PHYSICAL WORLD & MEASUREMENTS

1. State the rules for determining the number of significant figures in a measured quantity.

A: Few rules for determining the number of significant figures:

i) All non-zero digits are significant.

ii) All zeros between two non-zero digits are significant.

iii) For numbers without a decimal point, the terminal or trailing zero(s) are not significant.

---

2. What do you mean by dimensional formula? Give the dimensional formula of force.

A: Dimensional Formula(D.F) is an expression showing the powers of fundamental quantities in a derived quantity.

We know Force = mass × acceleration = mass × (length / time^2)

$\therefore$ Dimensional formula of Force is [F] = [M L T^{-2}]

---

3. How are the SI base units different from derived units? Give one example of each.

A: SI Base Units are the units of fundamental quantities which are independent of each other. Whereas Derived units are the units of derived quantities which are expressed as an algebraic combination of fundamental units.

SI unit for mass is kilogram (kg).

Derived unit of Area is m^2 .

---

4. Write the dimensional equation of kinetic energy. Use it to check the dimensional consistency of the formula K = ½mv^2.

A: We know that dimensional equation of Kinetic energy = **[M L^2 T^{-2}]**.....(1)

Given formula K = ½ mv^2 = mass × (velocity)^2= [M] × [L T^{-1}]^2 = **[M L^2 T^{-2}]**.....(2)

From (1) and (2), it is proved that the formula **K = ½mv^2 is dimensionally correct.**

---

5. State the principle of homogeneity of dimensions. How is it used to check the correctness of an equation?

A: Principle of Homogeneity of Dimensions states that only physical quantities having the same dimensions can be added, subtracted or equated.

Checking the correctness of an equation:

If the dimensions of all terms are the same on both sides, then the given equation is **dimensionally correct**.

MOTION ALONG A STRAIGHT LINE

6. A car moves with uniform acceleration. Write the relation among displacement, initial velocity, acceleration and time.

A: Displacement $x = v_0 t + \frac{1}{2} a t^2$. Here v_0 is initial velocity, a is acceleration, and t is time.

---

7. What do you mean by free fall? Mention the value and direction of acceleration in this case.

A: **Free fall:** When an object is dropped from a height, it gets accelerated downward due to the force of gravity. If **air resistance is neglected**, then the object is said to be in **free fall**.

Value of acceleration: g = 9.8 ms^{-2}

Direction: Always **vertically downward**

---

8. Why is instantaneous speed equal to the magnitude of instantaneous velocity?

A: Instantaneous speed is defined when time interval Ät→ 0.

Thus when Ät→ 0, the distance and magnitude of displacement become **equal**.

Thus instantaneous speed becomes equal to the magnitude of instantaneous velocity .

Hence, **instantaneous speed = |instantaneous velocity|**

---

9. Explain how the area under the velocity-time graph gives displacement.

A: In the **velocity - time graph,** the velocity represents height and time represents width of a strip.

$\therefore$ Area of a strip = $v \times \Delta t = \frac{\Delta s}{\Delta t} \times \Delta t = \Delta s = \text{displacement}$

---

10. Can a body have zero velocity and non-zero acceleration at the same time? Explain.

A: **Yes.** A body can have zero velocity and non-zero acceleration at the same time.

Ex: When a ball is thrown vertically upward, at the **highest point**, its velocity becomes zero momentarily. But the acceleration due to gravity (g = 9.8 m s^{-2}) continues to act on it in the downward direction.

---

11. A train starts from rest and attains a velocity of 36 km/h in 10 s. Assuming uniform acceleration, calculate the acceleration and distance covered in this time.

A: **Given:** v_0 = 0 (starts from rest),v = 36 km/h $= 36 \times \frac{5}{18}$ = 10 m/s, t = 10 s

Acceleration $a = \frac{v - v_0}{t} = \frac{10 - 0}{10} = 1\ ms^{-2}$

Distance $x = v_0t + \frac{1}{2}at^2 = 0 + \frac{1}{2}(1)(10)^2 = 50\text{m}$

$\therefore$ acceleration $a = 1\,\text{m s}^{-2}$, distance covered $x = 50\,\text{m}$

---

12. A man walks 2 km in 30 minutes and returns in 20 minutes. What is his average speed for the entire journey?

A: **Given:** One - way distance = 2 km, Total distance = 2 + 2 = 4 km

Total time = 30 + 20 = 50 min $= \frac{50}{60} = \frac{5}{6}\text{h}$

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{4}{5/6} = \frac{4\times6}{5} = \frac{24}{5} = 4.8 \text{ km/h}$$

---

13. An object moves with uniform acceleration and covers 100 m in 5 seconds. If its initial velocity is 4 m/s, find the acceleration.

A: **Given:** v_0 = 4 m/s, x = 100 m, t = 5 s

Formula: $x = v_0t + \frac{1}{2}at^2 \Rightarrow 100 = 4(5) + \frac{1}{2}a(5)^2$

$$\Rightarrow 100 = 20 + \frac{25a}{2} \Rightarrow 80 = \frac{25a}{2} \Rightarrow a = \frac{80\times2}{25} = \frac{160}{25} = 6.4 \qquad \therefore a = 6.4\,\text{m s}^{-2}$$

---

14. A bullet is fired horizontally from a police van moving at 30 km/h. If the muzzle speed is 150 m/s, find the speed of the bullet relative to a thief's car moving ahead at 192 km/h.

A: **Given:** Speed of van (A) $= 30\times\frac{5}{18} = 8.33\text{m/s}$, Muzzle speed of bullet = 150 m/s,

Speed of bullet w.r.t. the ground = van speed + muzzle speed = 150 + 8.33 = 158.33 m/s

Speed of thief's car (B) = $= 192\times\frac{5}{18} = 53.33\text{m/s}$

Relative speed of bullet w.r.t. thief's car: $v_{bullet} - v_{thief} = 158.33 - 53.33 = 105\,\text{m s}^{-1}$

15.. A ruler falls freely and travels 20 cm before being caught. Estimate the reaction time of the person. (use g = 10 m/s²)

A: **Given:** $v_0 = 0$, Distance d = 20 cm = 0.20 m, g = 10 ms^{-2}

Formula: Reaction time $t_r = \sqrt{\frac{2d}{g}} = \sqrt{\frac{2\times0.20}{10}} = \sqrt{\frac{0.40}{10}} = \sqrt{0.04} = 0.2\text{s}$

SYSTEM OF PARTICLES

16. A child is sitting at one end of a long trolley moving with uniform speed on a smooth horizontal floor. If the child gets up and runs on the trolley in any manner with speed U, what will be the centre of mass of the system (trolley + child)?

A: Even if the child runs on the trolley, the **centre of mass of the system continues to move with the same uniform velocity** since no external horizontal force acts on the system.
The child's running produces only internal forces, which cannot affect the motion of the centre of mass.

---

17. Newton's laws of motion are applicable to individual particles of a system. However, we can also describe the motion of the system as a whole using Newton's Laws. Justify.

A: Though Newton's laws of motion are applicable to individual particles of a system, they describe the system as a whole because the **acceleration of the centre of mass** depends only on the external force acting on the system given by $F_{ext}=MA$.
Thus, Newton's laws are applicable to both individual particles and the system as a whole.

---

18. In which of the following cases does the centre of mass of a body coincide with its geometric centre?
(a) The density continuously decreases from right to left.
(b) The density decreases from left to right up to the centre and then increases in the same proportion.

A: **(a) No.** The centre of mass does not coincide with the geometric centre because the mass distribution is non-uniform. It shifts towards the side of greater density.
(b) Yes. The centre of mass coincides with the geometric centre because the density distribution is symmetric about the centre. Hence, equal masses are distributed equally on both sides.

---

19. The stone of a hand flour grinder is provided with a handle near its rim. Give reason.

A: The handle is provided near the rim because the turning effect of a force (torque) increases with distance from the axis of rotation. Hence, a small force applied at the rim produces a larger turning effect, making the grinder easier to rotate.

---

20. A person sits near the edge of a circular platform revolving with a uniform angular speed. What will be the change in the motion of the platform if the person crawls to the centre?

A: When the person moves towards the centre, the **moment of inertia** of the system decreases because the mass comes closer to the axis of rotation. Since no external torque acts on the system, **angular momentum remains conserved**. As a result, the angular speed increases and the platform rotate faster.

MP OF SOLIDS

21. Differentiate between tensile stress and compressive stress.

A:

Tensile Stress	Compressive Stress
1) TS is produced when two equal and opposite forces are applied away from each other. 2) Length of body increases with TS. 3) **Ex:** Stretching a rubber band.	1) CS is produced when two equal and opposite forces are applied towards each other. 2) Length of body decreases with CS . 3) **Ex:** Compressing a spring.

---

22. Why is steel more elastic than rubber?

A: Elasticity is the ability to resist deformation and regain original shape.
A material that produces less strain for a given stress is considered **more elastic**.
Steel has a very **high Young's modulus**, so it undergoes very small strain for a large stress.
Rubber has a very **low Young's modulus**, so it undergoes large strain even for small stress.
Thus, **steel is more elastic than rubber**.

---

23. Why are sand heaps in pyramid shape?

A: Sand particles are loose and cannot withstand shearing forces. When sand is poured, it forms a heap with a slope equal to its **angle of repose**. If the slope becomes steeper than this angle, the sand particles slide down due to gravity until equilibrium is restored.
So, sand naturally forms a pyramidal(conical) heap with sides inclined at an angle of repose.

---

24. While constructing buildings and bridges, a pillar with distributed ends is preferred to a pillar with rounded ends. Why?

A: A pillar with rounded ends supports less load than that with a distributed shape at the ends. Hence pillar with distributed ends is preferred while constructing buildings and bridges.

---

25. Two identical solid balls, one of ivory and the other of wet clay, are dropped from the same height onto the floor. Which one will rise to a greater height after striking the floor? Why?

A: Ivory is more elastic than wet-clay. So ivory ball shall rise to a great height as compared to a clay ball. Infact, the ball of wet-clay may not rise at all.

MP OF FLUIDS

26. Write down the expression for variation of pressure with depth?

A: For a fluid at rest, the pressure P at a depth h below the surface (open to atmosphere) is:

$P = P_a + \rho gh$

where P_a is atmospheric pressure, ρ is the density of the fluid, and g is acceleration due to gravity. The excess pressure ($P - P_a$) is called gauge pressure.

---

27. Write down the equation of continuity?

A: **Equation of continuity:** For the steady flow of an incompressible fluid through a pipe of varying cross-section, the equation of continuity is: $A_1v_1 = A_2v_2 = \text{constant}$ or, in general, **Av = constant**, where A is the area of cross-section and v is the flow speed.
It is a statement of conservation of mass in fluid flow.

---

28. State two conditions under which Bernoulli's theorem is applicable.

A: i) The fluid must be **non-viscous.**
ii) The fluid must be **incompressible.**
iii) Flow must be **steady (streamline)**.

---

29. How does viscosity vary with temperature in case of gases and liquids?

A: **Viscosity in liquids:** Viscosity **decreases** with increase in temperature.
As T increases, intermolecular separation increases and cohesive forces decrease.
Viscosity in gases: Viscosity **increases** with increase in temperature.
As T increases, the exchange of momenta between molecular layers increases.

---

30. Write the expression for Stoke's law?

A: **Stokes' law Formula:** viscous drag force $F = 6\pi\eta av$
Here a is radius of small sphere , v is velocity, η is viscosity of the fluid

---

31. Define eddy flow in the case of a fluid?

A: Eddy flow is a kind of turbulent flow or disordered flow.
Eddy flow occurs when the velocity of a fluid exceeds its critical velocity. Here the flow becomes turbulent and the velocity of the fluid at any point varies rapidly and randomly with time.

---

32. How does surface tension vary with temperature?

A: The **surface tension of a liquid decreases with increase in temperature**. As temperature increases, the kinetic energy of the liquid molecules increases. Therefore, the intermolecular forces of attraction become weaker, resulting in a decrease in surface tension.
It becomes zero at a particular temperature called the **critical temperature** of the liquid.

TP OF MATTER

33. Do the values of coefficients of expansion differ when the temperatures are measured on Centigrade scale or on Fahrenheit scale?

A: Yes. One degree interval on Fahrenheit scale is less than one degree interval on Celsius scale.

Since, $x(^oC)^{-1} = x \times \frac{5}{9}(^oF)^{-1}$

---

34. Define specific heat capacity.

A: **Specific heat capacity** of a substance is the amount of heat required to raise the temperature of **unit mass** of the substance by **1 K (or 1°C)**.

Mathematically, $s = \frac{\Delta Q}{m\Delta T}$ **SI Unit:** J $kg^{-1}K^{-1}$

---

35. State the different modes of transmission of heat. Which of these modes require medium?

A: The three modes of transmission of heat are: Conduction, Convection, Radiation
Conduction, Convection requires a medium.

---

36. What is regelation of ice?

A: **Regelation** is the phenomenon in which **ice melts when pressure is applied and refreezes when the pressure is removed**. This occurs because the melting point of ice decreases with increase in pressure.

---

37. Define thermal expansion.

A: The increase in the dimensions (length/area/volume) of a body due to a rise in its temperature is called thermal expansion.

---

38. What is the principle of pressure cooker?

A: A pressure cooker works on the principle that the boiling point of a 'liquid increases with increase in pressure'**.** Due to this increased pressure, the boiling point of water rises above 100ºC . So, food is cooked at a higher temperature and cooks much faster than in an ordinary open vessel.

THERMODYNAMICS

39. Write the sign convention for heat energy (Q) and work (W).

Sol: In thermodynamics, the following sign convention is used:

i) Heat energy Q>0: Heat is supplied to (absorbed by) the system.

Q<0: Heat is released by the system to the surroundings.

ii) Work done : W>0: Work is done by the system on the surroundings.

W<0: Work is done on the system by the surroundings.

---

40. Why is the internal potential energy of an ideal gas zero?

A: The internal energy of a gas consists of the **kinetic energy** and **potential energy** of its molecules. In an **ideal gas**, the molecules are assumed to have **no intermolecular forces of attraction or repulsion** except during collisions. Since potential energy arises due to intermolecular forces, the **potential energy of an ideal gas is zero**.

---

41. Write the specific heat relation for an ideal gas.

A: For an ideal gas, the molar specific heat capacities at constant pressure (C_p) and at constant volume (C_v) are related by: $C_p - C_v = R$, R= Universal gas constant

---

42. Which of the two will increase the pressure more, an adiabatic or an isothermal process, in reducing the volume to 50%?

A: The pressure is more during an **adiabatic process.**

In isothermal compression by 50% on applying $P_1V_1 = P_2V_2$ we get $P_2 = 2P$...(1)

In adiabatic compression by 50% on applying $P_1V_1^{\gamma} = P_2^1V_2^{\gamma}$ we get $P_2 = 2^{\gamma}P$ ...(2) $\gamma>1$

Comparing (1) & (2) we see that pressure is more during adiabatic process

---

43. Explain the Isochoric and Isobaric processes.

A: **1) Isochoric process** is the process that takes place at constant volume of the system.

Ex: Heat is added to the gas enclosed in a cylinder having rigid walls and a fixed piston.

2) Isobaric process is the process that takes place at constant pressure of the system.

Ex: Heating of water at atmospheric pressure.

---

44. State second law of Thermodynamics.

A: The Second Law of Thermodynamics can be stated in two equivalent forms:

a) Kelvin - Plank Statement: It is impossible to construct an ideal heat engine with 100% thermal efficiency. (or) It is impossible to construct a heat engine that absorbs heat from a hot reservoir which converts completely that heat into work .

(b) Clausius Statement: It is impossible to construct an ideal refrigerator. (or)

It is impossible to transfer heat from a colder object to a hotter object

45. What are the processes involved in a Carnot engine?

A: A **Carnot engine** operates through a cycle consisting of **four reversible processes**:

1) Isothermal Expansion at the higher temperature (T_1):

The gas absorbs heat (Q_1) from the source and expands.

2) Adiabatic Expansion:

The gas expands without heat exchange and its temperature falls from T_1 to T_2.

3) Isothermal Compression at the lower temperature(T_2):

The gas releases heat (Q_2) to the sink while being compressed.

4) Adiabatic Compression:

The gas is compressed without heat exchange and its temperature rises from to, returning to its initial state.

---

46. What is a PV diagram?

A: A **PV diagram** is a graph showing how the pressure (P) of a thermodynamic system varies against volume V . The area under this curve represents the net work done during the process.

---

47. Why does the escaping air appear cold, when the valve of a bicycle tube is opened in summer?

A: When the valve of a bicycle tube is opened, the air expands under adiabatic process. It does some work against surroundings . So its internal energy decreases.
This causes a fall in temperature. Hence escaping air from a bicycle tube appears cold.

---

48. Why does the brake drum of an automobile get heated up while moving down at constant speed?

A: The brake drum of an automobile gets heated while moving downhill at constant speed because friction between the brake drum and brake shoes converts mechanical energy into heat energy. According to First law of thermodynamics, energy cannot be destroyed, it only changes the form.

---

49. Why a heat engine with 100% efficiency can never be realized in practice?

A: The efficiency of heat engine is given by $\eta = 1 - \frac{T_2}{T_1}$. Thus η is always less than one.

The value of η can be 1 only if $T_2 = 0$. This is possible only if the sink is at absolute zero temperature which cannot be attained in reality.
So heat engine with 100% efficiency is not possible.

PHYSICS OF EMERGING TECHNOLOGIES

50. Name another field of physics, besides astrophysics, where AI and ML accelerate discoveries.

A: **Besides astrophysics,** another field is **Particle Physics** where AI and ML accelerate discoveries.
ML is predominantly used for classifying collision events.

---

51. The Boston Dynamics' Spot robot uses principles of dynamics to maintain balance. Which physicist's laws are primarily applied for this?

A: **Newton's Laws of Motion** especially second and third law are primarily applied in **Boston Dynamics' Spot robot .**
The actuators of the Spot robot apply **Newton's laws** to maintain balance.

---

52. Why do materials like carbon nanotubes exhibit dramatically different properties at the nanoscale?

A: Properties like **conductivity and strength** change dramatically in carbon nano tubes at the nano scale. Carbon nanotubes are 50,000 times thinner than a human hair, are stronger than steel and highly conductive.

---

53. What is the key property of a qubit in a quantum computer that allows it to be more powerful than a classical bit?

A: The key property of a qubit is **Quantum Superposition.**
Unlike a classical bit (which is either 0 or 1), a **qubit can exist in multiple states simultaneously** (superposition). Combined with **entanglement**, this makes quantum computers exponentially more powerful.

---

54. Google's Sycamore demonstrated "quantum supremacy." What does this term mean?

A: **Quantum supremacy** means the ability of a quantum computer to solve a problem that classical supercomputers practically cannot solve in any reasonable amount of time.
Google's Sycamore solved a problem in **200 seconds** that would take a supercomputer **10,000 years.**

---

55. How does fusion energy mimic a natural process in our universe?

A: Fusion energy mimics the **Sun's power source.**
Just as the Sun fuses light atomic nuclei together to release vast amounts of energy, fusion energy technology attempts to do the same on Earth. This process requires **immense heat and pressure** to sustain, similar to conditions inside the Sun.

56. What is the primary function of the sunshield on the James Webb Space Telescope (JWST), and which branch of physics does this relate to?

A: The primary function of the sunshield on JWST is to **maintain cryogenic temperatures** to protect the telescope's sensitive instruments from heat.
This relates to **Thermodynamics** and radio active heat transfer.

---

57. Which physics principle is the basis for Magnetic Resonance Imaging (MRI), and how does it help doctors to diagnose?

A: The basis of MRI is **Nuclear Magnetic Resonance (NMR).**
MRI relies on **quantum mechanics and electromagnetic theory**
a) MRI creates **detailed images of organs** without invasive procedures.
b) MRI enables doctors to **detect tumors early** and diagnose diseases accurately.

---

58. Which property of light helps optical cable to send light to a long distance with minimal loss?

A: The property of light helps optical cable is **Total Internal Reflection.**
In fiber optic cables, light bounces within a **glass core** without loss using total internal reflection. This relies on **Snell's law and wave optics.** A single cable can carry **terabytes of data per second**, enabling global connectivity.