# S4 Science Practice Paper: Density and Buoyancy, Pressure and Hydraulic Systems, Ohm's Law and Series/Parallel Circuits, Speed and Acceleration, Heat Capacity and Latent Heat, Refraction and Acid-Base Neutralisation (100 marks)

Level: S4 | Subject: Science | 60 minutes | 100 marks | 24 questions | answer key

## Section A: Density, Buoyancy and Pressure (17 marks)

**Each question is worth 4-5 marks; state the formula and the unit.**

| # | Question | Answer | Marks |
|---|---|---|---|
| 1 | A metal block has a mass of 270 g and a volume of 100 cm3. (a) Find its density in g/cm3 and in kg/m3. (b) Water has a density of 1.00 g/cm3; will the block float or sink in water? Explain. | Density = mass / volume = 270 g / 100 cm3 = 2.70 g/cm3 = 2700 kg/m3. Since 2.70 g/cm3 is greater than 1.00 g/cm3, the block sinks. | 5 |
| 2 | A wooden cuboid measures 20 cm by 10 cm by 5 cm and has a mass of 900 g. (a) Find its density. (b) The cuboid is placed in water; find the percentage of its total volume that floats above the surface. | Volume = 20 x 10 x 5 = 1000 cm3, so density = 900 g / 1000 cm3 = 0.90 g/cm3. Since 0.90 g/cm3 is less than 1.00 g/cm3, 90% (900 cm3) is submerged and 10% floats above the surface. | 4 |
| 3 | A student weighs 300 N and stands on both feet with a total contact area of 0.05 m2. (a) Find the pressure he exerts on the ground. (b) If he stands on one foot so that the contact area is halved, what is the new pressure? | Pressure = force / area = 300 N / 0.05 m2 = 6000 Pa. Halving the area to 0.025 m2 doubles the pressure to 12000 Pa, because pressure is inversely proportional to area. | 4 |
| 4 | An object of volume 200 cm3 is completely immersed in water (density 1000 kg/m3, g = 10 N/kg). (a) Find the upthrust on the object. (b) The object weighs 5.0 N in air; find its apparent weight in water. | Volume = 200 cm3 = 0.0002 m3, so upthrust = 1000 x 10 x 0.0002 = 2.0 N. Apparent weight = 5.0 - 2.0 = 3.0 N. | 4 |

## Section B: Pressure Transmission and Hydraulic Systems (16 marks)

**Each question is worth 4 marks; take g = 10 N/kg.**

| # | Question | Answer | Marks |
|---|---|---|---|
| 5 | A hydraulic system has a small piston of area 5 cm2 and a large piston of area 200 cm2. A force of 50 N is applied to the small piston. (a) Find the pressure in the liquid. (b) Find the force the large piston can lift. (c) Find the mechanical advantage of the system. | Area = 5 cm2 = 0.0005 m2, so pressure = 50 N / 0.0005 m2 = 100000 Pa. With a large piston area of 0.02 m2, force = 100000 x 0.02 = 2000 N, and the mechanical advantage is 2000 / 50 = 40. | 4 |
| 6 | A water tank holds water 3.0 m deep and the surface is at atmospheric pressure of 101 kPa (water density 1000 kg/m3, g = 10 N/kg). (a) Find the water pressure at the bottom of the tank. (b) Find the total pressure at the bottom. | Water pressure = 1000 x 10 x 3.0 = 30000 Pa; total pressure = 30000 + 101000 = 131000 Pa. | 4 |

| | | | |
|---|---|---|---|
| 7 | In a hydraulic jack the ratio of the small piston area to the large piston area is 1 : 25. What force must be applied to the small piston to lift a car weighing 5000 N? | By Pascal pressure transmission, F1 / A1 = F2 / A2, so the effort = 5000 N / 25 = 200 N. | 4 |
| 8 | A gas in a sealed cylinder occupies 200 cm3 at 100 kPa. The gas is compressed to 80 cm3 at constant temperature. Find the new pressure. | Boyle law: P1V1 = P2V2, so P2 = 100 x 200 / 80 = 250 kPa. | 4 |

## Section C: Circuits, Ohm's Law and Energy Cost (18 marks)

**Each question is worth 4-5 marks; show your working.**

| # | Question | Answer | Marks |
|---|---|---|---|
| 9 | A 6 V battery is connected in series with a 4 ohm and an 8 ohm resistor. (a) Find the current. (b) Find the voltage across each resistor. (c) Find the power delivered by the battery. | Total resistance = 4 + 8 = 12 ohm, so current = 6 / 12 = 0.5 A. The voltages are 2 V across the 4 ohm and 4 V across the 8 ohm (2 + 4 = 6 V), and power = 6 x 0.5 = 3 W. | 5 |
| 10 | A 12 V supply is connected across a 6 ohm and a 4 ohm resistor in parallel. (a) Find the current in each branch. (b) Find the total current. (c) Find the equivalent resistance. | Each branch has 12 V, so the currents are 12 / 6 = 2 A and 12 / 4 = 3 A. Total current = 5 A and equivalent resistance = 12 / 5 = 2.4 ohm (1/R = 1/6 + 1/4). | 5 |
| 11 | A 2000 W heater runs continuously for 3 hours. Electricity costs 1.2 dollars per kWh. (a) Find the energy used in kWh. (b) Find the cost. | Energy = 2000 W x 3 h = 6000 Wh = 6 kWh, so the cost is 6 x 1.2 = 7.2 dollars. | 4 |
| 12 | The current through a resistor is 0.3 A when the voltage across it is 2.4 V. (a) Find the resistance. (b) If the voltage rises to 4.8 V, find the current at constant temperature. | R = V / I = 2.4 / 0.3 = 8 ohm. Doubling the voltage doubles the current to 0.6 A (I = V / R = 4.8 / 8). | 4 |

## Section D: Speed, Acceleration and Motion Graphs (17 marks)

**Each question is worth 4-5 marks; give units in every answer.**

| # | Question | Answer | Marks |
|---|---|---|---|
| 13 | A runner covers 120 m in 20 s. (a) Find her average speed in m/s. (b) Express it in km/h. | Average speed = 120 m / 20 s = 6 m/s, which is 6 x 3.6 = 21.6 km/h. | 4 |
| 14 | A car accelerates uniformly from rest at 2 m/s2 for 5 s, then travels at constant speed for a further 4 s. (a) Find the speed after 5 s. (b) Find the distance covered while accelerating. (c) Find the total distance. | v = at = 2 x 5 = 10 m/s. Accelerating distance = 0.5 x 2 x 5^2 = 25 m; constant-speed distance = 10 x 4 = 40 m; total = 65 m. | 5 |
| 15 | A car travelling at 20 m/s brakes and decelerates uniformly to rest in 8 s. (a) Find the acceleration. (b) Find the braking distance. | a = (0 - 20) / 8 = -2.5 m/s2. Braking distance = average speed x time = (20 + 0) / 2 x 8 = 80 m. | 4 |
| 16 | A car travels 60 km at 30 km/h and then another 60 km at 60 km/h. Find the average speed for the whole journey. | Time = 60 / 30 + 60 / 60 = 2 + 1 = 3 h. Total distance is 120 km, so average speed = 120 / 3 = 40 km/h (the speeds must not simply be averaged). | 4 |

## Section E: Heat Capacity, Latent Heat and Energy (16 marks)

**Each question is worth 4 marks; take the specific heat capacity of water as 4200 J/(kg C).**

| # | Question | Answer | Marks |
|---|---|---|---|
| 17 | 2 kg of water is heated from 20 C to 45 C. The specific heat capacity of water is 4200 J/(kg C). Find the energy required. | E = mcDT = 2 x 4200 x 25 = 210000 J (210 kJ). | 4 |
| 18 | 0.5 kg of ice at 0 C is melted completely into water at 0 C; the specific latent heat of fusion is 334000 J/kg. (a) Find the energy needed. (b) How long does a 500 W heater take? | E = mL = 0.5 x 334000 = 167000 J, so t = E / P = 167000 / 500 = 334 s. | 4 |
| 19 | 1 kg of water at 80 C is mixed with 1 kg of water at 20 C with no heat loss. Find the final temperature. | The masses and specific heat capacities are equal, so the heat lost equals the heat gained and the final temperature is (80 + 20) / 2 = 50 C. | 4 |
| 20 | A 1500 W kettle heats 1.5 kg of water from 20 C to 60 C (specific heat capacity 4200 J/(kg C)). (a) Find the energy needed. (b) Find the heating time, ignoring heat loss. | E = 1.5 x 4200 x 40 = 252000 J, so t = 252000 / 1500 = 168 s (2 min 48 s). | 4 |

## Section F: Refraction, Critical Angle and Neutralisation (16 marks)

**Each question is worth 4 marks; the molar mass of NaCl is 58.5 g/mol.**

| # | Question | Answer | Marks |
|---|---|---|---|
| 21 | A ray of light passes from air into a transparent medium at an angle of incidence of 45 degrees and is refracted at 30 degrees. (a) Find the refractive index. (b) Find the speed of light in the medium (speed in vacuum 3.0 x 10^8 m/s). | n = sin 45 / sin 30 = 0.7071 / 0.5000 = 1.41. The speed is v = c / n = 3.0 x 10^8 / 1.41 = about 2.1 x 10^8 m/s. | 4 |
| 22 | A glass has a refractive index of 1.5 and light travels from the glass into air. (a) Find the critical angle. (b) What happens at an angle of incidence of 45 degrees? | sin c = 1 / n = 1 / 1.5 = 0.667, so c is about 41.8 degrees. Since 45 degrees exceeds the critical angle, total internal reflection occurs and no light is refracted into the air. | 4 |
| 23 | 25.0 cm3 of 0.10 M hydrochloric acid is titrated with 0.10 M sodium hydroxide. (a) Find the volume of sodium hydroxide needed. (b) Find the number of moles of sodium chloride formed. (c) Find its mass (molar mass 58.5 g/mol). | The reaction is 1 : 1 and the concentrations are equal, so 25.0 cm3 of NaOH is needed. Moles = 0.0250 dm3 x 0.10 mol/dm3 = 0.0025 mol, and mass = 0.0025 x 58.5 = 0.146 g. | 4 |
| 24 | 10 cm3 of 0.10 M hydrochloric acid is diluted with water to 1000 cm3. (a) Find the hydrogen ion concentration. (b) Find the pH. | Dilution is 100-fold, so the concentration is 0.10 / 100 = 0.001 mol/dm3 and pH = -log(0.001) = 3.00. | 4 |