**Physics**
**Standard level**
**Paper 2**
TZ2

19/10/22

Thursday 28 April 2022 (morning)

Candidate session number

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

1 hour 15 minutes

**Instructions to candidates**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

$\frac{39}{50}$ $\cancel{\frac{38}{50}}$ = 78%

15 pages

2222–6517



16EP01

Please **do not** write on this page.

Answers written on this page will not be marked.

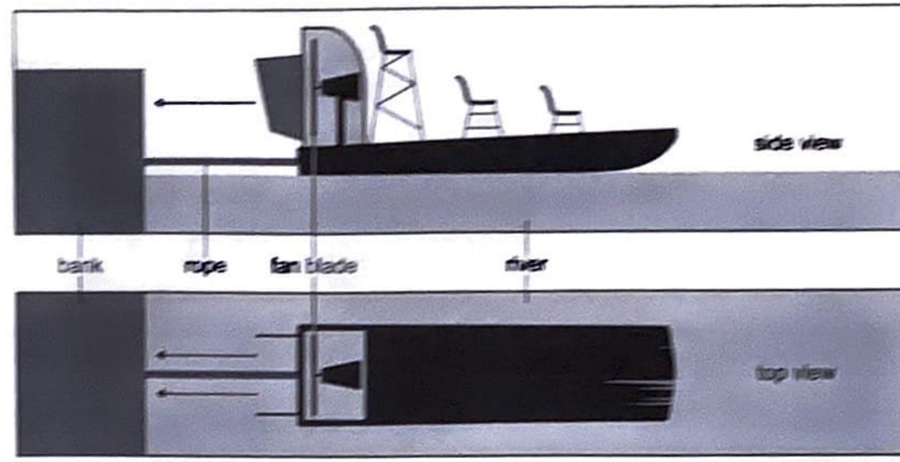






Answer **all** questions. Answers must be written within the answer boxes provided.

1. Airboats are used for transport across a river. To move the boat forward, air is propelled from the back of the boat by a fan blade.




An airboat has a fan blade of radius 1.8 m. This fan can propel air with a maximum speed relative to the boat of 20 m s$^{-1}$. The density of air is 1.2 kg m$^{-3}$.

(a) Outline why a force acts on the airboat due to the fan blade. [3]

=> Due to Newton's third law
=> As the fan blade propels air towards the rear the air will exert an equal and opposite force on the fan blade -> note that the "mass" property of air makes this possible
=> as the fan blade is attached to the boat the N3 force exerted on the fan blade, is exerted on the boat

3

**(This question continues on the following page)**

**(Question 1 continued)**

(b) In a test the airboat is tied to the river bank with a rope normal to the bank. The fan propels the air at its maximum speed. There is no wind.

(i) Show that a mass of about 240 kg of air moves through the fan every second. [2]

$A = \pi(1.8)^2 = 10.179\ m^2$

$v = 20\ ms^{-1}$

$\rho = 1.2\ kg\ m^{-3}$

In 1 second, $20 \times 10.179\ m^3$ moves through

$\therefore$ Mass per second $= 20 \times 10.179 \times 1.2$

$= 244\ kg s^{-1}$

$= 240\ kg\ s^{-1}$

2

(ii) Show that the tension in the rope is about 5 kN. [1]

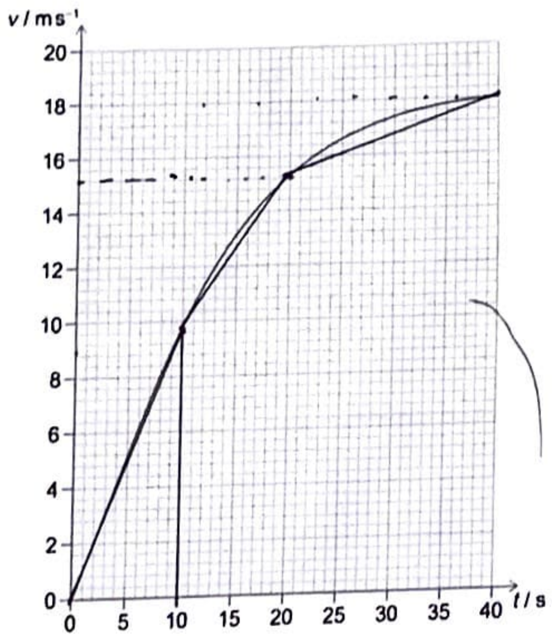
$Fv = \frac{1}{2}A\rho v^3 \rightarrow F = \frac{1}{2}A\rho v^2 = \frac{1}{2}(10.174)(1.2)(20^2)$

$= 4886\ N$

$= \cancel{4.9}\ 4.9\ kN$

1

(c) The rope is untied and the airboat moves away from the bank. The variation with time $t$ of the speed $v$ of the airboat is shown for the motion.




(This question continues on the following page)





**(Question 1 continued)**

(i) Estimate the distance the airboat travels to reach its maximum speed. [2]

Area $= 0 \rightarrow 10 + 10 \rightarrow 20 + 20 \rightarrow 40$

$= (\frac{1}{2})(10)(10) + ((10)(9) + (\frac{1}{2})(6)(10)) + ((15)(20) + (\frac{1}{2})(3)(20))$

$\therefore s = 495\ m$

$\therefore s \approx 500\ m$

2

(ii) Deduce the mass of the airboat. [3]

constant acceleration in first 10 s

$a = $ rise / run

$= 10/10$

$= 1\ ms^{-2}$

$\therefore F = ma$

$\therefore m = 5 \times 10^3 / 1 = 5 \times 10^3\ kg$

3

(d) The fan is rotating at 120 revolutions every minute. Calculate the centripetal acceleration of the tip of a fan blade. [2]

~~f = (120)(2π) rad min⁻¹~~

$f = 120\ rev\ min^{-1}$

$= 2\ Hz \rightarrow T = \frac{1}{2}\ s$

$a = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2(1.8)}{(1/2)^2}$

$= 142.1\ ms^{-2}$

$\approx 140\ ms^{-2}$

1

Turn over

Please **do not** write on this page.

Answers written on this page will not be marked.







**2.** A fixed mass of an ideal gas is contained in a cylinder closed with a frictionless piston. The volume of the gas is $2.5 \times 10^{-3}\,m^3$ when the temperature of the gas is 37 °C and the pressure of the gas is $4.0 \times 10^5\,Pa$.

(a) Calculate the number of gas particles in the cylinder. [2]

$n = pV/RT = \frac{4.0 \times 10^5 \times 2.5 \times 10^{-3}}{8.31 \times (273+37)} = 0.3882$ mol

$\therefore N = N_A n = 6.02 \times 10^{23} \times 0.3882 = 2.3369 \times 10^{23}$

$\therefore N \approx 2.3 \times 10^{23}$ particles

2

(b) Energy is now supplied to the gas and the piston moves to allow the gas to expand. The temperature is held constant.

Discuss, for this process, the changes that occur in the

(i) density of the gas. [2]

$\Rightarrow$ $\rho = M/\text{Volume}$ $\Rightarrow$ as volume increases, the density will decrease

$\Rightarrow$ physically, this means the ~~partic~~ average distance between particles will be greater as the same number of particles occupy more space/volume

2

(ii) internal energy of the gas. [2]

$\Rightarrow$ ~~$\bigstar$~~ $U = \bar{E}_K + E_P$, however $E_P = 0$ (ideal gas)

$\Rightarrow$ $U = \bar{E}_K = \frac{3}{2}k_B T$

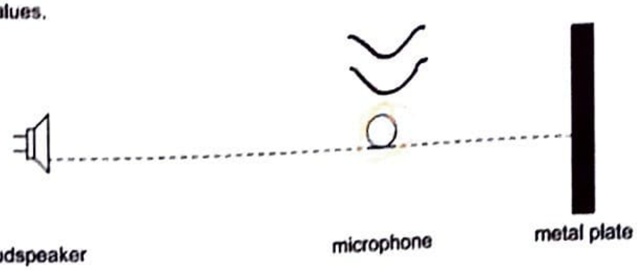
$\Rightarrow$ as T is kept constant, the average kinetic energy $\bar{E}_K$, hence also the internal energy, U, remain the same

2



Turn over

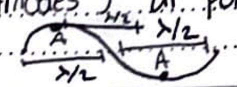
3. A loudspeaker emits sound waves of frequency $f$ towards a metal plate that reflects the waves. A small microphone is moved along the line from the metal plate to the loudspeaker. The intensity of sound detected at the microphone as it moves varies regularly between maximum and minimum values.




The speed of sound in air is $340\,\mathrm{m\,s^{-1}}$.

(a) (i) Explain the variation in intensity. [3]

⇒ the soundwaves that reflect off the metal plate superimpose with waves emitted from the loudspeaker
⇒ this creates a standing wave (stationary)
⇒ this standing wave will vary between maxima and minima ("antinodes") at points $\lambda/2$ along the line.




2

(ii) Adjacent minima are separated by a distance of 0.12 m. Calculate $f$. [2]

$\lambda = 0.12\ \mathrm{m}$ ✗ $\therefore f = v/\lambda$
$v = 340\ \mathrm{ms^{-1}}$ $\ulcorner 0.24\,\mathrm{m}$ $= 340/0.12$
$= 2833\ \mathrm{Hz}$
$\approx 2.8\times10^{3}\ \mathrm{Hz}$ FT
$\approx 2.8\ \mathrm{kHz}$

1

**(This question continues on the following page)**





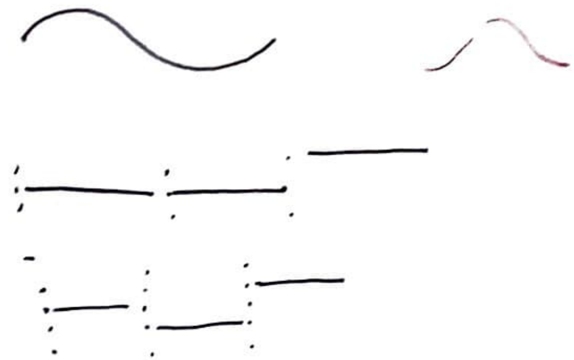
**(Question 3 continued)**

(b) The metal plate is replaced by a wooden plate that reflects a lower intensity sound wave than the metal plate.

State and explain the differences between the sound intensities detected by the same microphone with the metal plate and the wooden plate. [3]

⇒ wooden plate will reduce the amplitude of reflected wave
⇒ hence, the maximum superposition of both waves will be reduced
⇒ the destructive ability of the returning wave will reduce, hence increasing the minima.
⇒ Hence, the range of detected intensities will reduce.

3



4. (a) Identify the laws of conservation that are represented by Kirchhoff's circuit laws. [2]

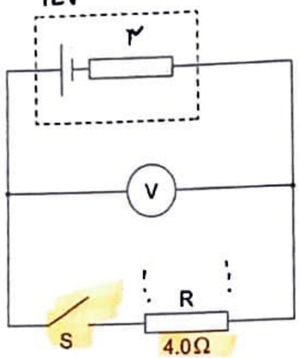
$\Rightarrow \Sigma V = 0$ in a loop?

$\Rightarrow \Sigma I = 0$ at a junction

1

(b) A cell is connected to an ideal voltmeter, a switch S and a resistor R. The resistance of R is 4.0Ω.

12V




$12 = \varepsilon \cancel{I} r$

$8 = \varepsilon$

When S is open the reading on the voltmeter is 12V. When S is closed the voltmeter reads 8.0V.

(i) State the emf of the cell. [1]

$\varepsilon = 12$ V {no current flowing when S open. ~~closed~~}

1

(ii) Deduce the internal resistance of the cell. [2]

$\Rightarrow \varepsilon = I(R + r) \rightarrow 12 = I(4 + r)$

$\Rightarrow V = F/R \rightarrow I = (8)/(4) = 2A$

$\Rightarrow 12 = 2(4 + r)$

$\therefore 2r = 12 - 8$

$\therefore r = 2\Omega$

2

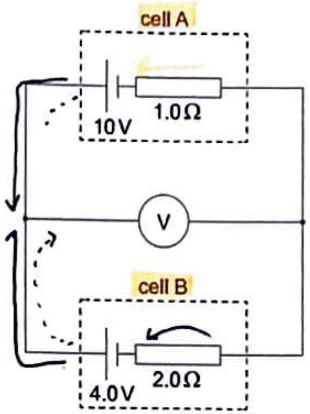
(This question continues on the following page)

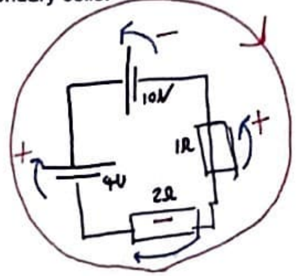




(Question 4 continued)

(c) The voltmeter is used in another circuit that contains two secondary cells.




$4 - 10 + I + 2I = 0$

$\therefore -6 - 3I = 0$

$\therefore I = 2$

$10 - 6 = 4$

$10 - 2 = 8$

$12 - 4 =$

Cell A has an emf of 10V and an internal resistance of 1.0Ω. Cell B has an emf of 4.0V and an internal resistance of 2.0Ω.

Calculate the reading on the voltmeter. [3]

~~$\Sigma V = 0$~~

~~$\therefore 10 - 4 + 2I - 1I = 0 \rightarrow I = 6A$~~

~~$\therefore V = -(2.0)(6) + 4$~~

~~$= -8$~~

~~$\therefore$ Voltmeter reading is 8.0 V~~

$10V + 1I = 4V - 2I$

$\therefore 3I = -6V$

$\therefore I = -2A = 2A$

$\Rightarrow$ Voltmeter $= 10V - 2V$

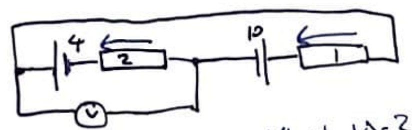
$= 8V$

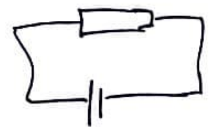
3

(This question continues on page 13)

$10/I\ \Omega$. $V = IR$

$V = IR$



$+4.0$

$\varepsilon = 4.0V$

$10 - 2I$

$4 - 2I = 10 - I$

$\therefore I = -6$

$4 + 2I = 10 - I$

$\therefore 3I = 6$

$\therefore I = 2$

$+4 - 1 - 10 - 2$

$(4 - 4)$

$\varepsilon = I(R + r)$

$\therefore 4 = I\left(\frac{10}{I} - 1 + 2\right)$

$\therefore 4 = 10 - I + 2I$

$8 = 4 - 2I$

$\therefore 2I = 4 \rightarrow I = -2$

Please **do not** write on this page.

Answers written on this page will not be marked.





**(Question 4 continued)**

(d) Electricity can be generated using renewable resources.

(i) Outline why electricity is a secondary energy source. [1]

⇒ It has been converted from another energy source (i.e. not in the "Raw", primary form)

1

(ii) Some fuel sources are renewable. Outline what is meant by renewable. [1]

⇒ They are replenished faster than they are depleted

⇒ They are ~~the~~ ~~theoret~~ practically infinite → never deplete

1

(e) (i) A fully charged cell of emf 6.0 V delivers a constant current of 5.0 A for a time of 0.25 hour until it is completely discharged.

The cell is then re-charged by a rectangular solar panel of dimensions 0.40 m × 0.15 m at a place where the maximum intensity of sunlight is 380 W m$^{-2}$.

The overall efficiency of the re-charging process is 18%.

Calculate the minimum time required to re-charge the cell fully. [3]

$Q = Pot = (6.0)(5.0)(15 \times 60) = 27000$ J

$P = (380)(0.40)(0.15)(0.18) = 4.104$ W

$\therefore$ time to charge $= \dfrac{27000}{4.104} = 6578.65$ s

$= 6600$ s

3

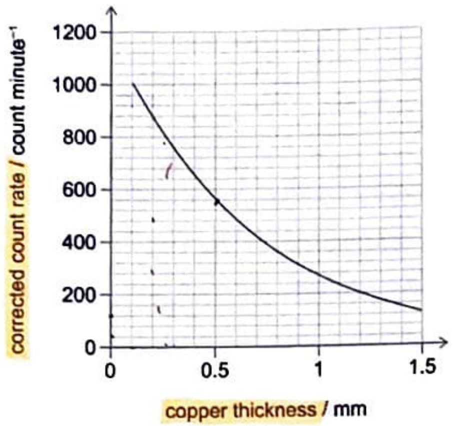
(ii) Outline why research into solar cell technology is important to society. [1]

⇒ Improve the efficiency of ~~solar~~ photovoltaic panels/cells.

⇒ ~~imp~~ this will accelerate transitions to renewables (i.e. accelerate the solution to climate change).

1

5. An experiment is carried out to determine the count rate, corrected for background radiation, when different thicknesses of copper are placed between a radioactive source and a detector. The graph shows the variation of corrected count rate with copper thickness.




(a) Outline how the count rate was corrected for background radiation. [1]

Observe systematic error: ~~bequerels~~ count rate of radiation without a radioactive substance. Subtract this off the recorded value during the experiment.

1

(b) When a single piece of thin copper foil is placed between the source and detector, the count rate is 810 count minute$^{-1}$. The foil is replaced with one that has three times the thickness. Estimate the new count rate. [2]

Using graph: 0.5 → 1.5 is 3× thickness.
ratio: 120/560 = 3/14

$\therefore 810 \times \frac{3}{14} = 174$ count minute$^{-1}$

×

(This question continues on the following page)





(Question 5 continued)

(c) Further results were obtained in this experiment with copper and lead absorbers.

| Absorber | Thickness / mm | Corrected count rate / count minute$^{-1}$ |
|---|---|---|
| copper | 3.5 | 32 |
| lead | 3.5 | 10 |

α: thin paper or few cm air

Comment on the radiation detected from this radioactive source. [4]

⇒ most likely Beta radiation ✓ → reasoning
⇒ this is due to the penetrative power ; ⇒ α could not penetrate any of the metal, ✓ even 3.5 mm.
⇒ gamma would not lose ~1/3 strength between copper and lead.

⇒ could be most likely gamma radiation
⇒ lead is a good absorber of gamma, which explains the drop.

3

(d) Another radioactive source consists of a nuclide of caesium ($^{137}_{55}Cs$) that decays to barium ($^{137}_{56}Ba$).

Write down the reaction for this decay. [2]

$^{137}_{56}Ba = {}^{137}_{55}Cs + {}^{0}_{1}\beta^{+}$ ×

$\therefore {}^{137}_{56}Ba = {}^{137}_{55}Cs + {}^{0}_{1}e^{+} + \nu_e$ ← normal neutrino (not anti)

0

References: