INDIAN ASSOCIATION OF PHYSICS TEACHERS

NATIONAL STANDARD EXAMINATION IN PHYSICS (NSEP) 2019-20

Examination Date : 24-11-2019 **Time: 2 Hrs.** **Max. Marks : 240**

Q. PAPER CODE : 62 **HBCSE Olympiad (STAGE - 1)**

Write the question paper code mentioned above on YOUR answer sheet (in the space provided), otherwise your answer sheet will NOT be assessed. Note that the same Question paper. Code appears on each page of the question paper.

INSTRUCTIONS TO CANDIDATES

1. Use of mobile phones, smart watches and ipads during examination is **STRICTLY PROHIBITED.**
2. In addition to this question paper, you are given answer sheet along with Candidate's copy.
3. On the answer sheet, make all the entries carefully in the space provided ONLY in **BLOCK** CAPITALS as well as by properly darkening the appropriate bubbles.
   Incomplete/Incorrect/carelessly filled information may disqualify your candidature.
4. On the answer sheet, use only **BLUE or BLACK BALL POINT PEN** for making entries and filling the bubbles.
5. Your **ten-digit roll number and date of birth** entered on the OMR Answer Sheet shall remain your login credentials means login id and password respectively for accessing your performance / result in NSE-2019.
6. Question paper has two parts. In Part A1(Q. Nos 1 to 60) each question has four alternatives, Out of which only one is correct. Choose the correct alternative and fill the appropriate bubble, as shown.

   Q. No.22 (a) (●) (c) (d)

   In Part A2 (*Q.* Nos. 61 to 70) each question has four alternatives out of which **any number of alternatives** (1, 2, 3 or 4) may be correct. You have to choose ALL correct alternatives and fill the appropriate bubbles, as shown.

   Q. No.64 (a) (●) (c) (●)

7. For Part A1, each correct answer carries 3 marks whereas 1 mark will be deducted for each wrong answer. In Part A2, you get 6 marks if all the correct alternatives are marked. No negative marks in this part.
8. Any rough work should be done only in the space provided.
9. Use of **non-programmable scientific** calculator is allowed.
10. No candidate should leave the examination hall before the completion of the examination.
11. After submitting your answer paper, take away the Candidate's copy for your reference.
    Please DO NOT make any mark other than filling the appropriate bubbles properly in the space provided on the answer sheet.
    Answer sheets are evaluated using machine, hence CHANGE OF ENTRY IS NOT ALLOWED.
    Scratching or overwriting may result in a wrong score.
    DO NOT WRITE ON THE BACK SIDE OF THE ANSWER SHEET.

Instructions to candidates :

You may read the following instructions after submitting the answer sheet.

12. Comments/Inquiries/Grievences regarding this quesiton paper, if any, can be shared on the Inquiry/Grievence column on www.iaptexam.in on the specified format till 27th November, 2019.

13. The answers/solutions to this question paper will be available on the website : www.iapt.org.in by 2nd December, 2019.

14. **CERTIFICATES and AWARDS –**
    Following certificates are awarded by the IAPT to students successful in NSEP-2019.
    (i) "CENTRE TOP 10%"
    (ii) "STATE TOP 1%"
    (iii) "NATIONAL TOP 1%" .
    (iv) "GOLD MEDAL & MERIT CERTIFICATE" to all students who attend OCSC-2020 at HBCSE Mumbai.
15. All these certificates (except GOLD Medal) will be sent/dispatched to the centre in-charge by February 1, 2020 along with the result sheet of the centre.
16. List of students (with centre number and roll number only) having score above MAS will be displayed on the website : www.iapt.org.in by **December 20nd, 2019**. **See the Minimum Admissible score Clause** on the Student's brochure on our website**.**
17. List of Students eligible for the Indian National Physics Olympiad (INPhO-2020) shall be displayed on www.iapt.org.in by December 28,2019. These students have to register/enroll themselves on the website : Olympiads.hbcse.tifr.in of HBCSE Mumbai within the specified period.

Total Time : 120 minutes (A–1 and A–2)

A – 1

ONLY ONE OUT OF FOUR OPTIONS IS CORRECT

1. A pendulum is made by using a thread of length 300 cm and a small spherical bob of mass 100 g. It is suspended from a point S. The bob is pulled from its position of rest at O to the point A so that the linear amplitude is 25 cm. The angular amplitude in radian and the potential energy of the bob in joule at A are respectively.

(A) 0.10 and 0.10 (B) 0.083 and 0.01 (C) 0.251 and 2.94 (D) 0.083 and 0.24

Ans. **(B)**

Sol. $\ell = 3$

$m = \frac{1}{10}$

$A = \frac{25}{100} = \frac{1}{4}m$

Angular amplitude potential energy

$\theta = \frac{1/4}{3} = \frac{1}{12} = .083$

$PE = \frac{1}{2}kA^2 = \frac{1}{2}m\omega^2A^2$

$= \frac{1}{2}m\frac{g}{\ell}\ell^2\theta^2$

$= \frac{1}{2}\times\frac{1}{10}\times10\times3\times\frac{1}{144}$

$= \frac{3}{288} = 0.010$

2. Consider the following physical expressions

(I) ρv^2 (ρ : density, v : velocity)

(II) $\frac{Y\Delta L}{L}$ (Y : Young's modules, L : length)

(III) $\frac{\sigma^2}{\varepsilon_0}$ (σ : surface density of charge)

(IV) $h\rho rg$ (h : rise of a liquid in a capillary tube of radius r)

The expressions having same dimensional formula are :

(A) I and II only (B) II and III only (C) II, III and IV only (D) I, II and III only

Ans. **(D)**

Sol. $\rho v^2 \equiv \frac{F}{A}$

$y\frac{\Delta\ell}{\ell} \equiv \frac{F}{A}$

$h\rho rg \equiv T = \frac{F}{\ell}$

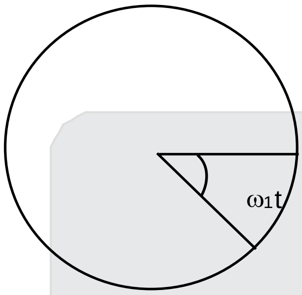
$\frac{\sigma^2}{\varepsilon_0} = \frac{F}{A}$

3. Two simple pendulums of lengths 1.44 m and 1.0 m start swinging to together in the same phase. The two will be in phase again after a time of

(A) 6 second (B) 9 second (C) 12 second (D) 25 second

Ans. **(C)**

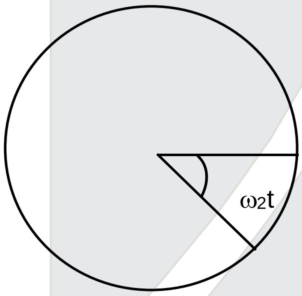
Sol. $\omega_1 = \sqrt{\frac{10}{1}}$



.....(1)

$\omega_1 > \omega_2$

$\omega_2 = \sqrt{\frac{g}{1.44}}$



$\omega_1 t = 2n\pi + \omega_2 t$

$t = \frac{2n\pi}{\omega_1 - \omega_2}$

$t = \frac{2n\sqrt{10}}{\sqrt{10} - \frac{\sqrt{10}}{1.2}} = \frac{2n}{0.2} \times 1.2 = 12n$

if n = 1

t = 12

4. A home aquarium partly filled with water slides down an inclined plane of inclination angle θ with respect to the horizontal. The surface of water in the aquarium

(A) remains horizontal

(B) remains parallel to the plane of the incline.

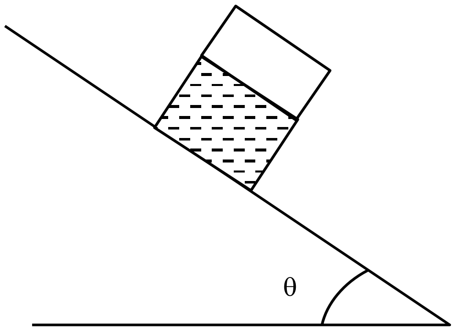
(C) forms an angle α with the horizon where $0 < \alpha < \theta$

(D) forms an angle α with the horizon where $0 < \alpha < 90$

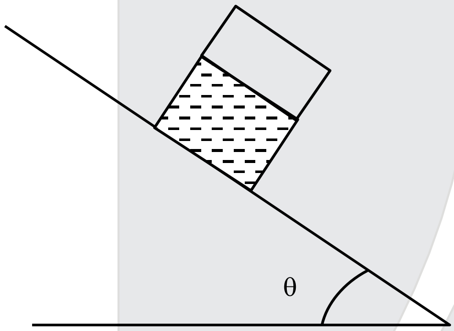
Ans. **(B or C)**

Sol. if $\mu = 0$

$\alpha = \theta$



Therefore if the surface is assume to be smooth only then correct answer is B.
if $\mu = \mu_s$
$\alpha = 0$



So $0 \le \propto < \theta$
Therefore correct option is (C)

5. A sound source of constant frequency travels with a constant velocity past an observer. When it crosses the observer the sound frequency sensed by the observer changes from 449 Hz to 422 Hz. If the velocity of sound is 340 m/s, the velocity of the source of sound is :
(A) 8.5 m/s (B) 10.5 m/s (C) 12.5 m/s (D) 14.5 m/s

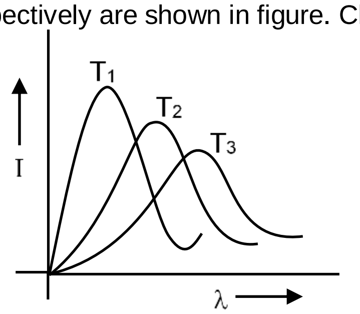
Ans. **(B)**

Sol. $$\frac{\frac{C}{C-v}f = 449}{\frac{C}{C+v}f = 422}$$

$(C + v)\,422 = (C - v)449$

$$v = \frac{27C}{(422+449)} = \frac{27\times340}{871} = 10.53\,m/s$$

6. Plots of intensity (I) of radiation emitted by a black body versus wavelength (λ) at three different temperature T_1, T_2 and T_3 respectively are shown in figure. Choose the correct statement :



(A) $T_1 > T_2 > T_3$ necessarily
(B) $T_3 > T_2 > T_1$ necessarily
(C) $T_2 = (T_1 + T_3)/2$ necessarily
(D) $T_2^2 > T_2 > T_3$ necessarily

Ans. **(A)**

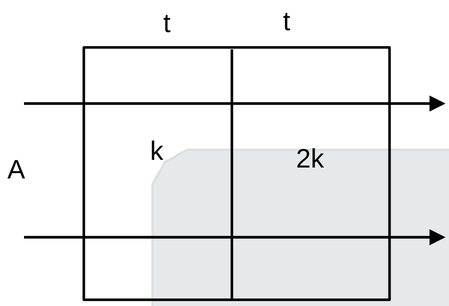
Sol. $\lambda_m T = C$
So $T_1 > T_2 > T_3$

7. Consider a composite slab consisting of two different materials having equal thickness and equal area of cross-section. The thermal conductivities are K and 2K respectively. The equivalent thermal conductivity of the composite slab is :

(A) $\frac{2K}{3}$ (B) $\sqrt{2}K$ (C) 3K (D) $\frac{4K}{3}$

Ans. **(D)**

Sol.



$R_{eq} = R_1 + R_2$

$$\frac{2t}{k_{eq}A} = \frac{t}{kA} + \frac{t}{2kA}$$

$$\frac{2}{k_{eq}} = \frac{1}{k} + \frac{1}{2k}$$

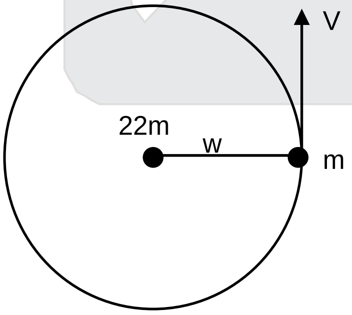
$$k_{eq} = \frac{4k}{3}$$

8. A large horizontal uniform disc can rotate freely about a rigid vertical axis passing through its centre O. A man stands at rest at the edge of the disc at a point A. The mass of the disc is 22 times the mass of the man. The man starts moving along the edge of the disc. When he reaches A, after completing one rotation relative to the disc, the disc has turned through

(A) 30° (B) 90° (C) 60° (D) 45°

Ans. **(A)**

Sol.



v : vel of man wrt disc

$$m(v - \omega R)R = \frac{22mR^2\omega}{2}$$

$$v - \omega R = 11\ \omega R$$

$$\omega R = \frac{V}{12}$$

$$t = \frac{2\pi R}{v}$$

$$\theta = \omega t = \omega\frac{2\pi R}{v} = \frac{2\pi}{12} = \frac{\pi}{6} = 30°$$

9. Two factories are sounding their sirens at 400 Hz each. A man walks from one factory towards the other at a speed of 2 m/s. The velocity of sound is 320 m/s. The number of beats heard by the person in one second will be

(A) 6 (B) 5 (C) 4 (D) 2.5

Ans. (B)

Sol. If = $\left(\frac{C+v}{C}-\frac{C-v}{C}\right)f$

$= \frac{2V}{C}f = \frac{4}{320}\times 400 = 5$

10. The temperature of an isolated black body falls from T_1 to T_2 in time t. Then, t = Cx where x is

(A) $\left(\frac{1}{T_2}-\frac{1}{T_1}\right)$ (B) $\left(\frac{1}{T_2^2}-\frac{1}{T_1^2}\right)$ (C) $\left(\frac{1}{T_2^3}-\frac{1}{T_1^3}\right)$ (D) $\left(\frac{1}{T_2^4}-\frac{1}{T_1^4}\right)$

Ans. (C)

Sol. $-Ms\,\frac{dT}{dt} = \sigma A T^4$

Let $\frac{\sigma A}{ms} = C$

$\frac{dT}{dt} = -C^1 T^4$

$\int_{T_1}^{T_2}\frac{dT}{T^4} = -\int_0^t dt$

$-\frac{1}{3}\left[\frac{1}{T_2^3}-\frac{1}{T_1^3}\right] = -C^1 t$

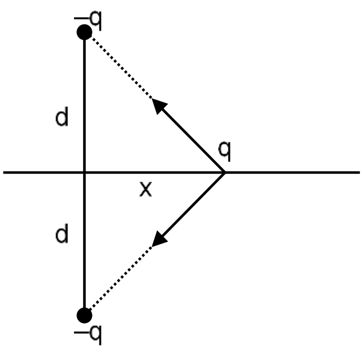
$t = C\left[\frac{1}{T_2^3}-\frac{1}{T_1^3}\right]$

11. Two charges –q and –q are placed at points (0, d) and (0, – d). A charge +q, free to move along X axis, will oscillate with a force proportional to

(A) $\frac{1}{x^2+d^2}$ (B) $\frac{1}{x^2}$ (C) $\frac{x}{(d^2+x^2)^{3/2}}$ (D) $\frac{1}{\sqrt{x^2+d^2}}$

Ans. (C)

Sol.



$F_{rest} = \frac{2kq^2x}{(d^2+x^2)^{3/2}}$

12. The average translational kinetic energy of oxygen (M = 32) molecules at a certain temperature is 0.048 eV. The translational kinetic energy of nitrogen (M = 28) molecules at the same temperature is (consider the two gases to be ideal)

(A) 0.0015 eV (B) 0.042 eV (C) 0.048 eV (D) 0.768 eV

Ans. **(C)**

Sol. $\langle KE \rangle_T = 3/2\ kT$

Independent of molar mass

13. A concave mirror has a radius of curvature R and forms the image of an object placed at a distance 1.5R from the pole of the mirror. An opaque disc of diameter half the aperture of the mirror is placed with the pole at the centre. As a result.

(A) the position of the image will be the same but its central half will disappear

(B) the position of the image will be the same but its outer half will disappear

(C) the complete image will be seen at the same position and it will be exactly identical with the initial image

(D) the complete image will be seen at the same position but it will not be identical in all respect with the initial image

Ans. **(D)**

Sol. Image will be formed at the same position but with lesser intensity because some rays will be blocked by the disc.

Correct answer should be D

14. A ray of white light is made incident on the refracting surface of a prism such that after refraction at this surface, the green component falls on the second surface at its critical angle. The colours present in the emergent beam will be

(A) violet, indigo and blue. (B) violet, indigo, blue, yellow, orange and red.

(C) yellow, orange and rd. (D) all colours

Ans. **(C)**

Sol. $\lambda\uparrow$, $n\downarrow$, $c\uparrow$

Max critical angle for red

$\rightarrow$ C increases

V I B G [Y O R]

So Y, O & R will be present

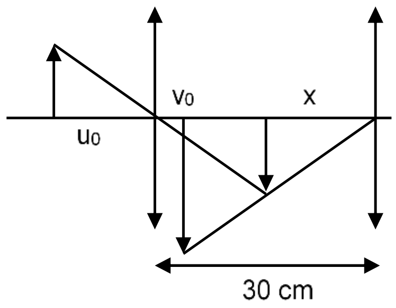
So Answer is (C)

15. In a compound microscope, having tube-length 30 cm, the power of the objective and the eye-piece are 100D and 10D respectively. Then the magnification produced by the microscope when the final image is at the least distance of distinct vision (25 cm) will be

(A) 55 (B) 64 (C) 77 (D) 90

Ans. **(C)**

Sol.



$x = \frac{Df_e}{D + f_e}$

$v_0 + \frac{Df_e}{D + f_e} = 30$

$v_0 + \frac{25 \times 10}{35} = 30$

$v_0 = 30 - \frac{250}{35}$

$= 30 - \frac{50}{7} = \frac{160}{7}$

$\frac{7}{160} - \frac{1}{u_0} = \frac{1}{1} \Rightarrow \quad \frac{1}{u_0} = \frac{7}{160} - 1$

$= -\frac{153}{160}$

$u_0 = -\frac{160}{153}$

$m = \frac{\frac{160}{7}}{\frac{160}{153}} \times \left\{1 + \frac{25}{10}\right\}$

$= \frac{153}{7}\left\{\frac{35}{10}\right\}$

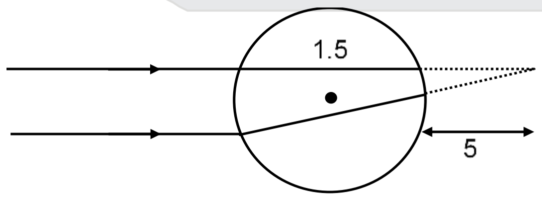
$\frac{153}{2} = 76.5$

16. Parallel rays are incident on a glass sphere of diameter 10 cm and having refractive index 1.5. The sphere converges these rays at a certain point. The distance of this point from the centre of the sphere will be :

(A) 2.5 cm (B) 5 cm (C) 7.5 cm (D) 12.5 cm

Ans. **(C)**

Sol.



First surface $\frac{1.5}{V} - \frac{1}{\infty} = \frac{1.5 - 1}{5}$

$\Rightarrow \quad \frac{V}{1.5} = 10$

$\Rightarrow \quad V = 15$

Second surface $\frac{1}{V_f} - \frac{3}{10} = \frac{1}{10}$

$\Rightarrow \quad \frac{1}{V_f} = \frac{4}{10}$

$\Rightarrow \quad V_f = 2.5$

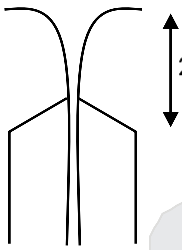
Hence distance from centre of sphere is 7.5 cm.

17. A jet of water from 15 cm diameter nozzle of a fire hose can reach the maximum height of 25m, The force exerted by the water jet on the hose is :

(A) 4.24 kN (B) 17.32 kN (C) 2.17 kN (D) 8.66 kN

Ans. **(D)**

Sol.



$f_t = v_{rel.}\dfrac{dm}{dt}$

$= v_{rel}\rho A v_{rel.}$

$= \delta A v_{rel}^2 = \rho A\ 2gh = \rho\dfrac{\pi D^2}{4}2gh = 8.83$ kN

18. In an electromagnetic wave the phase difference between electric vector and magnetic vector is

(A) zero (B) $\frac{\pi}{2}$ (C) π (D) $\frac{3\pi}{2}$

Ans. **(A)**

Sol. There is no phase diff. between E and B

19. A spherical capacitor is formed by two concentric metallic spherical shells. The capacitor is then charged so that the outer shell carries a positive charge and the inner shell carries an equal but negative charge. Even if the capacitor is not connected to any circuit, the charge will eventually leak away due to a small electrical conductivity of the material between the shells. What is the character of the magnetic field produced by leakage current ?

(A) Radially outwards from the inner shell to the outer shell.

(B) Radially inwards from the outer shell to the inner shell.

(C) Circular field lines between the shells and perpendicular to the radial direction.

(D) No magnetic field will be produced.

Ans. **(D)**

Sol. Due to spherical symmetry no magnetic field is preduced.

20. If a cell of constant emf produces the same amount of heat during the same time in two independent resistors R_1 and R_2 when they are separately connected across the terminals of the cell, one after the other. The internal resistance of the cell is

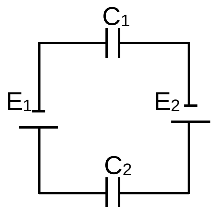
(A) $\dfrac{R_1+R_2}{2}$ (B) $\dfrac{R_1 \sim R_2}{2}$ (C) $\dfrac{\sqrt{R_1^2+R_2^2}}{2}$ (D) $\sqrt{R_1R_2}$

Ans. **(D)**

Sol. $\dfrac{\varepsilon^2}{(r+R_1)}R_1 = \dfrac{\varepsilon^2}{(r+R_2)^2}R_2$

on solving $r = \sqrt{R_1R_2}$

21. In the circuit shown beside the charge on each capacitor is



(A) $(C_1 + C_2)(E_1 - E_2)$

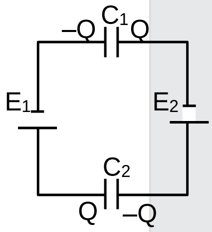
(B) $\frac{C_1C_2}{C_1+C_2}(E_1+E_2)$

(C) $\frac{C_1C_2}{C_1+C_2}(E_1-E_2)$

(D) $(C_1 - C_2)(E_1 + E_2)$

Ans. **(C)**

Sol. Applying KVL in the circuit



$+ E_1 - Q/C_2 - E_2 - Q/C_1 = 0$

$$\frac{Q}{C_1}+\frac{Q}{C_2}=E_1-E_2$$

$$Q=\frac{C_1C_2}{C_1+C_2}(E_1-E_2)$$

22. A stationary hydrogen atom emits photon corresponding to the first line (highest wave length) of Lyman series. If R is the Rydberg constant and M is the mass of the atom, the recoil velocity of the atom is

(A) $\frac{Rh}{4M}$ (B) $\frac{3Rh}{M}$ (C) $\frac{3Rh}{4M}$ (D) $\frac{Rh}{M}$

Ans. **(C)**

Sol. let λ is wavelength of first line of Lyman series

Then $\frac{1}{\lambda}=R\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$

$\Rightarrow \quad \frac{1}{\lambda}=R\left(\frac{3}{4}\right)$

From conservation of linear momentum of emitted photon = linear momentum of atom

$h/\lambda = Mv$

$$\frac{3Rh}{4}=Mv$$

23. Heat is absorbed or evolved when current flows in a conductor having a temperature gradient. This phenomenon is known as

(A) Joule effect (B) Peltier effect (C) Seeback effect (D) Thomson effect

Ans. **(D)**

24. Avalanche breakdown in a p-n junction depends on the phenomenon of

(A) doping (B) collision (C) recombination (D) ionization

Ans. **(B)**

25. A source emits photons of energy 5 eV which are incident on a metallic sphere of work function 3.0 eV. The radius of the sphere is $r = 8 \times 10^{-3}$ m. It is observed that after some time emission of photoelectrons from the metallic sphere is stopped. Charge on the sphere when the photoemission stops is :

(A) 1.77×10^{-16} C (B) 1.77×10^{-12} C (C) 1.11×10^{-12} C (D) 1.11×10^{-10} C

Ans. **(B)**

Sol. Maximum energy of emitted photo-electron = 5eV – 3eV = 2eV

Emission of photoelectrons from metallic sphere is stopped.

when energy of photoelectron becomes zero = $-\frac{KQe}{R} + 2eV = 0$ (where Q is charge of sphere)

$$-\frac{KQ}{R} + 2V = 0$$

$$\frac{KQ}{R} = 2V$$

$$Q = \frac{2R}{K} = \frac{2 \times 8 \times 10^{-3}}{9 \times 10^{9}} = \frac{16}{9} \times 10^{-12} = 1.77 \times 10^{-12} \text{ C}$$

26. The dc component of current in the output of a half-wave rectifier with peak value I_0 is

(A) zero (B) I_0/π (C) $I_0/2\pi$ (D) $2I_0/\pi$

Ans. **(B)**

Sol. Output is half-wave rectifier.

$i = i_0 \sin \omega t$ (for $0 < t < T/2$)

$i = 0$ ($T/2 < t < T$)

Average current = $\frac{\int i\,dt}{\int dt} = \frac{\int i_0 \sin\omega t\,dt + \int 0\,dt}{(t)}$

$$= \frac{i_0\left(-\frac{\cos\omega t}{\omega}\right)_0^{T/2} + 0}{T}$$

$$= \frac{i_0(-\cos\pi + \cos 0)}{\omega T} = \frac{2i_0}{T\omega} = \frac{2i_0}{2\pi} = \frac{i_0}{\pi}$$

27. In an experiment on photoelectric effect, the slope of straight line graph between the stopping potential and the frequency of incident radiation gives

(A) Electron charge (e) (B) Planck constant (h) (C) h/e (D) Work function (W)

Ans. **(C)**

Sol. $eV = hf - \phi$

$V = \frac{h}{e} f - \phi$

Slope = h/e

28. According to Bohr's theory the ionization energy H atom is 13.6 eV. The energy needed to remove an electron from Helium ion (He^+) is

(A) 13.6 eV (B) 16.8 eV (C) 27.2 eV (D) 54.4 eV

Ans. **(D)**

Sol. According to Bohr's theory

Ionization energy = $13.6 Z^2$

So, ionization energy of He^+ is $13.6 \times 2^2 = 54.4$ eV

29. The phenomenon inverse to phto electric effect is
(A) Compton effect
(B) Pair production
(C) Raman effect
(D) Production of X-rays in Coolidge tube

Ans. **(D)**

30. A stationary hydrogen atom emits a photon of wavelength 1025Å. Its angular momentum changes by
(A) h/π
(B) $2h/\pi$
(C) $h/2\pi$
(D) $3h/2\pi$

Ans. **(A)**

Sol. Energy of emitted photon = $\frac{hc}{\lambda} = \frac{12400 eVÅ}{1025Å}$
= 12.097 eV
which implies transition of e^- from 3rd orbit to 1st orbit
So, that change in angular momentum = $(3-1)\frac{h}{2\pi}$
$= \frac{h}{\pi}$

31. An observer stands on the platform at the front edge of the first bogie of a stationary train. The train starts moving with uniform acceleration and the first bogie takes 5 seconds to cross the observer. If all the bogies of the train are of equal length and the gap between them is negligible, the time taken by the tenth bogie to cross the observer is
(A) 1.07 s
(B) 0.98 s
(C) 0.91 s
(D) 0.81 s

Ans. **(D)**

Sol. Assume, acceleration of train = a
length of each bogie = L
Then, from given data $L = \frac{1}{2}a(5)^2$
$\frac{2L}{25} = a$
Time taken to cross 9 bogies $\Rightarrow \frac{1}{2}at_1^2 = 9L$
$t_1 = \sqrt{\frac{18L}{a}}$
Time taken to cross 10 bogies $\Rightarrow \frac{1}{2}at_2^2 = 10L$
$t_2 = \sqrt{\frac{20L}{a}}$
Time taken to cross 10th bogie = $t_2 - t_1$ = 0.81 sec

32. The resistive force on an aeroplane flying in a horizontal plane is given by $F_f = kv^2$, where k is constant and v is the speed of the aeroplane. When the power output from the engine is P_0, the plane flies at a speed v_0. If the power output of the engine is doubled the aeroplane will fly at a speed of
(A) $1.12\ v_0$
(B) $1.26\ v_0$
(C) $1.41\ v_0$
(D) $2.82\ v_0$

Ans. **(B)**

Sol. Power = F.V.
$P_0 = KV_0^2 \cdot V_0 = KV_0^3$ ......(1)
If power is doubled
$2P_0 = kV^3$ ......(2)
From equation (1) & (2)
$\frac{KV^3}{KV_0^3} = \frac{2P_0}{P_0}$
$V = 2^{1/3} V_0 = 1.26\ V_0$

33. A 3.0 cm thick layer of oil (density ρ_{oil} = 800 kg/m^3) floats on water (density ρ_w = 1000 kg/m^3) in a transparent glass beaker. A solid cylinder is observed floating vertically with 1/3 of it in water and 1/3 in the oil. Oil is gently poured into the beaker until they cylinder floats in oil only. The fraction of the solid cylinder in oil now is

(A) 3/5 (B) 2/3 (C) 3/4 (D) 8/9

Ans. **(C)**

Sol. $\rho_c Vg = \rho_{oil}\frac{V}{3}g + \rho_\omega \frac{V}{3}g$

$\rho_c = 600$ ……(1)

$\rho_c\ Vg = \rho_{oil}V'g$

$V' = \frac{600}{800}V = \frac{3}{4}V$

34. A wedge of mass M rest on a horizontal frictionless surface. A block of mass m starts sliding down the rough inclined surface of the wedge to its bottom. During the course of motion, the centre of mass of the block and the wedge system

(A) does not move at all (B) moves horizontally with constant speed

(C) moves horizontally with increasing speed (D) moves vertically with increasing speed

Ans. **(D)**

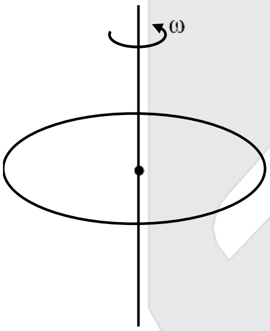
Sol. There is no external horizontal force on (block + wedge) system. and vertical external forces are unbalanced therefore D.

35. A uniform circular disc rotating at a fixed angular velocity ω about an axis normal to its plane and passing through its centre has kinetic energy E. If the same disc rotates with an angular velocity 2ω about a parallel axis passing through the edge, its kinetic energy will be

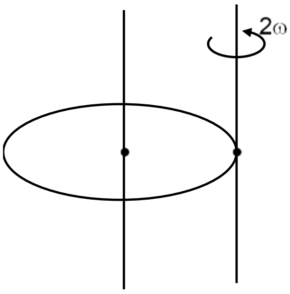
(A) 2E (B) 4E (C) 10E (D) 12E

Ans. **(D)**

Sol.



$E = \frac{1}{2}I\omega^2$



$E' = \frac{1}{2}(I')(2\omega)^2$

$\frac{E'}{E} = \frac{\frac{1}{2}\left(\frac{3}{2}mR^2\right)4\omega^2}{\frac{1}{2}\frac{mR^2}{2}\omega^2}$

$E' = 12E$

36. Light of wavelength 640 nm falls on a plane diffraction grating with 12000 lines per inch. In the diffraction pattern on a screen kept at a distance of 12 cm from the grating, the distance of the second order maximum from the central maximum is

(A) 1.81 cm (B) 2.41 cm (C) 3.62 cm (D) 7.25 cm

Ans. **(D)**

Sol. $\sin\theta = \frac{n\lambda}{d}$

Spacing between two consecutive slits

$d = \frac{0.0254}{12000}$

For second order maximum $\Rightarrow$ n = 2

$\sin\theta = \frac{2\times 640\times 10^{-9}}{\left(\frac{0.0254}{12000}\right)} \simeq 0.6$

$\frac{y}{12cm}$ = tan θ = 0.75 ⇒ y = 9 cm ⇒ the closest ans is 7.25 cm

37. If the force acting on a body is inversely proportional to its speed, the kinetic energy of the body varies with time t as

(A) t^0 (B) t^1 (C) t^2 (D) t^{-1}

Ans. **(B)**

Sol. $F \propto \frac{1}{v}$

$F = \frac{k}{V}$

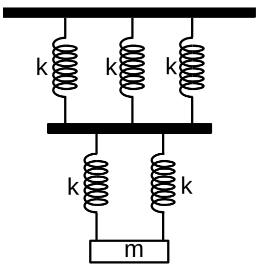
m v dv = kdt

Integrating both side

$\frac{1}{2}mv^2 = kt$

$\frac{1}{2}mv^2 \propto t$

38. As shown in the figure, a block of mass m is hung from the ceiling by the system of springs consisting of two layers. The force constant of each of the springs is k. The frequency of the vertical oscillations of the block is



(A) $\frac{1}{2\pi}\sqrt{\frac{k}{5m}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{4k}{5m}}$ (C) $\frac{1}{2\pi}\sqrt{\frac{5k}{6m}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{6k}{5m}}$

Ans. **(D)**

Sol. For spring mass system

$f = \frac{1}{2\pi}\sqrt{\frac{K_{eq}}{m}} = \frac{1}{2\pi}\sqrt{\frac{6K}{5M}}$

$\frac{1}{K_{eq}} = \frac{1}{3K} + \frac{1}{2K} = \frac{5}{6K}$

$K_{eq} = \frac{6K}{5}$

39. Two simple harmonic motions are given by x_1 = a sin ωt + a cos ωt and x_2 = a sin ωt + $\frac{a}{\sqrt{3}}$ cos ωt.

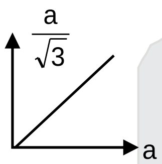
The ratio of the amplitudes of the first to the second and the phase difference between them respectively are

(A) $\sqrt{\frac{3.}{2}}\text{and}\frac{\pi}{12}$ (B) $\frac{\sqrt{3}}{2}\text{and}\frac{\pi}{12}$ (C) $\frac{2}{\sqrt{3}}\text{and}\frac{\pi}{12}$ (D) $\sqrt{\frac{3}{2}}\text{and}\frac{\pi}{6}$

Ans. **(A)**

Sol. X_1 = a sin ωt + a cos ωt

$= a\sqrt{2}\sin\left(\omega t+\frac{\pi}{4}\right)$



X_2 = a sin ωt + $\frac{a}{\sqrt{3}}\cos\omega t$

$=\frac{2a}{\sqrt{3}}\sin\left(\omega t+\frac{\pi}{6}\right)$

$\frac{X_1}{X_2}=\frac{a\sqrt{2}}{2a/\sqrt{3}}=\sqrt{\frac{3}{2}}$

$\phi_1-\phi_2=\frac{\pi}{4}-\frac{\pi}{6}=\frac{2\pi}{24}=\frac{\pi}{12}$

40. A particle is projected from the ground with a velocity $\vec{v}$ = $(3\hat{i}+10\hat{j})$ ms^{-1}. The maximum height attained and the range of the particle are respectively given by (use g = 10m/s^2)

(A) 5m and 6m (B) 3m and 10m (C) 6m and 5m (D) 3m and 5m

Ans. **(A)**

Sol. $\vec{V}=3\hat{i}+10\hat{j}\,m/s$

Maximum height = $\frac{(10)^2}{2g}=5m$

Range = $2.\frac{10}{g}.3=6m$

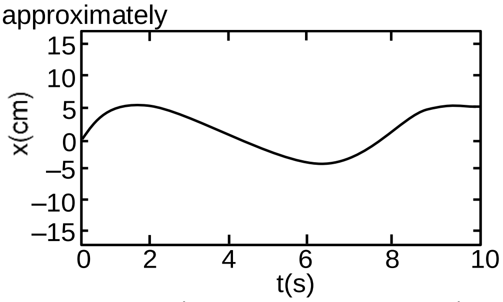
41. A 20 cm long capillary tube stands vertically with lower end just in water. Water rises up to 5 cm. If the entire system is now kept on a freely falling platform, the length of the water column in the capillary tube will be

(A) 5 cm (B) 10 cm (C) Zero (D) 20 cm

Ans. **(D)**

Sol. 20 cm

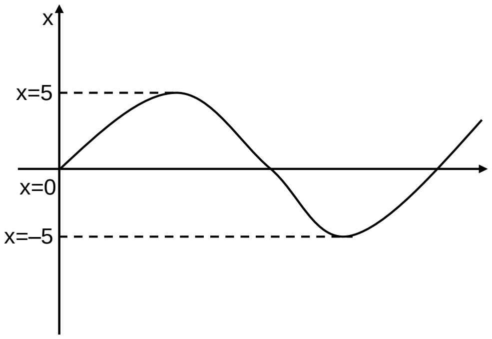
42. Position-time graph of a particle moving in a potential field is shown beside. If the mass of the particle is 1 kg its total energy is approximately



(A) 15.45 × 10^{-4}J (B) 30.78 × 10^{-4}J (C) 7.71 × 10^{-4}J (D) 3.85 × 10^{-4}J

Ans. **(C)**

Sol.



A = 5m
T = 8 sec

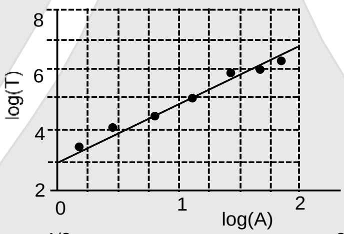
$\omega = \frac{2\pi}{8} = \frac{\pi}{4}$

$k = m\omega^2$

$k = 1 \times \frac{\pi^2}{16} = \frac{\pi^2}{16}$

$TE = \frac{1}{2}kA^2 = \frac{25\pi^2}{32\times100\times100} = 7.71 \times 10^{-4}J$

43. The log-log graph for a non–linear oscillator is shown below. Assuming the constants to have appropriate dimensions the relationship between time period (T) and the amplitude (A) can be expressed as



(A) $T = 1000A^2$ (B) $T = 4A^{1/2}$ (C) $T = 4A^2+B$ (D) $T = 8A^3$

Ans. **(A)**

Sol. From graph
logT = 3 + 2logA
On solving
$T = 1000A^2$

44. In many situations the point source emitting a wave starts moving, through the medium, with velocity V greater than the wave velocity in that medium. In such a case when source velocity (V) > wave velocity (v), the wave front changes.

(A) from spherical to plane (B) from spherical to conical
(C) from plane to spherical (D) from cylindrical to spherical

Ans. **(B)**

45. If the average mass of a smoke particle in an Indian kitchen is 3×10^{-17} kg, the rms speed of the smoke particles at 27ºC is approximately

(A) 2 cm/sec (B) 2 m/sec (C) 2 km/sec (D) none of these

Ans. **(A)**

Sol. $\sqrt{\frac{2\times25}{3}\times\frac{300}{3\times10^{-17}}}$ $\sqrt{\frac{3\times25}{3}\times\frac{300}{3\times10^{-17}}}$

$5 \times 10^{+9} \times 3.1$

$15 \times 10^{+9}$

$\sqrt{\frac{3\times25\times300}{3\times6.022\times10^{23}\times3}}$ = 2 cm/sec

46. Two wires, made of same material, one thick and the other thin are joined to form one composite wire. The composite wire is subjected to the same tension throughout. A wave travels along the wire and passes the point where the two wires are joined. The quantity which changes at the joint are

(A) frequency only (B) propagation speed only
(C) wavelength only (D) both propagation speed and wavelength

Ans. **(D)**

47. The frequency of the third overtone of a closed end organ pipe equals the frequency of the fifth harmonic of an open end organ pipe. Ignoring end correction, the ratio of their lengths $l_{open} : l_{close}$ is

(A) 10 : 7 (B) 10 : 9 (C) 2 : 1 (D) 7 : 10

Ans. **(A)**

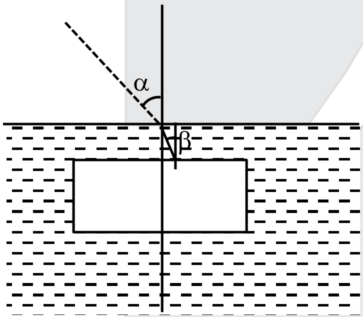
Sol. $\frac{7V}{4L_{close}} = \frac{5V}{2L_{open}} \Rightarrow \frac{L_{open}}{L_{close}} = \frac{10}{7}$

48. A rectangular slab of glass of refractive index 1.5 is immersed in water of refractive index 1.33 such that the top surface of the slab remains parallel to water leave. Light from a point source in air is incident on the surface of water at an angle α such that the light reflected from the glass slab is plane polarised, the angle α is

(A) 84.4° (B) 48.4° (C) 56.3° (D) 53.1°

Ans. **(A)**

Sol.



$1.\sin\alpha = 1.33\sin\frac{1.33}{1.5}$

$\alpha = 84.4°$

49. In a spectrometer the smallest main scale division is $\frac{1}{3}$ of a degree. The total number of divisions on the vernier scale attached to the main scale is 60 which coincide with the 59 divisions of the main circular scale. The least count of the spectrometer is

(A) 20' (B) 20" (C) 30" (D) 30'

Ans. **(B)**

Sol. $1VSD = \frac{59}{60} \times \frac{1°}{3} = \frac{59°}{180}$

$1MSD = \frac{1°}{3} = \frac{60°}{180}$

Least count = 1 MSD – 1 VSD

$= \frac{1°}{180} = 20''$

50. White light is used to illuminate two slits in Young's double sit experiment. Separation between the two slits is b and the screen is at a distance D (>>b) from the plane of slits. The wavelength missing at a point on the screen directly in front of one of the slits is

(A) $\frac{2b^2}{3D}$ (B) $\frac{2b^2}{D}$ (C) $\frac{b^2}{3D}$ (D) $\frac{b^2}{2D}$

Ans. **(C)**

Sol. $\Delta x = d\sin\theta \simeq d\tan\theta = dy/D$

For minima

$\Delta x = (2n + 1)\frac{\lambda}{2}$

$dy/D = \frac{dy}{D} = \frac{d \times d}{2D} = (2n+1)\frac{\lambda}{2}$

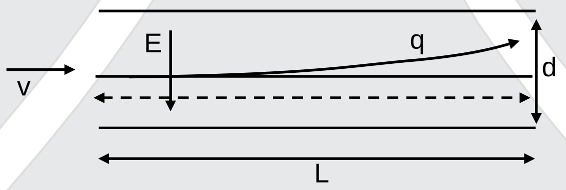
(d = b)

$\frac{b^2}{2D} = (2n+1)\frac{\lambda}{2}$

$\lambda = \frac{b^2}{(2n+1)D}$ (n = 1)

$\lambda = \frac{b^2}{3D}$

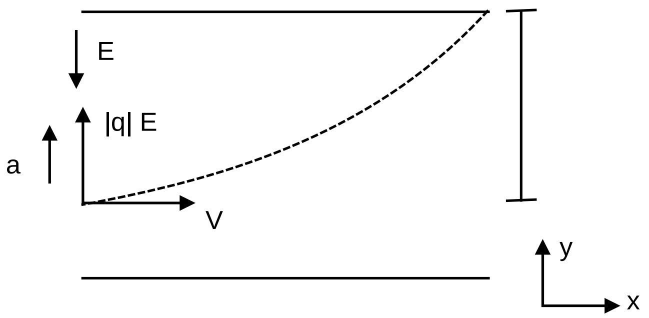
51. In an ink-jet printer, an ink droplet of mass m is given a negative charge q by a computer-controlled charging unit. The charged droplet then enters the region between two deflecting parallel plates of length L separated by distance d (see figure below) with a speed v. All over this region there exists a uniform downward electric field E (in the plane of paper). Neglecting the gravitational force on the droplet, the maximum charge that can be given to this droplet, so that it does not hit any of the plates, is



(A) $\frac{mv^2L}{Ed^2}$ (B) $\frac{mv^2d}{EL^2}$ (C) $\frac{md}{Ev^2L^2}$ (D) $\frac{mv^2L^2}{Ed}$

Ans. **(B)**

Sol.



$a = \frac{|q|E}{m}$

A/q when $\Delta x = L \Rightarrow vt = L \Rightarrow t = L / V$

$\Delta y \le d/2$

$\Rightarrow \frac{1}{2} \times at^2 \le \frac{d}{2}$ $\Rightarrow \frac{1}{2}\frac{|q|Et^2}{m} \le \frac{d}{2}$ $\Rightarrow |q| \le \frac{m}{E}\frac{v^2}{L^2}d$

52. A converging beam of light is pointing to P. Two observations are made with (i) a convex lens of focal length 20 cm and, (ii) a concave lens of focal length 16 cm placed in the path of the convergent beam at a distance 12 cm before the point P. It is observed that
(A) in both cases the images are real.
(B) in both cases the images are virtual.
(C) for (i) the image is real and for (ii) the image is virtual.
(D) for (i) the image is virtual and for (ii) the image is real.

Ans. **(A)**

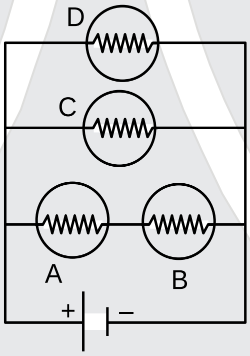
Sol. For convex lens
u = +12
f = 20

$v = \frac{fu}{u+f} = \frac{20 \times 12}{32} > 0 \Rightarrow$ Real image

for concave lens
u = + 12
f = – 16

$v = \frac{fu}{u+f} = \frac{(-16)(12)}{12-16} = \frac{-16 \times 12}{-4} = 48 > 0 = 1$ real image

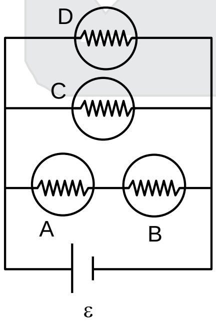
53. Identify the rank in order from the dimmest to the brightest when all the identical bulbs are connected in the circuit as shown below.



(A) A = B > C = D (B) A = B = C = D (C) A > C > B > D (D) A = B < C = D

Ans. **(D)**

Sol.



$V_D = V_C = \varepsilon$

$V_A = V_B = \frac{\varepsilon}{2}$

$P_C = P_D > P_A = P_B$

54. The unit of magnetizing field is
(A) tesla (B) newton (C) ampere (D) ampere turn/meter

Sol. **(D)**

$B = \mu_0 ni$

$\frac{B}{\mu_0} = ni$

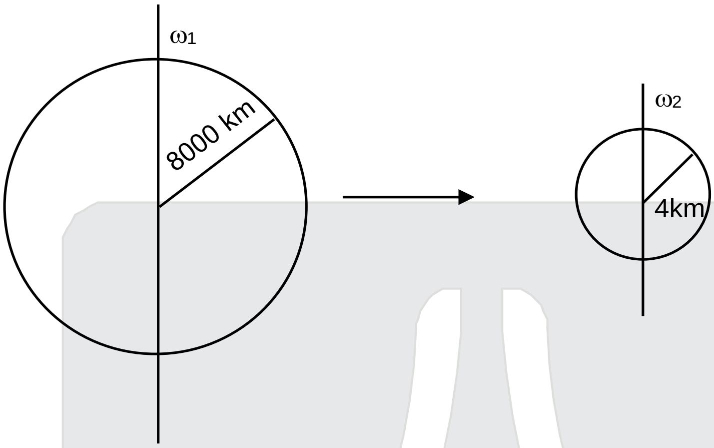
Am^{-1}

55. A star undergoes a supernova explosion. Just after the explosion, the material left behind forms a uniform sphere of radius 8000 km with a rotation period of 15 hours. This remaining material eventually collapses into a neutron star of radius 4 km with a period of rotation

(A) 14 s (B) 3.8 h (C) 0.021 s (D) 0.0135 s

Ans. **(D)**

Sol.



$L_i = L_f$

$I_1\omega_1 = I_2\omega_2$

$\Rightarrow \quad \frac{2}{5}mR_1^2\omega_1 = \frac{2}{5}mR_2^2\omega_2$

$\Rightarrow \quad \frac{T_2}{T_1} = \left(\frac{R_2}{R_1}\right)^2$

$\Rightarrow \quad T_2 = \left(\frac{R_2}{R_1}\right)^2 \times T_1$

$= \left(\frac{4}{28000}\right)^2 \times 15 \times 60 \times 60 = 0.013500$

56. A number of identical absorbing plates are arranged in between a source of light and a photo cell. When there is no plate in between, the photo current is maximum. Under the circumstances let us focus on the two statements-

(1) The photo current decreases with the increase in number of absorbing plates.

(2) The stopping potential increases with the increase in number of absorbing plates.

(A) Statements (1) and (2) are both true and (1) is the cause of (2)

(B) Statements (1) and (2) are both true but (1) and (2) are independent

(C) Statements (1) is true while (2) is not true and (1) and (2) are independent

(D) Statements (1) is true while (2) is not true and (2) is the effect of (1)

Ans. **(C)**

Sol. Due to the presence of absorbing plates the intensity of the light incident on ptotocell is reduced thereby decreasing the number of photons striking the photocell. So current is reduced

Stopping potential (Vs) is independent of the intensity rather it depends on the frequency of light.

57. In a nuclear reaction, two photons each of energy 0.51 MeV are produced by electron-positron annihilation. The wavelength associated with each photon is

(A) 2.44×10^{-12}m (B) 2.44×10^{-8}m

(C) 1.46×10^{-12}m (D) 3.44×10^{-10}m

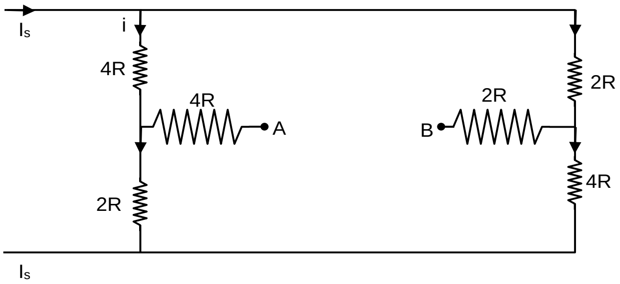
Ans. **(A)**

Sol. $\lambda = \frac{1240 \times 10^{-9}}{0.51 \times 10^{6}}$ m

$= 2431.3 \times 10^{-15}$ m

$= 2.44 \times 10^{-12}$ m

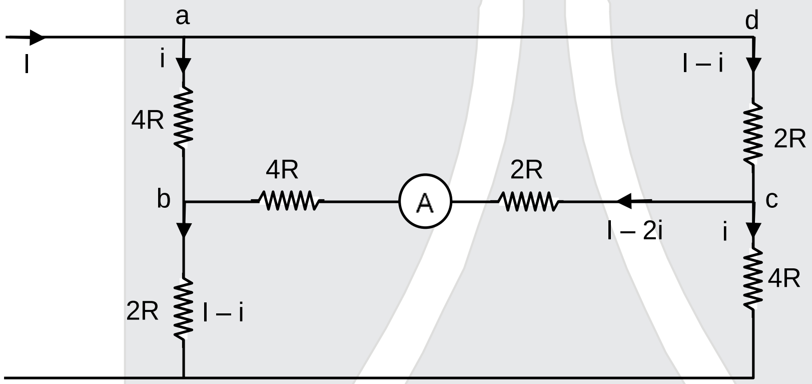
58. In the circuit shown if an ideal ammeter is connected between A and B then the direction of current and the current reading would be (assume I, remains uncharged)



(A) B to A and $I_s/2$ (B) A to B and $I_s/4$
(C) B to A and $I_s/9$ (D) B to A and $I_s/3$

Ans. **(C)**

Sol.



KVL in lets abcda

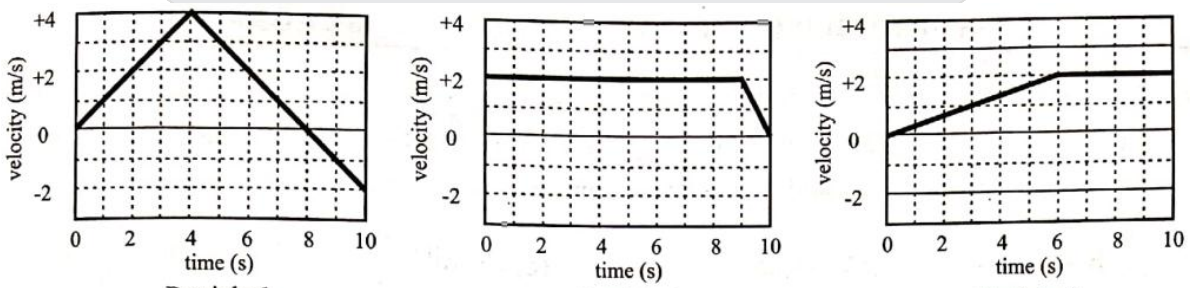
–i 4R + (I – 2i) 6R + (I – i) 2R = 0

–2i + 3I – 6i + (I – i) = 0

$\Rightarrow$ 4I = 9i $\Rightarrow$ I = $\frac{4}{9}$I

$\therefore$ current through ammeter = $I - 2i = I - \frac{8}{9}I = \frac{I}{9}$

59. In the following figures the velocity-time graphs for three particles 1, 2 and 3 are shown.



Particle 1 Particle 2 Particle 3

The magnitude of average acceleration of the three particles, over 10 s, bear the relationship

(A) $a_1 > a_2 > a_3$ (B) $a_2 > a_1 > a_3$ (C) $a_3 > a_2 > a_1$ (D) $a_1 = a_2 = a_3$

Ans. **(D)**

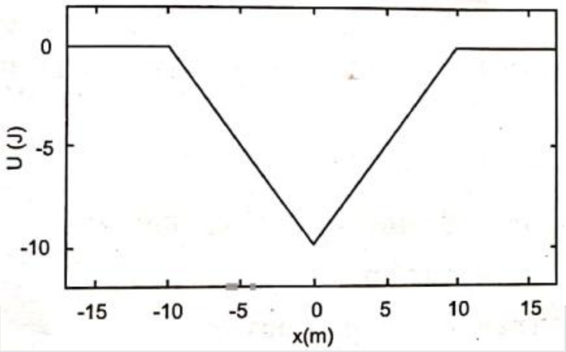
Sol. Particle

1. $\frac{\Delta V}{\Delta t} = \frac{-2-0}{10} = \frac{-2}{10} = -0.2 = a_1$

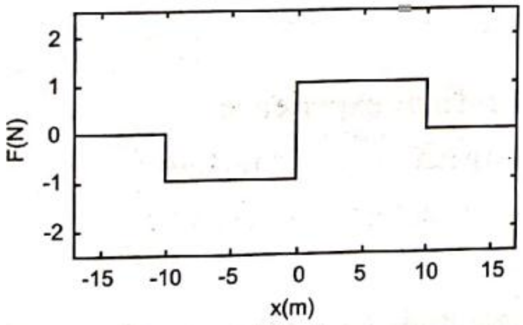
2. $\frac{\Delta V}{\Delta t} = \frac{0-2}{10} = -0.2 = -0.2 = a_2$

3. $\frac{\Delta V}{\Delta t} = \frac{2-0}{10} = 0.2 = 0.2 = a_3$ $\therefore |a_1| = |a_2| = |a_3|$

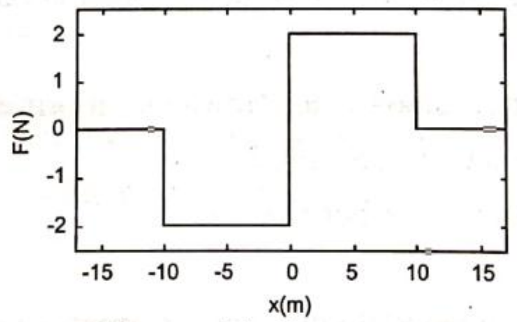
60. The potential energy (U) of a particle moving in a potential field varies with its displacement (x) as shown below.



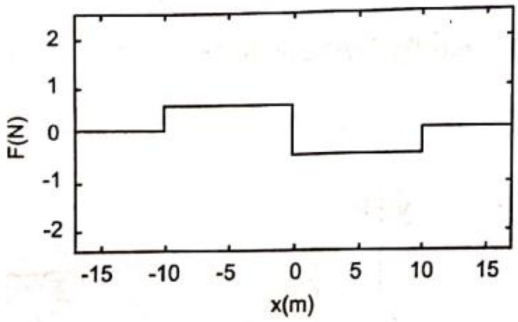
The variation of force F(x) acting on the particle as a function of x can be represented by



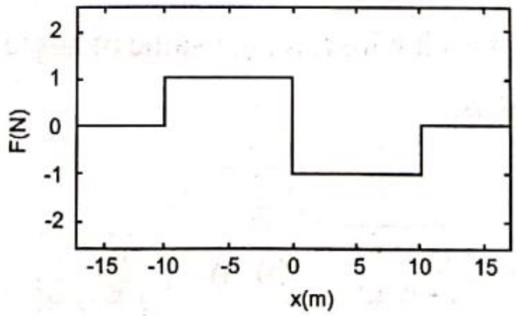
(Fig i)



(Fig ii)



(Fig iii)



(Fig iv)

(A) Fig (i) (B) Fig (ii) (C) Fig (iii) (D) Fig (iv)

Ans. **(D)**

Sol. for $-20 \le x \le -10$ $U = 0$ $\therefore F = \frac{-du}{dx} = 0$

$-10 \le x \le 0$ $\frac{du}{dx} = -1$ $F = +1$

$0 \le x \le 10$ $\frac{du}{dx} = 1$ $F = -1$

$10 < x \le 20$ $\frac{du}{dx} = 0$ $\therefore F = 0$

A – 2

In Q. Nos. 61 to 70 any number of options (A or B or C or all D) may be correct. You are to identify all of them correctly to get 6 marks. Even if one answer identified is incorrect or one correct answer is missed, you get zero marks.

61. A pin of small length 'a' is placed along the axis of a concave mirror of focal length f, at the distance u (>f) from its pole. The length of its image is 'b'. If the same object is placed perpendicular to its axis at the same distance u and the length of its image is now 'c', then

(A) $b = a\dfrac{f^2}{(u-f)^2}$ (B) $c = \sqrt{ab}$ (C) $c = b\dfrac{u-f}{f}$ (D) $bc = \dfrac{a^2f^3}{(u-f)^3}$

Ans. **(ABCD)**

Sol. $m_L = \dfrac{b}{a} = m^2$

$m = \sqrt{\dfrac{b}{a}}$ and $m = \dfrac{f}{u-f}$

$\dfrac{h_I}{a} = \sqrt{\dfrac{b}{a}}$

$C = h_I = \sqrt{ab}$

Also

$m = \sqrt{\dfrac{b}{a}} = \dfrac{f}{u-f} \Rightarrow b = \dfrac{f^2a}{(u-f)^2}$

$b = \left(\dfrac{f}{u-f}\right)^2 a$

$c = \left(\dfrac{f}{u-f}\right) a$

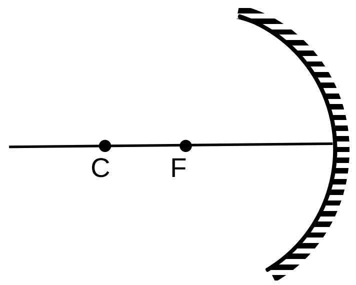
$\dfrac{b}{c} = \dfrac{f}{u-f}$

62. A thin rod of length 10 cm. is placed along the axis of a concave mirror of focal length 30 cm in such a way that one end of the image coincides with one end of the object. The length of the image may be

(A) 7.5 cm (B) 12 cm (C) 15 cm (D) 10 cm

Ans. **(ACD)**

Sol.



A and A_1 → same point at centre (u = 60 cm)

For B

$\dfrac{1}{V} + \dfrac{1}{-70} = \dfrac{1}{-30}$

$v = -52.5$

$L_I = 7.5$ cm

or $\frac{1}{v} + \frac{1}{-50} = \frac{1}{-30}$

v = – 75 cm

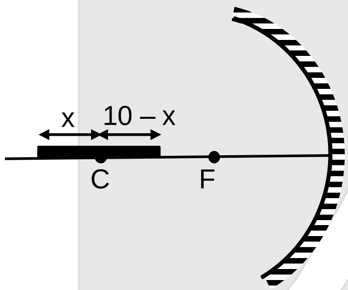
L_I = 15 cm

For D

If the rod is kept such that one end is at C and rest of the rod is beyond C its image is formed with length shorter than the rod. Now if it is shifted towards the mirror eventually when the other end of the rod reaches C and the rod is between C and F its image is formed with lentgh more than that of the rod. There fore in between these situations a case must arrive where the length of the image is same as the length of rod.

It can be checked analytically as follows.

Suppose left end of the rod is placed at a distance x to the left of C and its image is being from on the other end of the rod.



Applying mirror formula :

$$\frac{1}{-(50+x)} + \frac{1}{-(60+x)} = \frac{1}{30}$$

On solving

x = 5.413

63. The mass of an electron can be expressed as
(A) 0.512 MeV (B) 8.19×10^{-14} J/c^2 (C) 9.1×10^{-31} kg (D) 0.00055 amu

Ans. **(BCD)**

Sol. m = 9.1×10^{-31} kg
E = mC^2

64. Select the correct statement(s), out of the following, about diffraction at N parallel slits.
(A) There are (N-1) minima between each pair of principal maxima.
(B) There are (N-2) secondary maxima between each pair of principal maxima
(C) Width of principal maximum is proportional to 1/N
(D) The intensity at the principal maxima varies as N^2

Ans. **(ABCD)**

Sol. for N parallel slits the intensity at an angular position θ is given by

$$I = \left(A\frac{\sin\alpha}{\alpha}\right)^2 \frac{\sin^2 N\beta}{\sin^2\beta}$$

where A = amplitude at slit

$$\alpha = \frac{\pi e}{\lambda}\sin\theta$$

$$\beta = \frac{\delta}{2} = (e + d)\sin\theta\left(\frac{\pi}{\lambda}\right)$$

d = opaque space between slits.
For principal maxima B $\rightarrow$ 0

$\therefore$ I = $\left(A\frac{\sin\alpha}{\alpha}\right)^2 N^2$

$\therefore$ I α N^2

width of principal maxima = $\frac{2\lambda}{a} = \frac{2\lambda}{N(a+e)} \alpha \frac{1}{N}$

a = N(d + e)
Case (i) : Principal maxima: the resultant amplitude will take a maximum value if
sinβ = 0
β = ± n π ; n = 0,1,2,3…..

$\frac{\pi}{\lambda}(e+d)\sin\theta = \pm n\pi$

(e + d) sinθ = ±nλ .....(2.42)

n = 0 corresponds to zero order maximum. For n = 1,2,3... we obtain first second, third,.... principal maxima respectively. The ± sign indicates that there are two principal maxima of the same order lying on either side of zero order maximum.

Case (ii) : Minima Positions : The resultant amplitude takes mimimum value if sin Nβ =0
but sin β ≠ 0

$\therefore$ N β = ± mπ

$n\frac{\pi}{\lambda}(e+d)\sin\theta = \pm m\pi$

N (e + d) sin θ = ± mλ …….(2.43)

Where m has all integral values except m = 0, N, 2N, …., nN, because for these values sin β becomes zero and we get principal maxima. Thus m = 1, 2, 3, …., (N –1).

Hence
N(e + d) sinθ = ± mλ
where m = 1, 2, 3….(N –1), (N + 1), …..(2N –1)…..
gives the minima positions which are adjacent to the principal maxima

Case(iii) : Secondary maxima : As there are (N –1) minima between two adjacent principal maxima there must be (N –2) other maxima between two principal maxima. These are know as secondary maxima. To find their positions

$$\frac{dI}{d\beta} = 0$$

$$\frac{dI}{d\beta} = \left(A\frac{\sin\alpha}{\alpha}\right)^2 2\left(\frac{\sin N\beta}{\sin\beta}\right)\left[\frac{N\cos N\beta\sin\beta - \sin N\beta\cos\beta}{\sin^2\beta}\right] = 0$$

$$\therefore \frac{\sin\alpha}{\alpha} \neq 0; \sin N\beta \neq 0$$

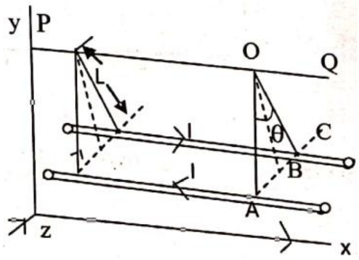
Only
[N cos N βsinβ – sin N βcosβ] = 0
N tanβ = tanNβ ………(2.44)
The roots of the above equation other than those for which β = ± nπ give the positions of secondary maxima.

65. An electric dipole placed in a non-uniform electric field may experience
(A) no net force, no torque
(B) a net force, but no torque
(C) no net force, but a torque
(D) a net force and a torque

Ans. **(ABCD)**

Sol. When a diople is placed along the electric field at a point where the field is symmetric as well as either maximum or minimum.

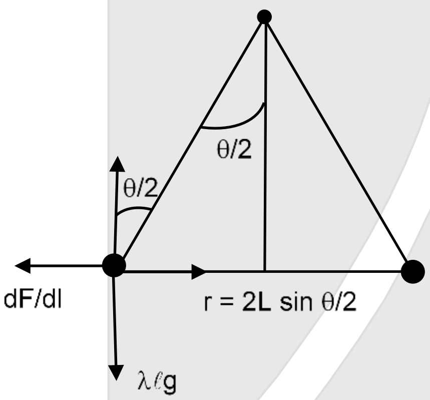
66. Two long parallel wires carry currents of equal magnitude (I) but in opposite directions. These wires are suspended from fixed rod PQ by four chords of equal length L as shown. The mass per unit length of each wire is λ, the value of angle θ subtended by two chords OA and OB, assuming it to be small, is



(A) $\theta = I\sqrt{\frac{\mu_0}{4\pi}\frac{\lambda}{gL}}$ (B) $\theta = I\sqrt{\frac{\mu_0}{\pi}\frac{1}{\lambda gL}}$ (C) $\theta = I\sqrt{\frac{\mu_0}{4\pi}\frac{g}{\lambda L}}$ (D) $\theta = I\sqrt{\frac{\mu_0}{\pi}\frac{\lambda g}{L}}$

Ans. **(B)**

Sol.



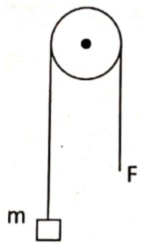
$2T\cos\frac{\theta}{2} = (\lambda l)g$

$2T\sin\frac{\theta}{2} = \frac{\mu_0}{2\pi}\frac{i^2\ell}{r}$

divide

$\theta \approx i\sqrt{\frac{\mu_0}{\pi\lambda g\ell}}$

67. A block of mass m = 10 kg is hanging over a frictionless light fixed pulley by an inextensible light rope. Initially the block is held at rest. The other end of the rope is now pulled by a constant force F in the vertically downward direction. The linear momentum of the block is seen to increase by 2 kgm/s in 1 s (in the first second). Therefore.



(A) the tension in the rope is F
(B) the tension in the rope is 3N
(C) the work done by the tension on the block, in first second, is = 19.8 J
(D) the work done against the force of gravity, in first second, is = 9.8 J

Ans. **(A,D)**

Sol. $\Delta V = \frac{\Delta P}{m} = 0.2\text{ m/s}$

at = 0.2

a = 0.2 m/s^2

$s = \frac{1}{2}at^2 = 0.1\text{ m}$

F – 98 = 10 × 0. 2

F = 100

w_g = – 9.8 J

W.D against gravity

+ 9.8 J

68. A ball of mass m_1 travels horizontally along the x-axis in the positive direction with an initial speed of v_0. It collides with another ball of mass m_2 that is originally at rest. After the collision, the ball of mass m_1 has velocity (v_{1x}i + v_{1y}j) and the ball of mass m_2 has velocity (v_{2x}i + v_{2y}j). Identify the correct relationship(s)

(A) $0 = m_1v_{1x} + m_2v_{2x}$

(B) $m_1v_0 = m_1v_{1y} + m_2v_{2y}$

(C) $0 = m_1v_{1y} + m_2v_{2y}$

(D) $m_1v_0 = m_1v_{1x} + m_2v_{2x}$

Ans. **(C,D)**

Sol. $m_1v_0\hat{i} = m_1\left(v_1x\hat{i} + v_1y\hat{j}\right) + m_2\left(v_2x\hat{i} + v_2y\hat{i}\right)$

$m_1v_1y + m_2v_2y = 0$

& $m_1 v_0 = m_1 v_1x + m_2 v_2 x$

69. In a real gas

(A) the force of attraction between the molecules depends upon intermolecular distance.

(B) internal energy depends only upon temperature.

(C) internal energy is a function of both temperature and volume

(D) internal energy is a function of both temperature and pressure

Ans. **(ACD)**

70. A particle of mass m is thrown vertically up with velocity u. Air exerts an opposing force of a constant magnitude F. The particle returns back to the point of projection with velocity v after attaining maximum height h, then

(A) $h = \frac{u^2}{2\left(g + \frac{F}{m}\right)}$

(B) $h = \frac{v^2}{2\left(g - \frac{F}{m}\right)}$

(C) $v = u\sqrt{\frac{\left(g - \frac{F}{m}\right)}{\left(g + \frac{F}{m}\right)}}$

(D) $v = u\sqrt{\frac{\left(g + \frac{F}{m}\right)}{\left(g - \frac{F}{m}\right)}}$

Ans. **(ABC)**

Sol. During upward motion

$a = \left(g + \frac{F}{m}\right)$

$\therefore\ h = \frac{u^2}{2a} = \frac{u^2}{2(g + F/m)}$

During descent

$a_2 = \left(g - \frac{F}{m}\right)$

$v = \sqrt{2a_2h} = u\sqrt{\frac{g - \frac{F}{m}}{g + \frac{F}{m}}}$

$h = \frac{v^2}{2a_2} = \frac{v^2}{2\left(g - \frac{F}{m}\right)}$