BINDURA UNIVERSITY OF SCIENCE EDUCATION

Faculty of Science Education

Department of Mathematics and Science Education

HBSCED-Physics

PH102 (1) Thermal Physics and Wave Motion

Duration: Three (3) Hours

INTSRUCTIONS

- *Answer ALL questions in Section A and any THREE questions from Section B. Section A carries 40 marks and each question of Section B carries 20 marks.*
- *Show ALL formulae and substitutions in ALL calculations.*
- *Leave your answers correct to 2 decimal places*

You may not start to read the questions printed on the subsequent pages until instructed to do so by the Invigilator.

(50)

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SECTION A

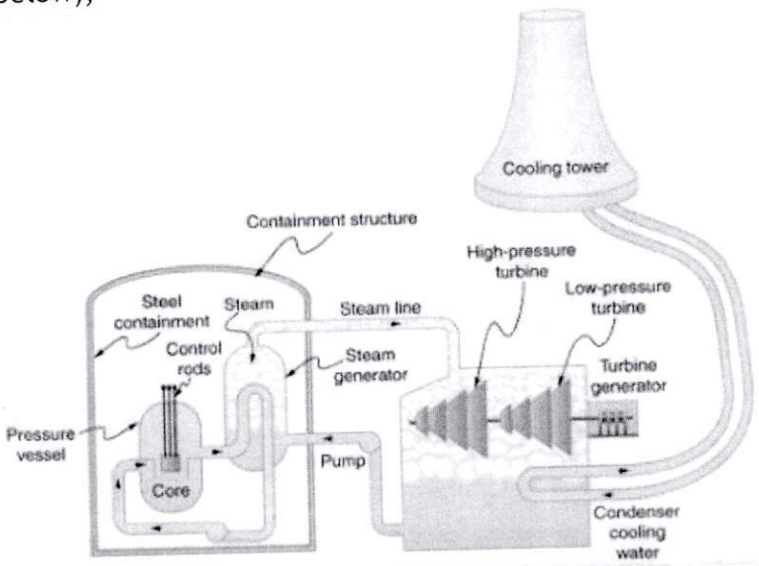
(Answer **ALL** questions in this section.)

QUESTION 1 (40 MARKS)

a) Find the Fourier transform of a rectangular pulse signal defined by;

$$x(t) = \begin{cases} 1, |t| < T_1 \\ 0, |t| > T_2 \end{cases}$$ (5)

b) A nuclear power reactor has pressurized water at 300°C. (Higher temperatures are theoretically possible but practically not, due to limitations with materials used in the reactor). Heat transfer from this water is a complex process (see the diagram below);



Steam, produced in the steam generator, is used to drive the turbine-generators. Eventually the steam is condensed to water at 27°C and then heated again to start the cycle over.

i) Calculate the maximum theoretical efficiency for a heat engine operating between these two temperatures. (5)

ii) Spontaneous heat transfer from hot to cold is an irreversible process. Calculate the total change in entropy if 4000J of heat transfer occurs from a hot reservoir at 327°C to a cold reservoir at −23°C, assuming there is no temperature change in either reservoir. (7)

c) Show that if one sound is twice as intense as another, it has a sound level about 3dB higher. (8)

d) $10g$ of a hydrogen gas sample (H_2) is at a temperature of $20°C$. The atomic mass of a hydrogen atom is $1u$.
   i) Calculate the energy of one molecule. (2)
   ii) Calculate total energy of the sample. (3)

e) Four moles of oxygen being initially at temperature T_0=300K is adiabatically compressed so the pressure becomes 128P0, ,P_0 is initial pressure find
   i) the gas temperature after compression
   ii) The work that has been performed on the gas. (5)

f) A well in a certain village has vertical sides and water at the bottom. It resonates at $7{,}00\ Hz$ and at no lower frequency. The air in the well has a density of $1{,}10\ kgm^{-3}$ and an adiabatic modulus of $1{,}33 \times 10^5\ Pa$. How deep is the well? (5)

SECTION B

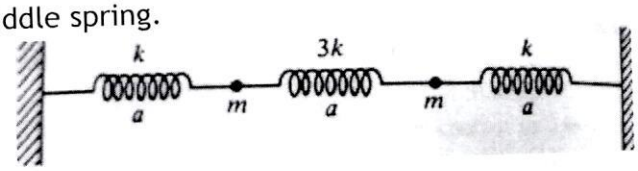
(Answer **ANY THREE** questions from this section)

QUESTION 2 (20 MARKS)

Two particles move in one dimension at the junction of three springs, as shown in the figure. The springs all have unstretched lengths equal to a, and the force constants and masses are shown. Find their;

a) Find their eigen frequencies, and normal modes. (18)

b) hence comment the displacements of the springs frequency exhibited by the middle spring. (2)



Hints: You may;

- ***Take x_1 and x_2 as coordinates of the masses starting from left.***
- ***Take X_1 as fixed coordinate of the left end of the left spring as well as X_2 as the fixed coordinate of the right end of the right-most spring.***
- ***Use η_1 and η_2 are deviations from the equilibrium position of the two masses.***

QUESTION 3 (20 MARKS)

a) Explain the concept of degrees of freedom in the kinetic theory of gases? State the equipartition of energy theorem showing how the concept of degrees of freedom is involved. (6)

b) How many degrees of freedom does a diatomic molecule have? Use a diagram to show how they arise. You may neglect any vibrations. (6)

c) Consider an ideal gas whose density is $1.3\ kgm^{-3}$ at standard pressure (1 atmosphere) and temperature (normal-ice-point). If the speed of sound propagation in this gas is $330\ ms^{-1}$, calculate the degrees of freedom of the gas molecules. (8)

QUESTION 4 (20 MARKS)

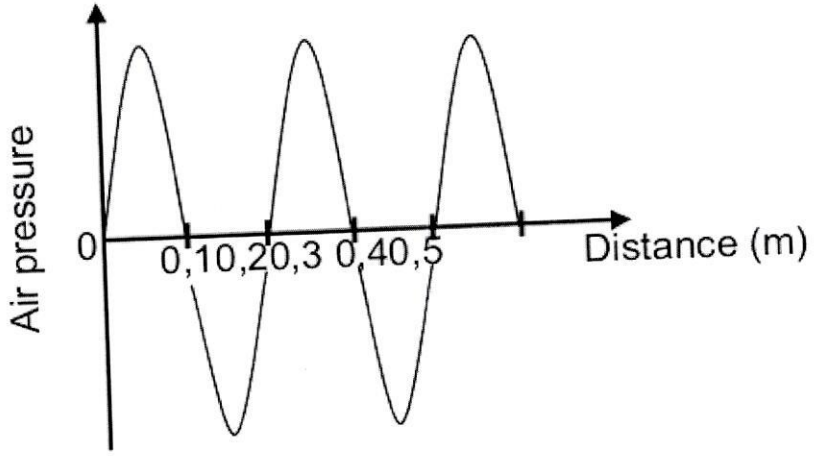
A bird flies directly towards a stationary bird watcher at constant velocity. The bird constantly emits sound waves at a frequency of 1 650 Hz. The birdwatcher hears a change in pitch as the bird comes closer to him.

a) Define the 'Doppler-effect'. (2)

b) Write down the property of sound that is related to pitch. (1)

c) Give a reason why the birdwatcher observes a change in pitch as the bird approaches him. (1)

The air pressure versus distance graph below represents the waves detected by the birdwatcher as the bird comes closer to him. The speed of sound in air is 340 $m \cdot s^{-1}$.



d) From the graph, write down the wavelength of the detected waves. (1)

e) Calculate the:

i. Frequency of the waves detected by the birdwatcher (3)

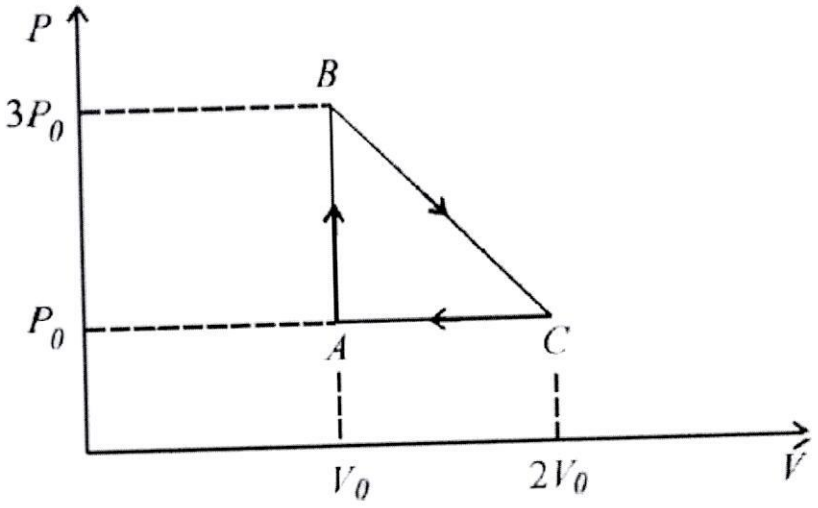
ii. Magnitude of the velocity at which the bird flies (5)

f) Explain how the Doppler effect is used to determine the direction of flow of blood in veins. (3)

g) Light emitted from distant stars demonstrates the phenomenon known as red shift. Briefly describe the phenomenon known as red shift and explain how it can be used to justify that the universe is expanding. (4)

QUESTION 5 (20 MARKS)

One mole of an ideal monatomic gas is taken round the cyclic process ABCA as shown in figure.



Calculate;

a) the work done by the gas. (3)

b) the heat rejected by the gas in the path CA and the heat absorbed by the gas in the path AB, (6)

c) the net heat absorbed by the gas in the path BC, (5)

d) the maximum temperature attained by the gas during the cycle. (6)

THE END

Some useful constants

Constant	Value
Boltzmann constant	$1.38 \times 10^{-23}\ m^2 2\ kgs^{-2}K^{-1}$
Planck's constant	$6.63 \times 10^{-34} m^2 kg\ /\ s$
Speed of light in a vacuum	$3 \times 10^8 ms^{-1}$