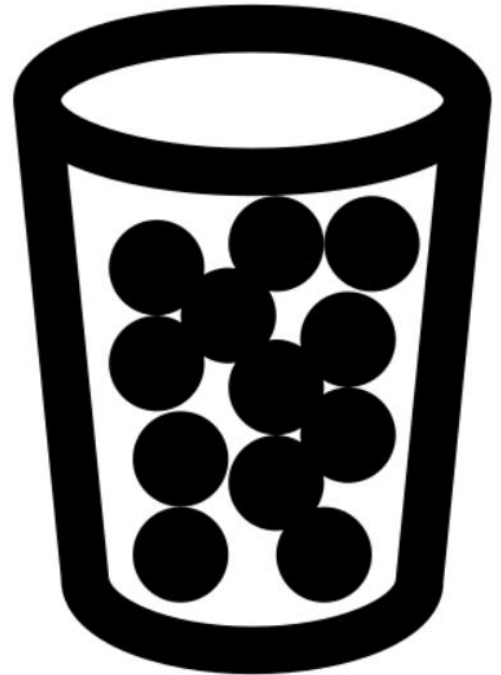


ESAT Physics Prep

Week 4 – Matter

ANSWERS



Week 1 – Electricity

Week 2 – Magnetism

Week 3 – Mechanics

Week 4 – Thermal physics

Week 5 – Matter

Week 6 – Waves

Week 7 – Radioactivity

There is one sample ESAT test – note that they use the same questions from NSAA 2020 specimen paper. Past NSAA & ENGAA questions are the most relevant.

There are no calculators in the ESAT.

Matter spec

P5.1 States of matter:

- Know the characteristic properties of solids, liquids and gases.
- Know and be able to apply particle models of solids, liquids and gases.
- Know and be able to explain properties of solids, liquids and gases in terms of particle motion and the forces and distances between the particles.

P5.2 Ideal gases:

- Be able to explain pressure and temperature in terms of the behaviour of particles.
- Understand and be able to apply the effect of pressure (P) on gas volume (V) at constant temperature, i.e. $PV = \text{constant}$.

P5.3 State changes:

- Understand the terms *melting point* and *boiling point*.
- Know and understand the terms *latent heat of fusion* and *latent heat of vaporisation*.
- Know and be able to apply specific latent heat calculations.

P5.4 Density:

- Know and be able to apply: $\text{density} = \frac{\text{mass}}{\text{volume}}$, $\rho = \frac{m}{V}$
- Understand the experimental determination of densities.
- Be able to compare the densities of solids, liquids and gases.

P5.5 Pressure:

- Know and be able to apply: $\text{pressure} = \frac{\text{force}}{\text{area}}$
- Know and be able to apply: hydrostatic pressure = $h\rho g$, where h is the height, or depth, of the liquid.

Q20 ENGAA 2023

$$PV = \text{constant}$$

20 A diver at the bottom of a lake of depth d fills a syringe with an ideal gas and seals the nozzle. The piston remains free to move. The volume of the gas in the syringe at the bottom of the lake is 90 cm^3 .

As the diver returns to the surface, the temperature of the gas does not change. At the surface of the lake the gas in the syringe is at atmospheric pressure and the volume of the gas is 720 cm^3 .

What is the volume of the gas in the syringe at a depth $\frac{d}{2}$?

A 160 cm^3

B 180 cm^3

C 206 cm^3

D 225 cm^3

E 288 cm^3

F 315 cm^3

G 360 cm^3

H 405 cm^3

Atmospheric $p = \frac{\text{constant}}{720}$

p at $d = \frac{\text{constant}}{90}$

p due to water at $d = \frac{\text{constant}}{90} - \frac{\text{constant}}{720} =$

p due to water at $\frac{d}{2} = \frac{1}{2} \left(\frac{\text{constant}}{90} - \frac{\text{constant}}{720} \right)$

Total p at $\frac{d}{2} = \frac{1}{2} \left(\frac{\text{constant}}{90} - \frac{\text{constant}}{720} \right) + \frac{\text{constant}}{720}$
atmospheric p

$$\frac{1}{2} \left(\frac{\text{constant}}{90} + \frac{\text{constant}}{720} \right) V = \text{constant}$$

$$\left(\frac{1}{90} + \frac{1}{720} \right) V = 2$$

$$\left(\frac{8}{720} + \frac{1}{720} \right) V = 2$$

$$\frac{9}{720} V = 2 \Rightarrow V = \frac{720 \times 2}{9} = 160 \text{ cm}^3$$

Q28 NSAA 2023

- 28 A solid, cylindrical metal bar has a uniform cross-sectional area of 12 cm^2 and a volume of 180 cm^3 .

The bar rests on a horizontal surface on one of its circular faces.

The pressure on the surface due to the bar is 0.45 N cm^{-2} .

What is the density of the metal, in g cm^{-3} ?

(gravitational field strength = 10 N kg^{-1})

A 2.5 g cm^{-3}

B 3.0 g cm^{-3}

C 3.75 g cm^{-3}

D 7.5 g cm^{-3}

E 15 g cm^{-3}

F 33 g cm^{-3}

$$\uparrow = A$$

$$P = \frac{F}{A} = \frac{10m}{12} = 0.45$$

$$m = 1.2 \times 0.45 = 0.54 \text{ kg}$$

$$\rho = \frac{m}{V} = \frac{0.54}{180} = 0.003 \text{ kg/cm}^3 = 3 \text{ g/cm}^3$$

Q33 NSAA 2023

- 33 10g of ice at 0°C is added to 20g of liquid water at 30°C .

The mixture reaches thermal equilibrium.

What is its equilibrium temperature, T ?

(specific latent heat of fusion of ice = 330 J g^{-1})

specific heat capacity of liquid water = $4.2 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$

assume that there is no heat transfer between the mixture and its surroundings)

A $T < 0^\circ\text{C}$

B $T = 0^\circ\text{C}$

C $0^\circ\text{C} < T < 20^\circ\text{C}$

D $T = 20^\circ\text{C}$

E $20^\circ\text{C} < T < 30^\circ\text{C}$

F $T = 30^\circ\text{C}$

G $T > 30^\circ\text{C}$

$$\text{Energy for ice to melt} = mL = 10 \times 330 = 3300 \text{ J}$$

$$\text{Max energy that water can lose before freezing} = mc\Delta T = 20 \times 4.2 \times 30 = 600 \times 4.2 = 2520 \text{ J}$$

Therefore not all ice has melted so $T = 0^\circ\text{C}$

Q38 NSAA 2022

38 A tall, smooth cylinder contains air at atmospheric pressure of $1.00 \times 10^5 \text{ Pa}$. The density of the air in the cylinder is 1.20 kg m^{-3} .

A heavy piston is now placed in the top of the cylinder and allowed to fall slowly downwards, compressing the air until the piston rests in equilibrium.

The mass of the piston is 50.0 kg and its cross-sectional area is 0.0200 m^2 .

What is the density of the air in the cylinder when the piston rests in equilibrium?

(gravitational field strength = 10 N kg^{-1} ; assume that the air behaves as an ideal gas and that the temperature remains constant)

- A 0.960 kg m^{-3}
- B 1.20 kg m^{-3}
- C 1.25 kg m^{-3}
- D 1.28 kg m^{-3}
- E 1.50 kg m^{-3}
- F 4.80 kg m^{-3}

Additional $P = \frac{F}{A} = \frac{500}{0.02} = 25000 \text{ Pa}$

Total $P = 1.25 \times 10^5 \text{ Pa}$ $\uparrow \times 1.25$

$PV = nRT$ $\rho = \frac{m}{V}$

$\uparrow \times 1.25$ $\downarrow \times 1.25$ $\downarrow \times 1.25$

$1.20 \times 1.25 = 1.50 \text{ kg/m}^3$

Q40 NSAA 2022

40 A solid cuboid has a mass of 32 kg and a density of 4.0 g cm^{-3} .

Faces 1, 2 and 3 of the cuboid have different areas.

When the cuboid rests on one of these faces on a flat horizontal surface, the pressure on the surface due to the cuboid is 1.6 N cm^{-2} .

When it rests on another of these faces, the pressure on the surface due to the cuboid is 0.80 N cm^{-2} .

What is the pressure on the surface due to the cuboid when it rests on the third of these faces?

(gravitational field strength = 10 N kg^{-1})

- A 0.40 N cm^{-2}
- B 1.2 N cm^{-2}
- C 3.2 N cm^{-2}
- D 6.4 N cm^{-2}
- E 8.0 N cm^{-2}

$\rho = \frac{m}{V} \Rightarrow V = \frac{m}{\rho}$

$V = \frac{32000}{4.0} = 8000 \text{ cm}^3$

$P = \frac{F}{A} \Rightarrow 1.6 = \frac{320}{xy} \Rightarrow xy = \frac{320}{1.6} = 200$

$P = \frac{F}{A} \Rightarrow 0.80 = \frac{320}{yz} \Rightarrow yz = \frac{320}{0.80} = 400$

$xy = 200$

$yz = 400$

$xz = 8000$

$200z = 8000 \Rightarrow z = 40 \text{ cm}$

$400x = 8000 \Rightarrow x = 20 \text{ cm}$

$40 \times 20 \times y = 8000 \Rightarrow y = 10 \text{ cm}$

3rd face = $xz = 20 \times 40 = 800 \text{ cm}^2$

$P = \frac{F}{A} = \frac{320}{800} = 0.40 \text{ N/cm}^2$

Q20 ENGAA 2022

- 20 A tall, smooth cylinder contains air at atmospheric pressure of $1.00 \times 10^5 \text{ Pa}$. The density of the air in the cylinder is 1.20 kg m^{-3} .

A heavy piston is now placed in the top of the cylinder and allowed to fall slowly downwards, compressing the air until the piston rests in equilibrium.

The mass of the piston is 50.0 kg and its cross-sectional area is 0.0200 m^2 .

What is the density of the air in the cylinder when the piston rests in equilibrium?

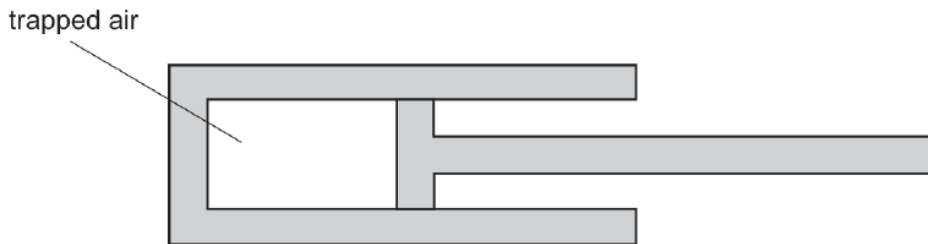
(gravitational field strength = 10 N kg^{-1} ; assume that the air behaves as an ideal gas and that the temperature remains constant)

- A 0.960 kg m^{-3}
- B 1.20 kg m^{-3}
- C 1.25 kg m^{-3}
- D 1.28 kg m^{-3}
- E** 1.50 kg m^{-3}
- F 4.80 kg m^{-3}

Accidentally same ρ
as NSAA 2022

Q2 ENGAA 2021

- 2 Air is trapped in a cylinder by a piston. The density of the air in the cylinder is ρ .



The piston is moved so that the pressure of the trapped air increases by 20%. The temperature of the trapped air does not change.

What is the new density of the trapped air?

(Assume that air is an ideal gas.)

- A 0.69ρ
- B 0.80ρ
- C 0.83ρ
- D 1.00ρ
- E** 1.20ρ
- F 1.44ρ

Handwritten notes:

$\uparrow \times 1.2$ (circled) $\uparrow \times 1.2$

$$pV = nRT$$

$\downarrow \times 1.2$

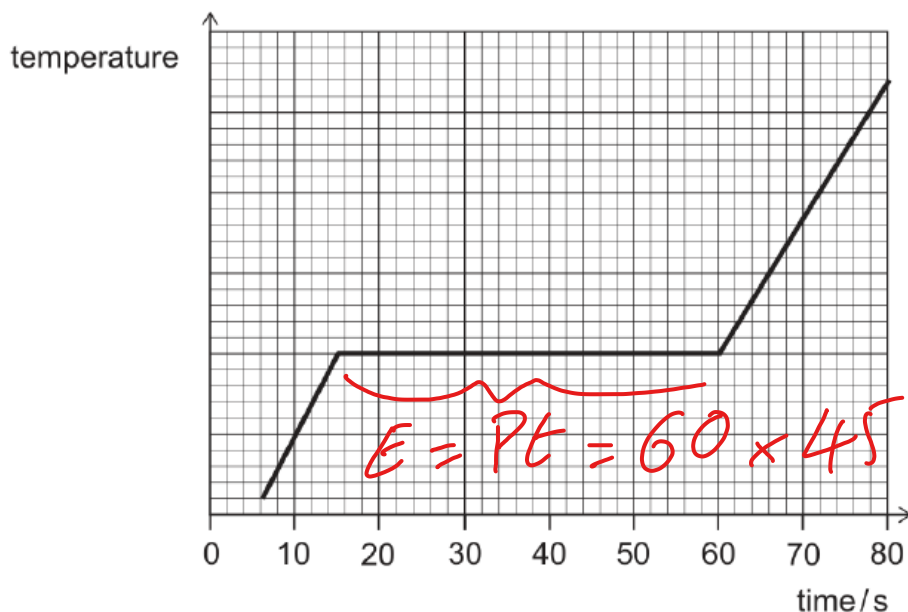
$$\rho = \frac{m}{V}$$

$\uparrow \times 1.2$ $\downarrow \times 1.2$

Q27 NSAA 2019

27 Heat is supplied to an initially solid substance at a rate of 60 W.

The graph shows the variation of the temperature of the substance with time.



What is the mass of the substance?

(specific latent heat of fusion of substance = 100 J g^{-1} ; assume that there is no heat transferred to the surroundings)

A 0.013 g

B 0.60 g

C 3.0 g

D 9.0 g

E 27 g

F 36 g

$$E = mL$$

$$60 \times 45 = 100m$$

$$m = \frac{60 \times 45}{100} = \frac{6 \times 45}{10} = \frac{270}{10} = 27 \text{ g}$$

$$m_c + m_w = 290$$

Q20 ENGAA 2018

20 A student places a measuring cylinder on a balance. She pours a volume V of water into the measuring cylinder, and finds that the mass of the measuring cylinder and water together is 290 g.

She then empties the measuring cylinder and dries it before putting it back on the balance.

She now pours the same volume V of olive oil into the measuring cylinder, and finds that the mass of the measuring cylinder and olive oil together is 270 g.

What is the mass of the measuring cylinder?

(densities: olive oil = 0.90 g cm^{-3} ; water = 1.0 g cm^{-3})

A 18 g

B 20 g

C 90 g

D 180 g

E 200 g

$$m_c + m_w = 290$$

$$m_c + m_o = 270$$

$$m_w - m_o = 20$$

$$0.90 = \frac{m_o}{V}$$

$$1.0 = \frac{m_w}{V}$$

$$V = \frac{m_o}{0.90} = m_w \Rightarrow m_o = 0.90 m_w$$

$$m_o = 0.90(m_o + 20)$$

$$0.10 m_o = 18$$

$$m_o = 180$$

$$m_c + 180 = 270 \Rightarrow m_c = 90$$

Q16 ENGAA 2017

16 The radius of an iron-56 atom is 3.0×10^4 times greater than the radius of an iron-56 nucleus.

What is the value of $\frac{\text{density of an iron atom}}{\text{density of an iron nucleus}}$?

A $(3.0 \times 10^4)^{-3}$

B $(3.0 \times 10^4)^{-2}$

C $(3.0 \times 10^4)^{-1}$

D $(3.0 \times 10^4)^1$

E $(3.0 \times 10^4)^2$

F $(3.0 \times 10^4)^3$

\rightarrow lower
 \hookrightarrow higher

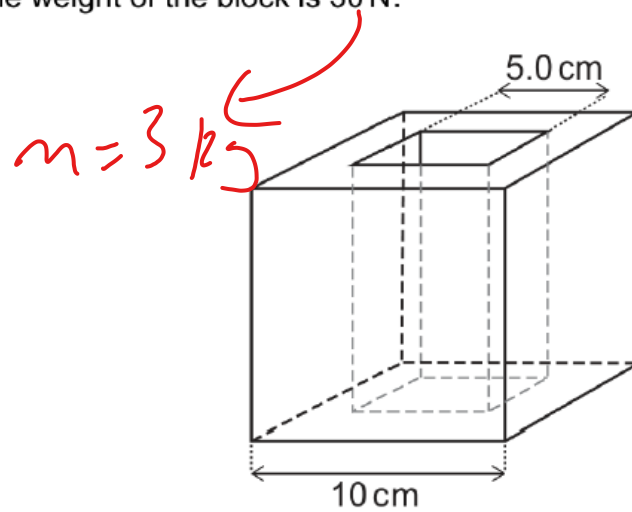
$$V = \frac{4}{3} \pi r^3$$

$\uparrow \times (3.0 \times 10^4)^3$

$$\rho = \frac{m}{V}$$

Q18 ENGAA 2018

- 18 A cubic block has a hole through it with a square cross-section. The dimensions are shown on the diagram. The weight of the block is 30 N.



$$\begin{aligned} V &= 10^3 - (5 \times 5 \times 10) \\ &= 1000 - 250 \\ &= 750 \text{ cm}^3 \end{aligned}$$

What is the density of the material from which the block is made?

(The gravitational field strength g is 10 N kg^{-1} .)

- A 0.30 g cm^{-3}
- B 0.40 g cm^{-3}
- C 0.60 g cm^{-3}
- D 1.2 g cm^{-3}
- E 3.0 g cm^{-3}
- F 4.0 g cm^{-3}
- G 6.0 g cm^{-3}
- H 12 g cm^{-3}

$$\begin{aligned} \rho &= \frac{m}{V} = \frac{3}{750} \text{ kg/cm}^3 \\ &= \frac{1}{250} \text{ kg/cm}^3 \\ &= 0.004 \text{ kg/cm}^3 \\ &= 4 \text{ g/cm}^3 \end{aligned}$$