PHYSICS

PAPER – 1

(THEORY)

(Three hours)

*(Candidates are allowed additional 15 minutes for **only** reading the paper.*
They must NOT start writing during this time.)

All questions are compulsory.
*Question number 1 is of **twenty** marks, with three subparts, all of which are **compulsory.***
Question numbers 2 to 8 carry 2 marks each with two questions having internal choice.
Question numbers 9 to 15 carry 3 marks each with two questions having internal choice.
Question numbers 16 to 18 carry 5 marks each. Each question has an internal choice.
The intended marks for questions are given in brackets [ ].
All working, including rough work should be done on the same sheet as and adjacent to the rest of the answer.) Answers to sub parts of the same question must be given in one place only. A simple scientific calculator without a programmable memory may be used for calculations.

PART – I

*Answer **all** questions.*

Question 1

(A) Attempt the following questions by choosing the correct alternative (i), (ii), (iii) or (iv). **[5×1]**

(a) The density of a cube is measured by measuring its mass and length of its side. If the maximum errors in the measurement of its mass and length are 3% and 2% respectively, the maximum error in the measurement of density would be:

(i) 12%
(ii) 14%
(iii) 7%
(iv) 9%

(b) A block rests on a rough inclined plane making an angle of 30^0 with the horizontal. The coefficient of static friction between the block and the plane is 0.8. If the frictional force on the block is 10 N, the mass of the block in kg is: (g= 10 m/s^2)

(i) 2.0
(ii) 4.0
(iii) 1.6
(iv) 2.5

(c) An **ideal** spring with spring constant k is hung from the ceiling and a block of mass M is attached to its lower end. The mass is released with the spring initially unstretched. Then the maximum extension in the spring is:

(i) $\frac{4Mg}{k}$

(ii) $\frac{2Mg}{k}$

(iii) $\frac{Mg}{k}$

(iv) $\frac{Mg}{2k}$

(d) The pressure of a fixed mass of air is 1.01×10^5 Pa. It is compressed slowly, keeping its temperature constant. Then Bulk modulus of air is, (approximately):

(i) 1.414×10^5 Pa

(ii) 1.67×10^5 Pa

(iii) 51.2×10^5 Pa

(iv) 1.01×10^5Pa

(e) A large soap bubble of diameter D breaks into 27 bubbles. If surface tension of the soap solution is T, the change in surface energy is:

(i) $2\pi TD^2$

(ii) $4\pi TD^2$

(iii) πTD^2

(iv) $8\pi TD^2$

(B) Answer the following questions briefly and to the point: **[7 × 1]**

(i) What are the dimensions of a/b in the relation F = a + bx, where F is force and x is distance?

(ii) Two straight lines drawn on the same displacement-time graph make angles 30° and 60° with time axis respectively, as shown in Figure 1. What is the ratio of the two velocities?

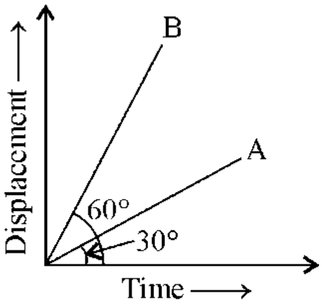

Figure – 1

(iii) Determine a unit vector in the direction of $\vec{A} = 2\hat{i} + \hat{j} + \hat{k}$.

(iv) In kinetic theory of gases, state the **law of equipartition of energy**.

(v) An **ideal** gas is compressed at a constant temperature. Will its **internal energy** increase or decrease?

(vi) A food packet is released from a helicopter which is **rising** steadily at 2 ms^{-1}. What is the velocity of the packet after two seconds? Take g = 9.8 ms^{-2}

(vii) A ball moving with a momentum of 5 kg ms^{-1} strikes against a wall at an angle of 45° and is reflected at the same angle. Calculate the **change** in its momentum.

(C) Answer the questions given below: **[4 × 2]**

(i) The Sun rotates around itself once in 27 days. What will be its period of rotation if the Sun were to expand to twice its present radius? Assume the Sun to be a sphere of uniform density.

(ii) Calculate the rms velocity of air molecules at STP. Given density of air at STP is 1.296 kg m^{-3} . (Take Standard pressure = 1.013 x 10^5 Pa.)

(iii) State Newton's Law of cooling and write its mathematical expression.

(iv) Obtain **Mayer's relation**, with the help of **first law of thermodynamics**.

PART – II

Question 2 **[2]**

Show that the average kinetic energy of a gas molecule is directly proportional to the absolute temperature of the gas.

Question 3 **[2]**

Show that the Newton's third law of motion is contained in his second law.

Question 4 **[2]**

State and explain the principle of **conservation of angular momentum**.

OR

Explain if angular momentum and rotational kinetic energy can be conserved in a system whose moment of inertia is decreased.

Question 5 **[2]**

Establish a relation for orbital speed of a satellite orbiting very close to the surface of the Earth.

Question 6 **[2]**

State any two limitations of the **first law of thermodynamics**.

Question 7 **[2]**

Obtain an expression for escape velocity of a body which is projected from the surface of the Earth.

OR

Calculate the minimum energy required to put a 250 kg satellite in a circular orbit which is at an altitude of 2R, where R is radius of the earth equal to 6400 Km.

Question 8 **[2]**

Derive an expression for the time period of a simple pendulum under small oscillations.

Question 9 **[3]**

The frequency ν of vibration of a stretched string depends upon:

(i) its length ℓ,

(ii) its mass per unit length 'm' and

(iii) the tension T in the string.

Obtain dimensionally an expression for frequency ν.

Question 10 **[3]**

Two blocks, M_1 and M_2 having masses 2 kg and 5 kg respectively are connected by an ideal string passing over a pulley (Figure 2). The block M_1 is free to slide on a rough surface inclined at an angle of 30° with the horizontal whereas the block M_2 hangs freely. Find the acceleration of the system and the tension in the string. Given $\mu = 0.30$.

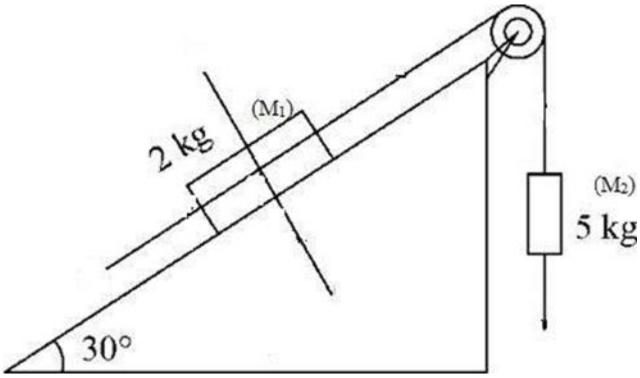

Figure 2

OR

A body m_1 of mass 5 kg is nailed onto a smooth horizontal table. (Figure 3)

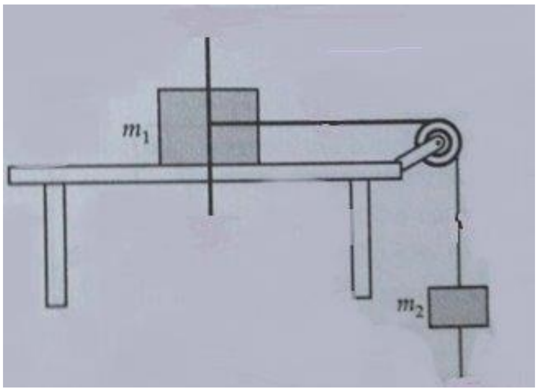

Figure - 3

It is connected to a string which passes over a frictionless pulley and carries at the other end, a body m_2 of mass 5 kg. What acceleration will be produced in the bodies when the nail fixed onto the table is removed? What will be the tension in the string during the motion of the bodies? Take $g = 9.8\ N\ kg^{-1}$.

Question 11 **[3]**

A **hundred metre** sprinter increases her speed from rest uniformly at the rate of 1 ms^{-2} upto three quarters of the total run and covers the last quarter with uniform speed. How much time does she take to cover the first half and the second half of the run?

Question 12 **[3]**

A flywheel (which may be considered as a uniform metallic disc) of mass 25 kg has a radius of 0.2 m. It is making 240 r.p.m. What is the torque necessary to bring it to rest in 20 s?

Question 13 **[3]**

State and prove **Bernoulli's principle** for the flow of non-viscous fluids.

OR

Derive an expression for the **excess pressure** inside a liquid drop.

Question 14 **[3]**

Derive an expression for the **terminal velocity** of a small spherical body falling through a viscous medium.

Question 15 **[3]**

A train stands at a platform blowing a whistle of frequency 400 Hz in still air.

(i) What is the frequency of the whistle heard by a man running towards the engine at 10ms^{-1}.

(ii) What is the wavelength of sound received by the running man?
Take speed of sound in still air = 340 ms^{-1}.

Question 16 **[5]**

A body is thrown from the surface of the earth with a velocity *u* making an angle θ with the horizontal. Show that its trajectory is a parabola. Derive expressions for:

(i) time of flight, and

(ii) horizontal range.

OR

A body is thrown horizontally with a velocity *u* from a certain height h above the ground. Show that its trajectory is a parabola. Derive expressions for its:

(i) time of flight, and

(ii) horizontal range.

Question 17 **[5]**

A body (like a ring, a sphere, a cylinder, etc) starts rolling from rest from the top of an inclined plane, without slipping. Prove that its linear translational velocity *v* at the bottom of the inclined plane of height *h* is given by:

$$v^2 = \frac{2gh}{1+\frac{K^2}{R^2}}$$

where K is the radius of gyration of the body about its symmetry axis and R is its radius.

Using the above said result, find out which of the two bodies, a ring or a solid sphere will reach the ground with greater velocity?

OR

Prove that in an elastic one-dimensional collision between two bodies, the relative velocity of approach before collision is equal to the relative velocity of separation after the collision. Hence derive expressions for the velocities of the two bodies in terms of their initial velocities before collision.

Question 18 **[5]**

(a) Obtain an expression for a **stationary** wave formed by superposition of two identical sinusoidal waves travelling along the same straight line, but in opposite directions.

(b) A cord 80 cm long is stretched by a load of 8 kgf. The mass per unit length of the cord is 4×10^{-5} kg m^{-1}. Find:

(i) Speed of the transverse wave in the cord, and

(ii) Fundamental frequency of vibration.

OR

(a) (i) Explain the phenomenon of beats

(ii) What is meant by 'beat frequency'?

(b) An organ pipe produces 4 beats/s when sounded with a tuning fork of frequency 512 Hz. When sounded with another tuning fork of frequency 514 Hz, it produces 6 beats/s. Find the frequency of the organ pipe. Explain your answer.