M2023

No. of Printed Pages : 4

Register Number | | | | | | | |

B

PART – III

, awgpay; / PHYSICS

(English Version)

Time Allowed : 3.00 Hours] [Maximum Marks: 70

Instructions :

(1) Check the question paper for fairness of printing. If there is any lack of fairness, inform the Hall Supervisor immediately.

(2) Use **Blue** or **Black** ink to write and underline and pencil to draw diagrams.

PART – I

Note :

(i) Answer **all** the questions. **15x1=15**

(ii) Choose the most appropriate answer from the given **four** alternatives and write the option code and the corresponding answer.

1. If a wire is stretched to double of its original length, then the strain in the wire is

(a) 3 (b) 1 (c) 4 (d) 2

2. Round of the following number 19.95 into three significant figures.

(a) 20.1 (b) 19.9 (c) 19.5 (d) 20.0

3. The graph between volume and temperature in Charles' law is

(a) a straight line (b) an ellipse

(c) a parabola (d) a circle

4. In the given SHM y = 2 sin $(20\pi t+1.5)$ the frequency of oscillation is:

(a) 10 Hz (b) 20 Hz (c) 15 Hz (d) π Hz

5. The kinetic energy of the satellite orbiting around the Earth is

(a) greater than kinetic energy (b) equal to potential energy

(c) zero (d) less than potential energy

6. The centrifugal force appears to exist

(a) in any accelerated frame (b) only in inertial frames

(c) both in inertial and non-inertial frames

(d) only in rotating frames

[Turn Over

7. If an object is falling from a height of 20 m, then the time taken by the object to reach the ground: (ignore air resistance and take g = 10 ms^{-2})

(a) 2 s (b) 1.732 s (c) 1.532 s (d) 1.414 s

8. The fundamental frequency of closed organ pipe whose length is 10 cm is:

(a) 4.5 vHz (b) 2.5 vHz (c) 10 vHz (d) 2 vHz

9. A particle executing SHM crosses points A and B with the same velocity. Having taken 3 s in passing from A to B, it returns to B after another 3 s. The time period is

(a) 12 s (b) 15 s (c) 9 s (d) 6 s

10. If the temperature and pressure of a gas is doubled the mean free path of the gas molecules

(a) tripled (b) remains same

(c) quadrupled (d) doubled

11. A uniform force of $(2\hat{\imath} + \hat{\jmath})$+ N acts on a particle of mass 1 kg. The particle displaces from position $(3\hat{\jmath} + \hat{k})$ m to $(5\hat{\imath} + 3\hat{\jmath})$.The work done by the force on the particle is :

(a) 10 J (b) 9 J (c) 12 J (d) 6 J

12. A rigid body rotates with an angular momentum L. If its kinetic energy is halved, the angular momentum becomes,

(a) 2L (b) L (c) $\frac{L}{\sqrt{2}}$ (d) $\frac{L}{2}$

13. Which one of the following physical quantities cannot be represented by a scalar?

(a) momentum (b) Mass

(c) magnitude of acceleration (d) length

14. The dimensional formula for coefficient of viscosity is :

(a) $ML^{-2}T^{-2}$ (b) MLT^{-2} (c) $ML^{-1}T^{-2}$ (d) $ML^{-1}T^{-1}$

15. A sound wave whose frequency is 5000 Hz travels in air and then hits the water surface. The ratio of its wavelengths in water and air is

(a) 5.30 (b) 4.30 (c) 1.23 (d) 0.23

B

PART – II

Note : Answer **any six** questions. Question No. **24** is **compulsory**. **6x2=12**

16. Write the rules for determining significant figures.
17. Define scalar. Give examples.
18. Under what condition will a car skid on a levelled circular road ?
19. Write any two differences between conservative and non-conservative Force.
20. What are the conditions in which Force cannot produce Torque ?
21. State Newton's Universal Law of Gravitation.
22. Define Poisson's ratio.
23. State Zeroth Law of Thermodynamics.
24. Two objects of masses 3 kg and 6 kg are moving with the same momentum of $30 kgms^{-1}$. Will they have same kinetic energy ?

PART – III

Note : Answer **any six** questions. Question No. **33** is **compulsory**. **6x3=18**

25. What is Gross Error ? State the reasons for it and how to minimize the errors.
26. Write the properties of scalar product of two vectors.
27. State the differences between centripetal force and centrifugal force.
28. State the various types of potential energy. Explain its formulae.
29. Explain geostationary satellites.
30. Write the practical applications of capillarity.
31. State the Laws of Simple Pendulum.
32. Write down the postulates of kinetic theory of gases.
33. During a cyclic process, a heat engine absorbs 600 J of heat from a hot reservoir, does work and ejects an amount of heat 200 J into the surroundings (cold reservoir). Calculate the efficiency of the heat engine.

PART – IV

Note : Answer **all** the questions. **5x5=25**

34. (a) Obtain an expression for the time period T of a simple pendulum. The time period depends on :
    (i) mass 'm' of the bob
    (ii) length 'l' of the pendulum and
    (iii) acceleration due to gravity 'g' at the place where the pendulum is suspended. (Constant k = 2π)

OR

(b) Explain in detail the Triangle Law of Vector Addition.

35. (a) Show that in an inclined plane, angle of friction is equal to angle of repose.

OR

(b) Derive an expression for power and velocity.

36. (a) Derive the expression for moment of inertia of a rod about its centre and perpendicular to the rod.

OR

(b) Explain the variation of Acceleration due to gravity (g) with depth from the earth's surface.

37. (a) Derive the expression for the terminal velocity of a sphere moving in a high viscous fluid using Stoke's law.

OR

(b) Derive Meyer's relation for an ideal gas.

38. (a) Derive the expression of pressure exerted by the gas molecules on the walls of the container.

OR

(b) Derive Newton's formula for velocity of sound waves in air. Explain the Laplace's correction in it.

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HIGHER SECONDARY FIRST YEAR EXAMINATION – MARCH 2023
PHYSICS ANSWER KEY

Note:

1. Answers written with **Blue** or **Black ink** only to be evaluated.
2. Choose the most suitable answer in Part A, from the given alternatives and write the **option code** and the **corresponding answer.**
3. For answers in Part-II, Part-III and Part-IV like reasoning, explanation, narration, description and listing of points, students may write in their own words but without changing the concepts and without skipping any point.
4. In numerical problems, if formula is not written, marks should be given for the remaining correct steps.
5. In graphical representation, physical variables for X-axis and Y-axis should be marked.

PART – I

Answer all the questions. 15x1=15

Q. No.	OPTION	TYPE – A	Q. No.	OPTION	TYPE – B
1	(d)	$ML^{-1}T^{-1}$	1	(b)	1
2	(a)	2 s	2	(d)	20.0
3	(b)	remains same	3	(a)	a straight line
4	(a)	a straight line	4	(a)	10 Hz
5	(a)	momentum	5	(d)	Less than potential energy
6	(b)	4.30	6	(d)	Only in rotating frames
7	(a)	10 Hz	7	(a)	2 s
8	(a)	12 s	8	(b)	2.5 vHz
9	(b)	2.5 vHz	9	(a)	12 s
10	(a)	10J	10	(b)	remains same
11	(c)	$\frac{L}{\sqrt{2}}$	11	(a)	10J
12	(d)	Only in rotating frames	12	(c)	$\frac{L}{\sqrt{2}}$
13	(d)	Less than potential energy	13	(a)	momentum
14	(b)	1	14	(d)	$ML^{-1}T^{-1}$
15	(d)	20.0	15	(b)	4.30

DEPARTMENT OF PHYSICS, SRMHSS, KAVERIYAMPOONDI, TIRUVANNAMALAI.

PART – II

Answer **any six** questions. Question number **24 is compulsory.** 6x2=12

16	1. All **non-zero digits** are significant. Ex.**1342** has **four** significant figures 2. All **zeros between two non-zero** digits are significant. Ex. **2008 has four** significant figures. 3. All **zeros to the right of a non-zero** digit but to the left of a decimal point are significant. Ex. **30700. has five** significant figures. 4. The **number without a decimal point**, the terminal or trailing zero(s) are not significant. Ex. **30700 has three** significant figures. All zeros are significant if they come from a measurement Ex. **30700 m** has **five** significant figures 5. If the number is **less than 1,** the zero (s) on the right of the decimal point but to left of the **first non-zero digit are not significant.** Ex. **0.00345** has **three** significant figures. 6. All zeros to the right of a decimal point and to the right of non-zero digit are significant. Ex. **40.00 has four** significant figures and **0.030400** has **five** significant figures. 7. The number of significant figures **does not depend on the system of units** used 1.53 cm, 0.0153 m, 0.0000153 km, all have **three** significant figures.	Any 2 2x1=2
17	It is a property which can be described **only by magnitude**. In physics a number of quantities can be described by scalars. **Examples Distance, mass, temperature, speed and energy.**	2
18	If the static friction is **not able to provide enough centripetal force** to turn, the vehicle will start to skid. $\mu < \frac{v^2}{rg}$ (skid)	2

	Conservative forces	Non-conservative forces	
19	Work done is **independent of the path**	Work done **depends upon the path**	
	Work done in a **round trip is zero**	Work done in a **round trip is not zero**	
	Total energy **remains constant**	Energy is **dissipated as heat energy**	2
	Work done is **completely recoverable**	Work done is **not completely recoverable**	
	Force is the negative gradient of potential energy	No such relation exists.	

20	The torque is zero when $\vec{r}$ and $\vec{F}$ are parallel or anti-parallel. If parallel, then θ=0 and sin 0 =0. If **anti-parallel, then θ=180 and sin 180=0**. Hence, τ = 0. The torque is zero if the force acts at the reference point. i.e. as $\vec{r}$ = 0, τ = 0.	2
21	Newton's law of gravitation states that a particle of mass M_1 attracts any other particle of mass M_2 in the universe with an attractive force. The strength of **this force of attraction** was found to be **directly proportional to the product of their masses and is inversely proportional to the square of the distance between them. (or)** $\vec{F} = -G\frac{m_1 m_2}{r^2}\hat{r}$	2 1
22	**The ratio of relative contraction (lateral strain) to relative expansion (longitudinal strain).** It is denoted by the symbol μ. Poisson s ratio, μ **= Lateral strain / Longitudinal strain**	2
23	The zeroth law of thermodynamics states that **if two systems, A and B, are in thermal equilibrium with a third system, C, then A and B are in thermal equilibrium with each other.**	
24	The kinetic energy of the mass is given by KE $=\frac{P^2}{2m}$ For the object of mass 3kg, kinetic energy is $KE_1 = \frac{(30)^2}{2x3} = \frac{900}{6}$ = 150J For the object of mass 6kg, kinetic energy is $KE_2 = \frac{(30)^2}{2x6} = \frac{900}{12}$ = 75J the kinetic energy of **both masses is not the same.** The kinetic energy of the **heavier object has lesser kinetic energy than smaller mass.**	

PART – II

Answer **any six** questions. Question number **33 is compulsory.** 6x3=18

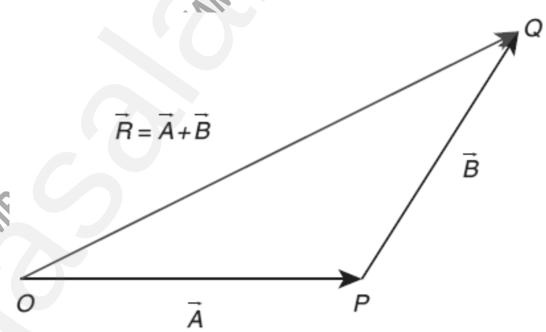
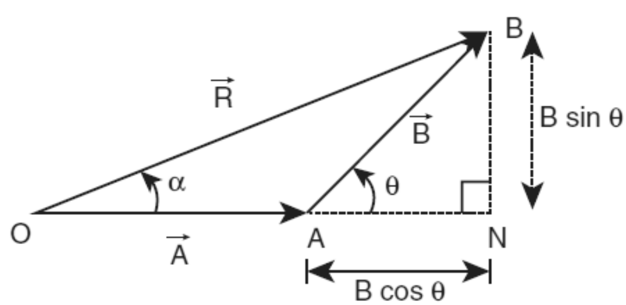
25	**Gross Error** The error caused due to the shear carelessness of an observer is called gross error. For example (i) Reading an instrument without setting it properly. (ii) Taking observations in a wrong manner without bothering about the sources of errors and the precautions. (iii) Recording wrong observations. (iv) Using wrong values of the observations in calculations. These errors can be minimized only when an observer is careful and mentally alert.	3
26	**Properties of scalar products** 1) The product **quantity $\vec{A}\,.\,\vec{B}$ is always a scalar**. It is positive if the angle between the vectors is acute (i.e., < 90°) and negative if the angle between them is obtuse (i.e. 90°<θ< 180°). 2) The **scalar product is commutative**, i.e. $\vec{A}\,.\,\vec{B} = \vec{B}\,.\,\vec{A}$ 3) The **vectors obey distributive law** i.e. $\vec{A}\,.\,(\vec{B}+\vec{C}) = \vec{A}\,.\,\vec{B} + \vec{A}\,.\,\vec{C}$ 4) The angle between the vectors $\theta = \cos{-1}\left[\frac{\vec{A}\,.\,\vec{B}}{AB}\right]$ 5) The **scalar product of two vectors will be maximum** when Cos θ = 1, i.e. θ = 0^0, i.e., when the vectors are parallel; $(\vec{A}\,.\,\vec{B})_{max} = AB$ 6) The **scalar product of two vectors will be minimum**, when Cos θ = –1, i.e. θ = 180^0 $(\vec{A}\,.\,\vec{B})_{min} = -AB$ when the vectors are anti-parallel. 7) If **two vectors $\vec{A}$ and $\vec{B}$, are perpendicular** to each other than their scalar Product $\vec{A}\,.\,\vec{B} = 0$, because Cos 90^0 =0. Then the vectors $\vec{A}$ and $\vec{B}$. are said to be mutually orthogonal. 8) The scalar product of a vector with itself is termed as self-dot product and is given by $(\vec{A})^2 = \vec{A}\,.\,\vec{A}$=AA Cos θ = A^2 .Here angle θ = 0° The **magnitude or norm of the vector $\vec{A}$ is $\lvert\vec{A}\rvert$ = A = $\sqrt{\vec{A}.\vec{A}}$** 9) In case of a unit vector $\hat{n}$, $\hat{n}\,.\,\hat{n}$ = 1 x 1 x Cos 0 = 1. For example, $\hat{\imath}.\hat{\imath} = \hat{\jmath}.\hat{\jmath} = \hat{k}.\hat{k} = 1$ 10) In the case of **orthogonal unit vectors** $\hat{\imath}$, $\hat{\jmath}$ and $\hat{k}$, $\hat{\imath}\,.\,\hat{\jmath} = \hat{\jmath}.\hat{k} = \hat{k}$. $\hat{\imath}$ = 1.1 Cos90^0 = 0 11) In terms of components the scalar product of $\vec{A}$ and $\vec{B}$ can be written As $\vec{A}\,.\,\vec{B} = (A_x\hat{\imath} + A_y\hat{\jmath} + A_z\hat{k})\,.\,(B_x\hat{\imath} + B_y\hat{\jmath} + B_z\hat{k})$ $= A_xB_x + A_yB_y + A_zB_z$ with all other terms zero. The magnitude of vector $\lvert\vec{A}\rvert$ is given by $\lvert\vec{A}\rvert = A = \sqrt{A_x^2 + A_y^2 + A_z^2}$	Any 3 3x1=3

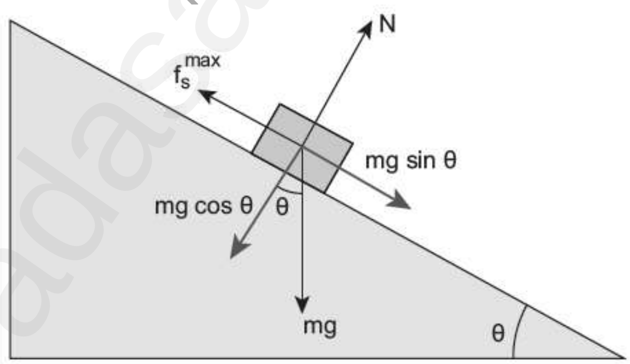
Q.No	Centripetal force	Centrifugal force	Marks
27	It is a real force which is exerted on the body by the external agencies like gravitational force, tension in the string, normal force etc.	It is **a pseudo force or fictitious force** Which cannot arise from gravitational force, tension force, normal force etc.	Any 3 3x1=3
	Acts in **both inertial and non-inertial frames**	**Acts only in rotating frames** (non-inertial frame)	
	It **acts** towards the **axis of rotation** or center of the circle in circular motion	It **acts outwards from the axis of rotation** or radially outwards from the center of the circular motion	
	$\lvert F_{cp} \rvert = m\omega^2 r = \frac{mv^2}{r}$	$\lvert F_{cf} \rvert = m\omega^2 r = \frac{mv^2}{r}$	
	Real force and has real effects.	**Pseudo force but has real effects**	
	Origin of **centripetal force is interaction between two objects**	Origin of **centrifugal force** is inertia. It does not arise from interaction.	
	In inertial frames centripetal force has to be included when free body diagrams are drawn.	In an inertial frame the object's inertial motion appears as centrifugal force in the rotating frame. In inertial frames there is no centrifugal force. In rotating frames, both centripetal and centrifugal force have to be included when free body diagrams are drawn.	
28	1. The energy possessed by the body due to gravitational force gives rise to gravitational potential energy U = mgh 2. The energy due to spring force and other similar forces give rise to elastic potential energy. U = ½ Kx^2 3. The energy due to electrostatic force on charges gives rise to electrostatic potential energy. U = – E. dr		3x1=3
29	1) The satellites orbiting the Earth have different time periods corresponding to different orbital radii. Can we calculate the orbital **radius of a satellite if its time period is 24 hours.** 2. Substituting for the **time period (24 hrs = 86400 seconds)**, mass, and **radius of the Earth, h turns out to be 36,000 km**. Such satellites are called **"geo-stationary satellites"**, since they appear to be stationary when seen from Earth. 3) Geo-stationary satellites for the purpose of telecommunication. Another type of **satellite which is placed at a distance of 500 to 800 km** from the surface of the Earth orbits the Earth from north to south direction. 4) This type of satellite that **orbits Earth from North Pole to South Pole** is called a polar satellite. The **time period of a polar satellite is nearly 100 minutes and the satellite completes many revolutions in a day.**		Any 3 3x1=3

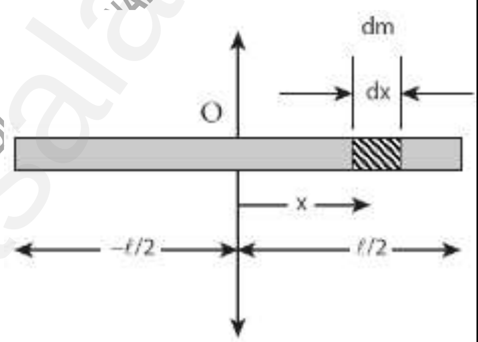
30	Practical applications of capillarity • Due to capillary action, oil rises in the cotton within an earthen lamp. Likewise, sap rises from the roots of a plant to its leaves and branches. • Absorption of ink by a blotting paper • Capillary action is also essential for the tear fluid from the eye to drain constantly. • Cotton dresses are preferred in summer because cotton dresses have fine pores which act as capillaries for sweat.	Any 3 3x1=3
31	**Law of length:** For a given value of acceleration due to gravity, the time period of a simple pendulum is **directly proportional to the square root of length of the pendulum. T** $\alpha \sqrt{l}$ **Law of acceleration:** For a fixed length, the time period of a simple pendulum is **inversely proportional to square root of acceleration due to gravity. T** $\alpha \frac{1}{\sqrt{g}}$	1 1 1
32	1) All the molecules of a gas **are identical, elastic spheres**. 2) The molecules of **different gases are different.** 3) The number of molecules in a gas is **very large and the average** separation **between them is larger than size of the gas molecules.** 4) The molecules of a gas are in **a state of continuous random motion.** 5) The molecules collide with one another and also with the walls of the container. 6) These **collisions are perfectly elastic so that there is no loss of kinetic energy during collisions.** 7) Between two successive collisions, **a molecule moves with uniform velocity.** 8) The molecules do not exert any force of attraction or repulsion on each other except during collision. **The molecules do not possess any potential energy and the energy is wholly kinetic.** 9) The collisions are instantaneous. The time spent by a molecule in each collision is very small compared to the time elapsed between two consecutive collisions. 10) These **molecules obey Newton's laws of motion even though they move randomly.**	Any 3 3x1=3
33	The efficiency of heat engine is given by $\eta = 1 - \frac{Q_L}{Q_H}$; $\eta = 1 - \frac{200}{600}$; $= 1 - \frac{2}{6}$; $\eta = 1 - 0.33$; 0.67 The heat engine has 67% efficiency, implying that this heat engine converts only 67% of the input heat into work.	1 1 1

PART – IV

Answer **all** the questions. 5x5=25

34 (a)	T∝ $m^a l^b g^c$; T = k $m^a l^b g^c$ Here k is the dimensionless constant. Rewriting the above equation with dimensions $[T^1] = [M^a]\,[L^b]\,[LT^{-2}]^c$ $[M^0L^0T^1] = [M^a\,L^{b+c}\,T^{-2c}]$ Comparing the powers of M, L and T on both sides, a=0, b+c=0, -2c=1 Solving for a,b and c a = 0, b = 1/2, and c = −1/2 From the above equation T = k. $m^0\, l^{1/2}\, g^{1/2}$ **T = k $\left(\frac{l}{g}\right)^{1/2}$; k $\sqrt{l/g}$; Experimentally k = 2π, hence T = 2π $\sqrt{l/g}$**	1 1 1 1 1
34 (b)	1) Represent the vectors $\vec{A}$ and $\vec{B}$ by the two adjacent sides of a triangle taken in the same order. Then the resultant is given by the third side of the triangle taken in the opposite order.  2) The **head of the first vector $\vec{A}$ is connected to the tail of the second vector $\vec{B}$. Let θ be the angle between $\vec{A}$ and $\vec{B}$. Then $\vec{R}$ is the resultant vector connecting the tail** of the first vector $\vec{A}$ to the head of the second vector $\vec{B}$. 3) The magnitude of $\vec{R}$ (resultant) is given geometrically by the length of $\vec{R}$ (OQ) and the direction of the resultant vector is the angle between $\vec{R}$ and $\vec{A}$ Thus we write **$\vec{R} = \vec{A} + \vec{B}$. ∵ $\overrightarrow{OQ} = \overrightarrow{OP} + \overrightarrow{PQ}$** **Magnitude of resultant vector:** 4) Consider the triangle ABN, which is obtained by extending the side OA to ON. ABN is a right angled triangle.  Cos θ = $\frac{AN}{B}$ ∴ AN = B Cos θ *and* Sin θ = $\frac{BN}{B}$ ∴ BN = B Sin θ For ΔOBN, we have $OB^2 = ON^2 + BN^2 \Rightarrow R^2 = (A + B\cos\theta)^2 + (B\sin\theta)^2$ $\Rightarrow R^2 = A^2 + B^2\cos^2\theta + 2AB\cos\theta + B^2\sin^2\theta$ $\Rightarrow R^2 = A^2 + B^2(\cos^2\theta + \sin^2\theta) + 2AB\cos\theta$ $\Rightarrow \mathbf{R = \sqrt{A^2 + B^2 + 2AB\cos\theta}}$	5

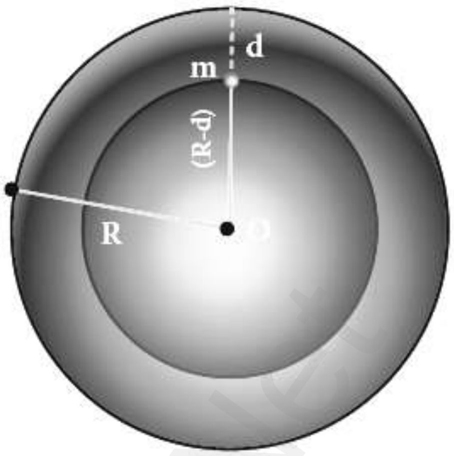
	which is the magnitude of the resultant of *A* and *B* **Direction of resultant vectors:** 5) If θ is the angle between $\vec{A}$ and $\vec{B}$, then $\lvert\vec{A}+\vec{B}\rvert = \sqrt{A^2 + B^2 + 2AB\cos\theta}$ If $\vec{R}$ makes an angle α with $\vec{A}$, then in ΔOBN, $\tan\alpha = \frac{BN}{ON} = \frac{BN}{OA+AN}$ $\tan\alpha = \left(\frac{B\sin\theta}{A+B\cos\theta}\right)$; $\alpha = \tan^{-1}\left(\frac{B\sin\theta}{A+B\cos\theta}\right)$	
35 (a)	**Angle of Friction.** The angle of friction is defined as the **angle between the normal force (N) and the resultant force (R)** of normal force and maximum friction force f_s^{max}) **Angle of repose.** The same as angle of friction. But the difference is that the angle of repose refers to **inclined surfaces and the angle of friction is applicable** to any **type of surface.** i) Consider an inclined plane on which an object is placed. Let the angle which this plane makes with the horizontal be θ . For small angles of θ,the object may not slide down. ii) As θ is increased, for a particular value of θ , the object begins to slide down. This value is called angle of repose. Hence, the angle of repose is the angle of inclined plane with the horizontal such that an object placed on it begins to slide.  iii) Consider the various forces in action here. **The gravitational force mg is resolved into components parallel (mg sin θ) and perpendicular (mg cos θ) to the inclined plane.** **iv) The component of force parallel to the inclined plane (mg sin θ)** tries to move the object down. **The component of force perpendicular to the inclined plane (mg cos θ)** is balanced by the Normal force (N). N = mg cos θ -------------(1) When the object just begins to move, the static friction attains its maximum value, $f_s = f_s^{max} = \mu_s$ N. This friction also satisfies the relation $f_s^{max} = \mu_s$ mg sinθ ----------- (2) Equating the right hand side of equations (1) and (2), we get $(f_s^{max}) / N = \sin\theta / \cos\theta$ From the definition of angle of friction, we also know that $\tan\theta = \mu_s$ in which **θ** is the angle of friction. **Thus the angle of repose is the same as angle of friction.**	5

35 (b)	i) The work done by a force $\vec{F}$ for a displacement $d\vec{r}$ is W = $\int \vec{F}.d\vec{r}$ --- (1) Left hand side of the equation (1) can be written as W = $\int dW = \int \frac{dW}{dt}dt$ (multiplied and divided by dt) ------------- (2) ii) Since, velocity $\vec{v} = \frac{d\vec{r}}{dt}$; $d\vec{r} = \vec{v}$ dt. Right hand side of the equation (1) can be written as $\int \vec{F}.d\vec{r} = \int \left(\vec{F}.\frac{d\vec{r}}{dt}\right)dt$ $= \int (\vec{F}.\vec{v})dt \quad \left[\vec{v} = \frac{d\vec{r}}{dt}\right]$ ---- (3) Substituting equation (2) and equation (3) in equation (1), we get $\int \frac{dW}{dt}dt = \int (\vec{F}.\vec{v})dt$; $\int \left(\frac{dW}{dt} - \vec{F}.\vec{v}\right)dt = 0$ iii) This relation is true for any arbitrary value of dt. This implies that the term within the bracket must be equal to zero, i.e., $\frac{dW}{dt} = \vec{F}.\vec{v} = 0$ (or) $\frac{dW}{dt} = \vec{F}.\vec{v}$	5
36 (a)	1) Let us consider a uniform rod of mass (M) and length (l) as shown in Figure. Let us find an expression for moment of inertia of this rod about an **axis that passes through the center of mass and perpendicular to the rod.**  2) **First an origin is to be fixed for the coordinate system** so that it coincides with the center of mass, which is also the geometric center of the rod. The rod is now along the x axis. 3) We take an infinitesimally small mass (dm) at a distance (x) from the origin. The moment of inertia (dI) of this mass (dm) about the axis is, **dI = (dm)x²** As the mass is uniformly distributed, the mass per unit length (λ) of the rod is, $\boldsymbol{\lambda = \frac{M}{l}}$ The (dm) mass of the infinitesimally small length as, dm = λ, dx $= \frac{M}{l}$dx. The moment of inertia (I) of the entire rod can be found by integrating dI, $I = \int dI = \int (dm)x^2$; $\int \left(\frac{M}{l}dx\right)x^2$; $I = \frac{M}{l}\int x^2 dx$ 4) As the **mass is distributed on either side of the origin, the limits for integration are taken from** $-\frac{l}{2}$ **to** $\frac{l}{2}$ $I = \frac{M}{l}\int_{-\frac{l}{2}}^{\frac{l}{2}} x^2 dx \quad = \frac{M}{l}\left[\frac{x^3}{3}\right]_{-\frac{l}{2}}^{\frac{l}{2}}$ $I = \frac{M}{l}\left[\frac{l^3}{24} - \left(-\frac{l^3}{24}\right)\right] \quad = \frac{M}{l}\left[\frac{l^3}{24} + \frac{l^3}{24}\right]$ $I = \frac{M}{l}\left[2\left(\frac{l^3}{24}\right)\right]$; $\mathbf{I = \frac{1}{12}}\mathbf{m}\boldsymbol{l}^2$	5

<table>
<tr>
<td>36
(b)</td>
<td>

Variation of g with depth:

Consider a **particle of mass m which is in a deep mine on the earth. Ex. Coal mines – in Neyveli**). Assume the **depth of the mine as d.** To Calculate g at a depth d, consider the following points. The **part of the Earth which is above the radius (R_e – d) do not contribute to the acceleration.** The result is proved earlier and is given as $g' = \frac{GM'}{(R_e-d)^2}$ Here M is the mass of the Earth of radius (R_e – d). Assuming the density of earth ρ to be constant,



$\rho = \frac{M'}{V'}$; $\frac{M'}{V'} = \frac{M}{V}$ and $M' = \frac{M}{V}V'$

$M' = \left(\frac{M}{\frac{4}{3}\pi R_e^3}\right)\left(\frac{4}{3}\pi(R_e-d)^3\right)$;

$M' = \frac{M}{R_e^3}(R_e - d)^3$

$\mathbf{g' = G\frac{M}{R_e^3}(R_e - d)^3 \cdot \frac{1}{(R_e-d)^2}}$;

$g' = GM\frac{R_e\left(1-\frac{d}{R_e}\right)}{R_e^3}$

$g' = GM\frac{\left(1-\frac{d}{R_e}\right)}{R_e^2}$ thus $\mathbf{g' = g\left(1-\frac{d}{R_e}\right)}$. Here also $\mathbf{g'<g}$.

As depth increases, g' decreases.

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<td>37(a)</td>
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Expression for terminal velocity:

Consider a sphere of radius *r* which falls freely through a highly viscous liquid of coefficient of viscosity η. Let the density of the material of the sphere be ρ and the density of the fluid be σ.

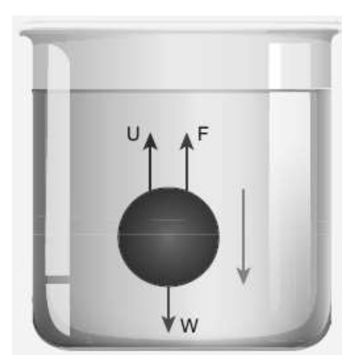
Gravitational force acting on the sphere, F_G = mg = $\frac{4}{3}\pi r^3\rho g$

(Downward force)

Up thrust, U = $\frac{4}{3}\pi r^3\sigma g$ (upward force)

Viscous force F = $6\pi\eta r v_t$

At terminal velocity v_t, downward force = upward force



$F_G - U = F \Rightarrow \frac{4}{3}\pi r^3\rho g - = \frac{4}{3}\pi r^3\sigma g = 6\pi\eta r v_t$

$\mathbf{V_t = \frac{2}{9} x \frac{r^2(\rho-\sigma)}{\eta} g \Rightarrow V_t \propto r^2}$

Here, it should be noted that the terminal speed of the sphere is directly proportional to the square of its radius. If σ is greater than ρ, then the term (ρ - σ) becomes negative leading to a negative terminal velocity.

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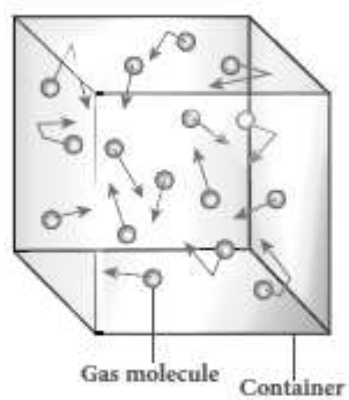
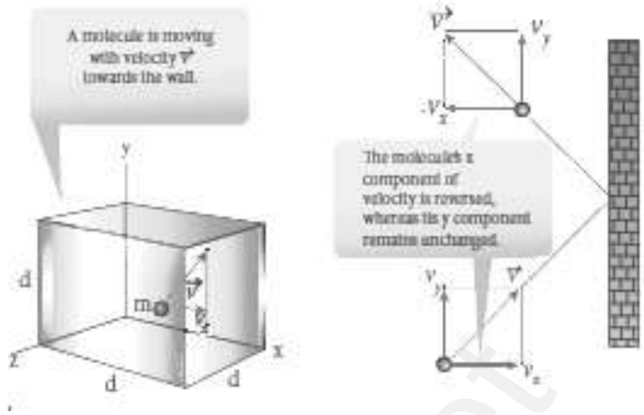
37 (b)	**Meyer's relation** 1) Consider μ mole of an ideal gas in a container with volume V, pressure P and temperature T. 2) When **the gas is heated at constant volume the temperature increases by dT. As no work is done by the gas, the heat that flows into the system will increase only the internal energy**. Let the change in internal energy be dU. If Cv is the molar specific heat capacity at constant volume, $\mathbf{dU = \mu C_v dT}$ ------------ 1 3) Suppose the gas is heated at constant pressure so that the temperature increases by dT. If 'Q' is the heat supplied in this process and 'dV' the change in volume of the gas. $\mathbf{Q = \mu C_p dT}$ ----------- 2 4) If W is the work done by the gas in this process, then W = PdV ------------3 But from the first law of thermodynamics, **Q = dU + W** --------4 Substituting equations (1), (2) and (3) in (4), we get, $\mathbf{\mu C_p dT = \mu C_v\, dT + PdV}$ -----------5 5) For mole of ideal gas, the equation of state is given by $PV = \mu RT \Rightarrow PdV + VdP = \mu RdT$ ---------- 6 Since the pressure is constant, dP=0 $\therefore C_p dT = C_v dT + RdT$ $\mathbf{\therefore C_P = C_v + R}$ **(or)** $\mathbf{C_p - C_v = R}$ ----------- 7 This relation is called Meyer's relation.	5
38 (a)	1) Consider a monatomic gas of N molecules each having a mass m inside a cubical container of side *l* as shown in the Figure (a).  2) The **molecules of the gas are in random motion. They collide with each other and also with the walls of the container**. As the collisions are elastic in nature, there is no loss of energy, but a change in momentum occurs. 3) **The molecules of the gas exert pressure on the walls of the container due to collision on it. During each collision, the molecules impart certain momentum to the wall**. Due to transfer of momentum, the walls experience a continuous force. 4) The force experienced per unit area of the walls of the container determines the pressure exerted by the gas. It is essential to determine the total momentum transferred by the molecules in a short interval of time.	5

(ii)

5) A molecule of mass m moving with a velocity $\bar{v}$ having components (v_x, v_y, v_z) hits the right side wall. Since we have assumed that the collision is elastic, the particle rebounds with same speed and its x-component is reversed. This is shown in the Figure (b). The components of velocity of the molecule after collision are ($-v_x$, v_y, v_z).

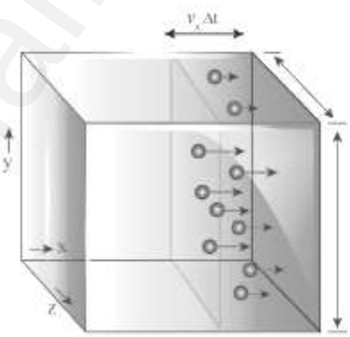


The x-component of momentum of the molecule before collision = mv_x

The x-component of momentum of the molecule after collision = $-mv_x$

6) The change in momentum of the molecule in x direction =Final momentum – initial momentum = $-mv_x - mv_x = -2mv_x$ **According to law of conservation of linear momentum, the change in momentum of the wall = $2mv_x$**

7) The number of molecules hitting the right side wall in a small interval of time Δt is calculated as follows. The molecules within the distance of $v_x\Delta t$ from the right side wall and moving towards the right will hit the wall in the time interval Δt. This is shown in the Figure. The number of molecules that will hit the right side wall in a time interval Δt is equal to the product of volume ($Av_x\Delta t$) and number density of the molecules (n). Here A is area of the wall and n is number of molecules per unit volume $\left(\frac{N}{V}\right)$. We have assumed that the number density is the same throughout the cube.



8) Not all the n molecules will move to the right, therefore on an average only half of the n molecules move to the right and the other half moves towards left side. The number of molecules that hit the right side wall in a time interval $\Delta t = \frac{n}{2} Av_x \Delta t$ ------------------- 1

In the same interval of time Δt, the total momentum transferred by the molecules $\Delta p = \frac{n}{2} Av_x \Delta t \times 2mv_x = Av_x^2 nm\Delta t$ ----------2

9) From Newton's second law, the change in momentum in a small interval of time gives rise to force. The force exerted by the molecules on the wall (in magnitude) $F = \frac{\Delta P}{\Delta t} = nm Av_x^2$ ------------- 3

Pressure, P = force divided by the area of the wall.

$P = \frac{F}{A} = nmv_x^2$ ----------------- 4

	Since all the molecules are moving completely in random manner, they do not have same speed. So we can replace the term v_x^2 by the average $\overline{v_x^2}$ in equation. P = nm $\overline{v_x^2}$ --------------- 5 10) Since the gas is assumed to move in random direction, it has no preferred direction of motion (the effect of gravity on the molecules is neglected). It implies that the molecule has same average speed in all the three direction. So, $\overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2}$. **The mean square speed is written as $\overline{v^2} = \overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2}$** $\overline{v_x^2} = \frac{1}{3}\overline{v^2}$ Using this in equation (5), we get, $\overline{v_x^2} = \frac{1}{3}nm\overline{v^2}$ or $P = \frac{1}{3}\frac{N}{V}m\overline{v^2}$ as $\left[n = \frac{N}{V}\right]$	
38 (b)	1) Newton assumed that when sound propagates in air, the formation of **compression and rarefaction takes place in a very slow manner** so that the process is isothermal in nature. 2) That is, the **heat produced during compression (pressure increases, volume decreases)**, and **heat lost during rarefaction (pressure decreases, volume increases)** occur over a period of time such that the temperature of the medium remains constant. Therefore, by treating the air molecules to form an ideal gas, the changes in pressure and volume obey Boyle's law, PV = Constant ----------- 1 3) Differentiating equation (1), we get PdV + VdP = 0 or $P = -V\frac{dP}{dV} = B_T$ -------- 2 where, BT is an isothermal bulk modulus of air. Substituting equation (2) in equation $V = \sqrt{\frac{B}{\rho}}$ the speed of sound in air is $V_T = \sqrt{\frac{B_T}{\rho}} = \sqrt{\frac{P}{\rho}}$ ------------3 Since P is the pressure of air whose value at NTP (Normal Temperature and Pressure) is 76 cm of mercury, we have **$P = (0.76 \times 13.6 \times 10^3 \times 9.8)\ N\ m^{-2}$** ρ = 1.293 kg m-3. here ρ is density of air Then the speed of sound in air at Normal Temperature and Pressure (NTP) is $V_T = \sqrt{\frac{0.76 \times 13.6 \times 10^3 \times 9.8}{1.293}}$ **$= 279.80\ ms^{-1} \approx 280$ ms-1** (theoretical value) But the speed of sound in air at 0°C is experimentally observed as **$332ms^{-1}$ which is close upto 16% more than theoretical value** (Percentage error is $\frac{(332-280)}{332}$ x 100% = 15.6%) This error is not small.	5

Laplace's correction:

1) Laplace assumed that when the sound propagates through a medium, the particles oscillate very rapidly such that the **compression and rarefaction occur very fast.** Hence the exchange of heat produced due to compression and cooling effect due to rarefaction do not take place, because, air (medium) is a bad conductor of heat.

2) Since, temperature is no longer considered as a constant here, **sound propagation is an adiabatic process. By adiabatic considerations, the gas obeys Poisson's law** (not Boyle's law as Newton assumed), which is Pv^{γ} = Constant ----------4

Where, $\gamma = \frac{C_P}{C_V}$, which is the ratio between specific heat at constant pressure and specific heat at constant volume. Differentiating equation (4) on both the sides, we get

v^{γ} dP + P$(\gamma V\gamma^{-1} dV)$ = 0 or $\gamma^{P} = -V\frac{dP}{dV}$ B_A ------------5

where, BA is the adiabatic bulk modulus of air. Now, substituting equation (5) in equation $V = \sqrt{\frac{B}{\rho}}$ the speed of sound in air is

$V_A = \sqrt{\frac{B_T}{\rho}} = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\gamma} V_T$ ------------6

$V_A = 331 ms^{-1}$