Pressure on the lower surface of the metal block > pressure on the upper surface of the metal block
Force on the lower surface of the metal block > force on the upper surface of the metal block
A resultant force acts upwards.
This resultant force is the buoyant force.
(c) Weight of block in air = mg
$= 0.050 \times 9.81$
$= 0.49$ N
When the metal block is in water:
Weight of metal block in water = 0.20 N
Apparent loss in weight of the metal block = 0.49 – 0.20
= 0.29 N
Buoyant force = apparent loss in weight of the metal block
= 0.29 N
Buoyant force, $F_B = \rho V g$,
ρ = density of water
V = volume of water displaced
$\rho V g = 0.29$
$1\ 000 \times V \times 9.81 = 0.29$
$V = 2.96 \times 10^{-5}$ m^3

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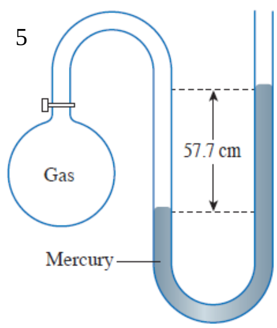

When the block is in oil:
Volume of oil displaced = volume of water displaced
$= 2.96 \times 10^{-5}$ m^3
Weight of metal block in oil = 0.25 N
Apparent loss in weight of the metal block = 0.49 – 0.25
= 0.24 N
Buoyant force = apparent loss in weight of the metal block
= 0.24 N

Buoyant force, $F_B = \rho V g$,
ρ = density of oil
V = volume of oil displaced
$\rho V g = 0.24$
$\rho \times 2.96 \times 10^{-5} \times 9.81 = 0.24$
$\rho = 826.5$ kg m^{-3}