B.K. BIRLA CENTRE FOR EDUCATION

SARALA BIRLA GROUP OF SCHOOLS
A CBSE DAY-CUM-BOYS' RESIDENTIAL SCHOOL

TERM-1 EXAMINATION (2025-26)

PHYSICS (042) (SET-II)

MARKING SCHEME

Class: XI | **Time: 3hr**
Date: 12.02.26 | **Max Marks: 70**

Section A (16 X 1M)

1. (a) Length and Mass
2. (b) Zero
3. (c) Horizontal velocity
4. (a) 60°
5. (c) 1 : 2
6. (c) Moment of inertia
7. (a) 1 m/s
8. (a) $\frac{x^2}{2L^2}$
9. (b) Zero
10. (a) J kg^{-1} K^{-1}
11. (a) Conservation of energy
12. (a) 50 J
13. (c) A is True, R is False
14. (c) A is True, R is False
15. (b) A is True, R is True but R is not correct explanation
16. (a) A is True, R is True and R is correct explanation

Section-B (5 X 2M)

17. Derive second equation of motion graphically (2 marks)

From the **velocity–time graph**, displacement is equal to **area under the graph**.

Area =rectangle +triangle

$$s = ut + \frac{1}{2}(v - u)t$$

$$s = ut + \frac{1}{2}(v - u)t$$

Using $v - u = at$,

$$s = ut + \frac{1}{2}at^2$$

Hence, the **second equation of motion** is:

$$\boxed{s = ut + \frac{1}{2}at^2}$$

OR (Ball in hall question)

Given: $u = 40\, m/s$, ceiling height $H = 25\, m$

Maximum height:

$$H = \frac{u^2 \sin^2 \theta}{2g}$$

$$25 = \frac{1600 \sin^2 \theta}{2 \times 9.8} \Rightarrow \sin^2 \theta = \frac{25 \times 19.6}{1600} = 0.30625$$

$$\sin \theta \approx 0.553$$

Range:

$$R = \frac{u^2 \sin 2\theta}{g}$$

$$\sin 2\theta = 2\sin \theta \cos \theta$$

$$\cos \theta = \sqrt{1 - \sin^2 \theta} = \sqrt{1 - 0.30625} = 0.833$$

$$\sin 2\theta = 2(0.553)(0.833) = 0.922$$

$$R = \frac{1600 \times 0.922}{9.8} \approx 150.5\, m$$

Maximum horizontal distance:

$$\boxed{R \approx 150\, m}$$

18. State and explain law of momentum (2 marks)

Law of conservation of momentum:

In an isolated system (no external force), the **total momentum remains constant**.

Mathematically:

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

i.e. **Total momentum before collision = Total momentum after collision**.

19. State and prove Work-Energy Theorem (constant force) (2 marks)

Statement: Work done by a constant force on a body equals the **change in kinetic energy**.

$$W = Fs$$

Using $F = ma$,

$$W = mas$$

From equation $v^2 - u^2 = 2as$,

$$as = \frac{v^2 - u^2}{2}$$

So,

$$W = m \cdot \frac{v^2 - u^2}{2}$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

Therefore:

$$\boxed{W = \Delta K}$$

20. Work done in an isothermal process (2 marks)

In an **isothermal process**, temperature remains constant, so for an ideal gas:

$$PV = constant$$

Work done:

$$W = \int_{V_1}^{V_2} P\, dV$$

Using $P = \frac{nRT}{V}$,

$$W = \int_{V_1}^{V_2} \frac{nRT}{V} dV = nRT\ln\left(\frac{V_2}{V_1}\right)$$

Hence,

$$\boxed{W = nRT\ln\left(\frac{V_2}{V_1}\right)}$$

21. Define SHM and write mathematical expression (2 marks)

Simple Harmonic Motion (SHM): Motion in which the **restoring force** (or acceleration) is **directly proportional to displacement** and always directed towards mean position.

Mathematically:

$$a \propto -x \Rightarrow a = -\omega^2 x$$

SHM displacement equation:

$$\boxed{x = A\sin(\omega t + \phi)}$$

SECTION-C (7 X 3M)

22. Limitations of dimensional analysis + 2 failures (3 marks)

Limitations

1. **It cannot give numerical constants** like $\frac{1}{2}, 2, \pi$etc.
2. It **cannot tell whether terms are added/subtracted** (cannot derive full equation form).
3. It **fails for relations involving trig/exponential/log functions** like $\sin, \cos, e^x, \ln\ x$.
4. It cannot distinguish between **different physical quantities with same dimensions** (like work and torque).

Examples where it fails

- **Example 1:**
  Formula of kinetic energy is
  $$K = \frac{1}{2}mv^2$$
  Dimensional analysis gives only $K \propto mv^2$, cannot give $\frac{1}{2}$.
- **Example 2:**
  For simple pendulum, time period is
  $$T = 2\pi\sqrt{\frac{l}{g}}$$
  Dimensional analysis gives only $T \propto \sqrt{\frac{l}{g}}$, cannot give 2π.

23. Distance covered by car (3 marks)

Given:

$a = 2\,m/s^2, u = 5\,m/s, t = 10\,s$

Use equation:

$$s = ut + \frac{1}{2}at^2$$
$$s = 5(10) + \frac{1}{2}(2)(10^2)$$
$$s = 50 + 100 = 150\,m$$

Distance covered = $\boxed{150\,m}$

24. Train on unbanked circular track + banking angle (3 marks)

Given:

Radius $r = 30m$

Speed $v = 54\,km/hr = 15\,m/s$

(i) What provides centripetal force?

On an **unbanked** track, the **centripetal force is provided by lateral friction due to rails** (not engine).

Answer: **Rails provide the centripetal force (through friction).**

(ii) Angle of banking required

For no wear (no friction required):

$$\tan\,\theta = \frac{v^2}{rg}$$
$$\tan\,\theta = \frac{15^2}{30 \times 9.8} = \frac{225}{294} = 0.765$$
$$\theta \approx 37°$$

Required banking angle:

$$\boxed{\theta \approx 37°}$$

25. Electric power consumed by pump (3 marks)

Let tank volume be V.

Mass of water:

$$m = \rho V$$

Work done to lift water to height $h = 40m$:

$$W = mgh = \rho Vgh$$

Time $t = 15\,min = 900s$

Output power:

$$P_{out} = \frac{W}{t} = \frac{\rho Vgh}{t}$$

Efficiency:

$$\eta = \frac{P_{out}}{P_{in}} \Rightarrow P_{in} = \frac{P_{out}}{\eta}$$

Given $\eta = 30\% = 0.3$:

$$P_{in} = \frac{\rho Vgh}{0.3t}$$

Put values ($\rho = 1000, g = 9.8, h = 40, t = 900$):

$$P_{in} = \frac{1000 \times V \times 9.8 \times 40}{0.3 \times 900}$$
$$P_{in} \approx 1451V\,W$$

Electric power consumed:

$$\boxed{P \approx 1.45 \times 10^3 V\ W}$$

(where $V$is in m^3)

26. Moment of inertia definition + unit + dimensions + factors (3 marks)

Definition:

Moment of inertia of a body about an axis is:

$$I = \sum mr^2$$

It is the **rotational analogue of mass** and measures resistance to rotation.

Unit:

$$\boxed{kg\, m^2}$$

Dimensions:

$$\boxed{[M^1 L^2 T^0]}$$

Depends on:

1. **Mass** of body
2. **Distribution of mass** about axis
3. **Position of axis of rotation**
4. Shape and size of body

27. Compressional strain in each column (3 marks)

Given: total mass $M = 50000\ kg$, 4 columns

Load on each column:

$$F = \frac{Mg}{4}$$

Inner radius $r_i = 0.30m$, outer radius $r_o = 0.60m$

Area of hollow column:

$$A = \pi(r_o^2 - r_i^2)$$
$$A = \pi(0.36 - 0.09) = 0.27\pi\, m^2$$

Stress:

$$\sigma = \frac{F}{A} = \frac{Mg}{4A}$$

Strain:

$$\text{strain} = \frac{\sigma}{Y}$$

For mild steel $Y \approx 2 \times 10^{11} N/m^2$

Now:

$$F = \frac{50000 \times 9.8}{4} = 122500N$$
$$\sigma = \frac{122500}{0.27\pi} \approx 1.44 \times 10^5 N/m^2$$
$$\text{strain} = \frac{1.44 \times 10^5}{2 \times 10^{11}} = 7.2 \times 10^{-7}$$

Compressional strain of each column:

$$\boxed{7.2 \times 10^{-7}}$$

OR (Hydrostatic reasons)

(a) BP at feet > brain:

Pressure increases with depth:

$$P = \rho g h$$

Feet are at greater depth than brain so **pressure is higher** at feet.

(b) Pressure becomes half at 6 km:

Atmospheric pressure decreases exponentially with height due to decrease in air density; hence pressure falls rapidly and becomes nearly half at about 6 km.

28. Newton's formula for speed of sound + error + Laplace correction (3 marks)

Newton's formula:

$$v = \sqrt{\frac{P}{\rho}}$$

What was wrong?

Newton assumed changes in pressure and volume are **isothermal**, but sound propagation happens **very quickly** so there is no time for heat exchange.

Laplace correction:

Laplace assumed process is **adiabatic**, so

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

where γ is ratio of specific heats.

SECTION-D (Case Study Based Questions)

29. Average Speed & Average Velocity (MCQ Answers)

(i) A 250 m long train crosses a 750 m bridge

Total distance = $250 + 750 = 1000\, m$

Speed = $45\, km/h = 12.5\, m/s$

$$t = \frac{1000}{12.5} = 80\, s$$

Answer: (c) 80 s

(ii) Average speed of truck

$$v = \frac{150}{3} = 50\, km/h$$

Answer: (a) 50 km/h

(iii) Average speed between A and D

Given speeds & time:

- AB: $v_1 = 20\, m/s$, $t_1 = 20s \Rightarrow s_1 = 400m$
- BC: $v_2 = 15\, m/s$, $t_2 = 10s \Rightarrow s_2 = 150m$
- CD: $v_3 = 10\, m/s$, $t_3 = 5s \Rightarrow s_3 = 50m$

Total distance:

$$s = 400 + 150 + 50 = 600m$$

Total time:

$$t = 20 + 10 + 5 = 35s$$

$$v_{avg} = \frac{600}{35} = 17.14\, m/s$$

Answer: (a) 17.14 m/s

OR (iii) Speed varies 0 to 30 m/s in 5 s

For uniform acceleration:

$$v_{avg} = \frac{u + v}{2} = \frac{0 + 30}{2} = 15\, m/s$$

Answer: (d) 15 m/s

(iv) Cyclist half revolution in 40 s, radius 40 m

Average velocity = displacement/time

Half revolution displacement = diameter = $2r = 80m$

$$v_{avg} = \frac{80}{40} = 2\, m/s$$

Answer: (b) 2

30. Case Study (RMS speed, Average speed, Most probable speed)

(i) Moon has no atmosphere because

Correct reason: molecules escape since rms speed is greater than escape velocity.

Answer: (c)

(ii) For an ideal gas, $\frac{C_P}{C_V}$is

$$\gamma = \frac{C_P}{C_V} > 1$$

Answer: (a) > 1

(iii) $\boldsymbol{u_{rms}(H_2) = 5 \times u_{rms}(N_2)}$. Temperature relation?

$$u_{rms} = \sqrt{\frac{3RT}{M}}$$

At same T, lighter gas has higher rms speed. So this statement matches the fact that at equal temperature, hydrogen has higher rms speed.

Answer: (a) $T(H_2) = T(N_2)$

(iv) Temperature tripled and $\boldsymbol{N_2}$dissociates to atom

Original rms speed:

$$v_0 = \sqrt{\frac{3RT}{M}}$$

New: $T' = 3T$and gas becomes N atom: $M' = \frac{M}{2}$

$$v' = \sqrt{\frac{3R(3T)}{M/2}} = \sqrt{\frac{9RT \cdot 2}{M}} = \sqrt{6}\sqrt{\frac{3RT}{M}} = \sqrt{6}\, v_0$$

Answer: (a) $\sqrt{6}\, v_0$

OR (iv) Velocities = $\boldsymbol{v, 2v, 3v, 4v, 5v}$

$$v_{rms} = \sqrt{\frac{v^2 + (2v)^2 + (3v)^2 + (4v)^2 + (5v)^2}{5}}$$

$$= \sqrt{\frac{(1+4+9+16+25)v^2}{5}} = \sqrt{\frac{55v^2}{5}} = \sqrt{11}\, v$$

Answer: (b) $v\sqrt{11}$

SECTION-E

31. Derive expression for escape velocity from Earth's surface. Also calculate its value. (5 marks)

(A) Derivation of Escape Velocity

Escape velocity is the minimum velocity with which a body should be projected from Earth so that it can go to infinity **without returning**, ignoring air resistance.

Let:

- Mass of Earth = M
- Mass of body = m
- Radius of Earth = R
- Escape velocity = v_e

At Earth's surface, the body has kinetic energy:

$$K = \frac{1}{2}mv_e^2$$

Gravitational potential energy at distance r:

$$U = -\frac{GMm}{r}$$

For escape, the body reaches infinity with **zero speed**:

- Final K.E. at infinity = 0
- Potential energy at infinity $U_\infty = 0$

So total energy at launch must equal total energy at infinity:

$$\frac{1}{2}mv_e^2 - \frac{GMm}{R} = 0$$

$$\frac{1}{2}mv_e^2 = \frac{GMm}{R}$$

$$v_e^2 = \frac{2GM}{R}$$

$$\boxed{v_e = \sqrt{\frac{2GM}{R}}}$$

Now since:

$$g = \frac{GM}{R^2} \Rightarrow GM = gR^2$$

Substitute:

$$v_e = \sqrt{\frac{2gR^2}{R}} = \sqrt{2gR}$$

Final formula:

$$\boxed{v_e = \sqrt{2gR}}$$

(B) Numerical Value for Earth

Given:

$$R = 6.4 \times 10^6\, m, g = 9.8\, m/s^2$$

$$v_e = \sqrt{2gR} = \sqrt{2(9.8)(6.4 \times 10^6)}$$

$$v_e = \sqrt{125.44 \times 10^6} = \sqrt{1.2544 \times 10^8}$$

$$v_e \approx 1.12 \times 10^4\, m/s$$

Escape velocity on Earth:

$$\boxed{v_e \approx 11.2 \times 10^3\, m/s = 11.2\, km/s}$$

OR: Expression for g at surface, above and below Earth's surface (5 marks)

(1) g at Earth's surface

$$F = \frac{GMm}{R^2} = mg \Rightarrow g = \frac{GM}{R^2}$$

$$\boxed{g = \frac{GM}{R^2}}$$

(i) g at height h above surface

At height h, distance from centre:

$$r = R + h$$

$$g_h = \frac{GM}{(R+h)^2}$$

$$\boxed{g_h = g\left(\frac{R}{R+h}\right)^2}$$

For small $h \ll R$:

$$g_h \approx g\left(1-\frac{2h}{R}\right)$$

(ii) g at depth d below surface
At depth d:

$$r = R - d$$

Assuming Earth of uniform density:

$$M_r = M\left(\frac{r^3}{R^3}\right)$$

$$g_d = \frac{GM_r}{r^2} = \frac{GM\left(\frac{r^3}{R^3}\right)}{r^2} = \frac{GM}{R^3}r$$

$$g_d = g\frac{r}{R} = g\frac{R-d}{R}$$

Final:

$$\boxed{g_d = g\left(1-\frac{d}{R}\right)}$$

32. Wave equation $y(x,t) = 0.005\sin(80x - 3t)$(5 marks)
Given wave:

$$y(x,t) = A\sin(kx - \omega t)$$

Compare:
- $A = 0.005\, m$
- $k = 80\, rad/m$
- $\omega = 3\, rad/s$

(a) Amplitude

$$\boxed{A = 0.005\, m = 5 \times 10^{-3}\, m}$$

(b) Wavelength

$$k = \frac{2\pi}{\lambda} \Rightarrow \lambda = \frac{2\pi}{k}$$

$$\lambda = \frac{2\pi}{80} = 0.0785\, m$$

$$\boxed{\lambda \approx 7.85 \times 10^{-2}\, m}$$

(c) Period and frequency

$$\omega = 2\pi f \Rightarrow f = \frac{\omega}{2\pi}$$

$$f = \frac{3}{2\pi} = 0.477\, Hz$$

$$T = \frac{1}{f} = \frac{2\pi}{3} = 2.09\, s$$

$$\boxed{f \approx 0.477\, Hz, T \approx 2.09\, s}$$

Displacement at x=30 cm and t=20 s
Given:

$$x = 30cm = 0.30m$$
$$t = 20s$$
$$y = 0.005\sin(80(0.30) - 3(20))$$
$$y = 0.005\sin(24 - 60)$$
$$y = 0.005\sin(-36)$$

Now $\sin(-\theta) = -\sin\theta$

$$\sin(36\,rad) \approx -0.992$$
$$y \approx 0.005(-0.992) = -0.00496\,m$$
$$\boxed{y \approx -4.96 \times 10^{-3}\,m}$$

OR: Phase relation between x, v and a in SHM (5 marks)
In SHM:

$$x = A\sin(\omega t + \phi)$$

Velocity

$$v = \frac{dx}{dt} = A\omega\cos(\omega t + \phi)$$

So **velocity leads displacement by $\frac{\pi}{2}$**.
Acceleration

$$a = \frac{dv}{dt} = -A\omega^2\sin(\omega t + \phi)$$
$$a = -\omega^2 x$$

So **acceleration is opposite in phase to displacement** (phase difference π).
Key phase results:

- $v$leads $x$by $\pi/2$
- $a$is πout of phase with x
- $a$leads $v$by $\pi/2$

(Graph: $x$sine curve, $v$cosine curve, $a$negative sine curve.)
33. (i) Surface tension definition, formula, unit + (ii) Capillary rise (5 marks)
(i) Surface tension
Definition
Surface tension is the **force per unit length** acting **tangentially** to the surface of a liquid, tending to **minimize surface area**.
Formula

$$\boxed{T = \frac{F}{l}}$$

where
F= force acting along surface
l= length along which force acts
SI unit

$$\boxed{N/m}$$

(ii) Derivation of capillary rise
Consider a capillary tube of radius $r$dipped in a liquid of surface tension T.
Angle of contact = θ
Upward force due to surface tension:

$$F_{up} = T \times \text{circumference} \times \cos\theta$$
$$F_{up} = T(2\pi r)\cos\theta$$

Weight of liquid column of height h:
Volume:

$$V = \pi r^2 h$$

Mass:
$$m = \rho V = \rho \pi r^2 h$$
Weight:
$$W = mg = \rho \pi r^2 hg$$
At equilibrium:
$$T(2\pi r)\cos\,\theta = \rho \pi r^2 hg$$
Cancel πr:
$$2T\cos\,\theta = \rho rhg$$
$$\boxed{h = \frac{2T\cos\,\theta}{\rho rg}}$$
Final expression for capillary rise:
$$\boxed{h = \frac{2T\cos\,\theta}{\rho rg}}$$

OR (Alternative 33)

(i) Relation between α, β, γ

Let:

- α= linear expansion
- β= superficial (area)
- γ= cubical (volume)

For small change in temperature ΔT:
$$L = L_0(1 + \alpha\Delta T)$$
Area:
$$A = A_0(1 + \beta\Delta T) \Rightarrow \beta = 2\alpha$$
Volume:
$$V = V_0(1 + \gamma\Delta T) \Rightarrow \gamma = 3\alpha$$
Relations:
$$\boxed{\beta = 2\alpha, \gamma = 3\alpha}$$

(ii) Prove $C_P - C_V = R$

For ideal gas:
$$PV = nRT$$
At constant pressure:
$$dQ_P = nC_P dT$$
At constant volume:
$$dQ_V = nC_V dT$$
From First law:
$$dQ = dU + dW$$
At constant volume:
$$dW = 0 \Rightarrow dQ_V = dU \Rightarrow dU = nC_V dT$$
At constant pressure:
$$dW = PdV \Rightarrow dQ_P = dU + PdV$$
$$nC_P dT = nC_V dT + PdV$$
For ideal gas:
$$PdV = nRdT$$
So:
$$nC_P dT = nC_V dT + nRdT$$
Divide by ndT:
$$\boxed{C_P - C_V = R}$$
