FINAL JEE–MAIN EXAMINATION – APRIL, 2024

(Held On Friday 05th April, 2024) **TIME : 9 : 00 AM to 12 : 00 NOON**

PHYSICS **TEST PAPER WITH SOLUTION**

SECTION-A

31. Light emerges out of a convex lens when a source of light kept at its focus. The shape of wavefront of the light is:

(1) Both spherical and cylindrical

(2) Cylindrical

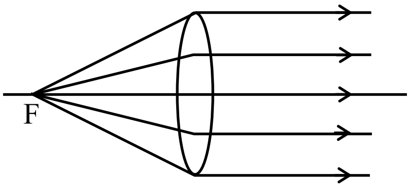
(3) Spherical

(4) Plane

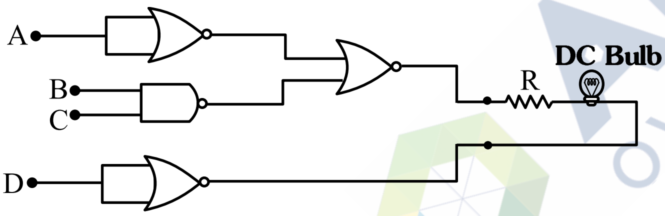
Ans. (4)

Sol. Light emerges parallel

∴ planor wavefront



32. Following gates section is connected in a complete suitable circuit.



For which of the following combination, bulb will glow (ON):

(1) A = 0, B = 1, C = 1, D = 1

(2) A = 1, B = 0, C = 0, D = 0

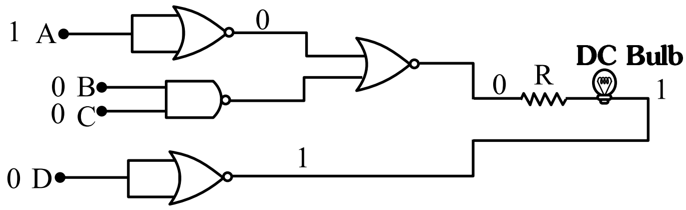
(3) A = 0, B = 0, C = 0, D = 1

(4) A = 1, B = 1, C = 1, D = 0

Ans. (2)

Sol. Bulb will glow if bulb have potential drop on it. One end of bulb must be at high (1) and other must be at low (0).

Option (2) satisfy this condition



33. If G be the gravitational constant and u be the energy density then which of the following quantity have the dimension as that the $\sqrt{uG}$:

(1) Pressure gradient per unit mass

(2) Force per unit mass

(3) Gravitational potential

(4) Energy per unit mass

Ans. (2)

Sol. $[uG] = [(M^1L^{-1}T^{-2})\ (M^{-1}L^3T^{-2})]$

$[uG] = [M^0L^2T^{-4}]$

$[\sqrt{uG}] = [L^1T^{-2}]$

Option (2) is correct

34. Given below are two statements :

Statement-I: When a capillary tube is dipped into a liquid, the liquid neither rises nor falls in the capillary. The contact angle may be 0°.

Statement-II: The contact angle between a solid and a liquid is a property of the material of the solid and liquid as well :

In the light of above statement, choose the **correct** answer from the options given below.

(1) **Statement-I** is false but **Statement-II** is true.

(2) Both **Statement-I** and **Statement-II** are true.

(3) Both **Statement-I** and **Statement-II** are false.

(4) **Statement-I** is true and **Statement-II** is false.

Ans. (1)

Sol. Capillary rise

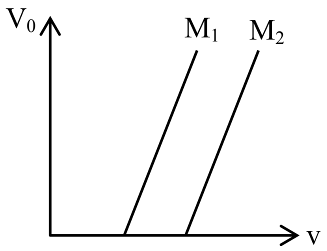
$$h = \frac{2T\cos\theta}{\rho g r};$$

If θ = 0° then rise is non-zero

∴ Statement-1 is incorrect.

Option(1) is correct

35. Given below are two statements:



Statement-I: Figure shows the variation of stopping potential with frequency (ν) for the two photosensitive materials M_1 and M_2. The slope gives value of $\frac{h}{e}$, where h is Planck's constant, e is the charge of electron.

Statement-II: M_2 will emit photoelectrons of greater kinetic energy for the incident radiation having same frequency.

In the light of the above statements, choose the most appropriate answer from the options given below.

(1) **Statement-I** is correct and **Statement-II** is incorrect.

(2) **Statement-I** is incorrect but **Statement-II** is correct.

(3) Both **Statement-I** and **Statement-II** are incorrect.

(4) Both **Statement-I** and **Statement-II** are correct.

Ans. (1)

Sol. $eV_0 = h\nu - \phi$

$$V_0 = \frac{h}{e}\nu - \frac{\phi}{e}$$

M_2 material has higher work function, so statement-(II) is incorrect.

Option (1) is correct.

36. The angle between vector $\vec{Q}$ and the resultant of $(2\vec{Q}+2\vec{P})$ and $(2\vec{Q}-2\vec{P})$ is:

(1) 0°

(2) $\tan^{-1}\frac{(2\vec{Q}-2\vec{P})}{2\vec{Q}+2\vec{P}}$

(3) $\tan^{-1}\left(\frac{P}{Q}\right)$

(4) $\tan^{-1}\left(\frac{2Q}{P}\right)$

Ans. (1)

Sol. $\vec{R} = (2\vec{Q}+2\vec{P}) + (2\vec{Q}-2\vec{P})$

$\vec{R} = 4\vec{Q}$

Angle between $\vec{Q}$ and $\vec{R}$ is zero

Option (1) is correct

37. In hydrogen like system the ratio of coulombian force and gravitational force between an electron and a proton is in the order of:

(1) 10^{39} (2) 10^{19}

(3) 10^{29} (4) 10^{36}

Ans. (1)

Sol. $F_e = \frac{kQ_1Q_2}{r^2} = \frac{9\times10^9\times1.6\times10^{-19}\times1.6\times10^{-19}}{r^2}$

$$F_g = \frac{Gm_1m_2}{r^2} = \frac{6.67\times10^{-11}\times9.1\times10^{-31}\times1.6\times10^{-27}}{r^2}$$

$$\frac{F_e}{F_g} \cong 0.23\times10^{40} \cong 2.3\times10^{39}$$

Option (1)

38. In a co-axial straight cable, the central conductor and the outer conductor carry equal currents in opposite directions. The magnetic field is zero.

(1) inside the outer conductor

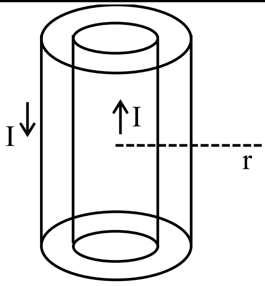
(2) in between the two conductors

(3) outside the cable

(4) inside the inner conductor

Ans. (3)

Sol.



$$\oint \vec{B}.d\vec{\ell} = \mu_0 i_{enc} = 0$$

$\therefore$ B = 0 outside the cable

39. An electron rotates in a circle around a nucleus having positive charge Ze. Correct relation between total energy (E) of electron to its potential energy (U) is:

(1) E = 2U
(2) 2E = 3U
(3) E = U
(4) 2E = U

Ans. (4)

Sol. $F = \frac{k(Ze)(e)}{r^2} = \frac{mv^2}{r}$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}\frac{K(Ze)(e)}{r}$$

$$PE = -\frac{K(Ze)(e)}{r}$$

$$TE = \frac{K(Ze)(e)}{2r} - \frac{K(Ze)(e)}{r} = \frac{-K(Ze)(e)}{2r}$$

$$TE = \frac{PE}{2}$$

2TE = PE

Option (4)

40. If the collision frequency of hydrogen molecules in a closed chamber at 27°C is Z, then the collision frequency of the same system at 127° C is :

(1) $\frac{\sqrt{3}}{2}Z$
(2) $\frac{4}{3}Z$
(3) $\frac{2}{\sqrt{3}}Z$
(4) $\frac{3}{4}Z$

Ans. (3)

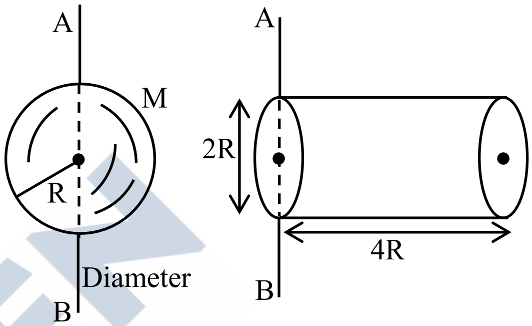
Sol. Assuming mean free path constant.

$$f \propto v \propto \sqrt{T}$$

$$\frac{f_1}{f_2} = \sqrt{\frac{T_1}{T_2}} = \sqrt{\frac{300}{400}}$$

$$f_2 = \sqrt{\frac{4}{3}} = f_1 = \frac{2}{\sqrt{3}}Z$$

41. Ratio of radius of gyration of a hollow sphere to that of a solid cylinder of equal mass, for moment of Inertia about their diameter axis AB as shown in figure is $\sqrt{\frac{8}{x}}$. The value of x is:



(1) 34
(2) 17
(3) 67
(4) 51

Ans. (3)

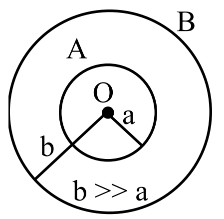
Sol. $I_{sphere} = \frac{2}{3}MR^2 = Mk_1^2$

$$I_{cylinder} = \frac{1}{12}M(4R^2) + \frac{1}{4}MR^2 + M(2R)^2$$

$$= \frac{67}{12}MR^2 = Mk_2^2$$

$$\frac{k_1}{k_2} = \sqrt{\frac{2}{3}.\frac{12}{67}} = \sqrt{\frac{8}{67}}$$

42. Two conducting circular loops A and B are placed in the same plane with their centres coinciding as shown in figure. The mutual inductance between them is:



(1) $\frac{\mu_0 \pi a^2}{2b}$
(2) $\frac{\mu_0}{2\pi}.\frac{b^2}{a}$
(3) $\frac{\mu_0 \pi b^2}{2a}$
(4) $\frac{\mu_0}{2\pi}.\frac{a^2}{b}$

Ans. (1)

Sol. $\phi = Mi = BA$

$$\Rightarrow Mi = \frac{\mu_0 i}{2b}\pi a^2$$

$$\therefore M = \frac{\mu_0 \pi a^2}{2b}$$

43. Match **list-I** with **list-II**:

	List-I		List-II
(A)	Kinetic energy of planet	(I)	$-\frac{GMm}{a}$
(B)	Gravitation Potential energy of Sun-planet system.	(II)	$\frac{GMm}{2a}$
(C)	Total mechanical energy of planet	(III)	$\frac{Gm}{r}$
(D)	Escape energy at the surface of planet for unit mass object	(IV)	$-\frac{GMm}{2a}$

(Where a = radius of planet orbit, r = radius of planet, M = mass of Sun, m = mass of planet)

Choose the correct answer from the options given below:

(1) (A) – II, (B) – I, (C) – IV, (D) – III

(2) (A) – III, (B) – IV, (C) – I, (D) – II

(3) (A) – I, (B) – IV, (C) – II, (D) – III

(4) (A) – I, (B) – II, (C) – III, (D) – IV

Ans. (1)

Sol. $KE = \frac{1}{2}mv^2 = \frac{GMm}{2a}$

$PE = -2KE$

$TE = -KE$

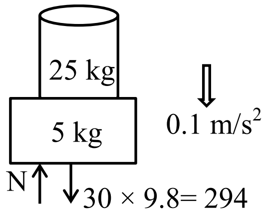
44. A wooden block of mass 5kg rests on soft horizontal floor. When an iron cylinder of mass 25 kg is placed on the top of the block, the floor yields and the block and the cylinder together go down with an acceleration of 0.1 ms^{-2}. The action force of the system on the floor is equal to:

(1) 297 N (2) 294 N

(3) 291 N (4) 196 N

Ans. (3)

Sol. Taking $g = 9.8\ m/s^2$



$294 - N = 30 \times 0.1$

$N = 291$

45. A simple pendulum doing small oscillations at a place R height above earth surface has time period of $T_1 = 4$ s. T_2 would be it's time period if it is brought to a point which is at a height 2R from earth surface. Choose the correct relation [R = radius of Earth]:

(1) $T_1 = T_2$ (2) $2T_1 = 3T_2$

(3) $3T_1 = 2T_2$ (4) $2T_1 = T_2$

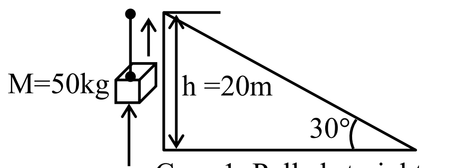
Ans. (3)

Sol. $T_1 = 2\pi\sqrt{\frac{\ell}{GM}(2R)^2}$

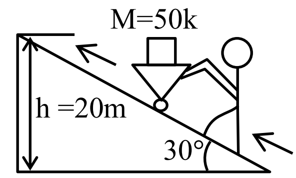
$$T_2 = 2\pi\sqrt{\frac{\ell}{GM}(3R)^2}$$

$$\therefore \frac{T_1}{T_2} = \frac{2}{3}$$

46. A body of mass 50 kg is lifted to a height of 20 m from the ground in the two different ways as shown in the figures. The ratio of work done against the gravity in both the respective cases, will be:



Case-1: Pulled straight up



Case-2: Along the ramp

(1) 1 : 1 (2) 2 : 1

(3) $\sqrt{3} : 2$ (4) 1 : 2

Ans. (1)

Sol. Work done by gravity is independent of path. It depends only on vertical displacement so work done in both cases will be same.

Option (1) is correct

47. Time periods of oscillation of the same simple pendulum measured using four different measuring clocks were recorded as 4.62 s, 4.632 s, 4.6 s and 4.64 s. The arithmetic mean of these reading in correct significant figure is.

(1) 4.623 s (2) 4.62 s

(3) 4.6 s (4) 5 s

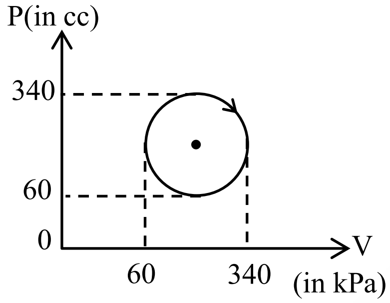
Ans. (3)

Sol. Sum of number by considering significant digit

sum = 4.6 + 4.6 + 4.6 + 4.6 = 18.4

Arithmetic Mean = $\frac{\text{sum}}{4} = \frac{18.4}{4} = 4.6$

48. The heat absorbed by a system in going through the given cyclic process is :



(1) 61.6 J (2) 431.2 J

(3) 616 J (4) 19.6 J

Ans. (1)

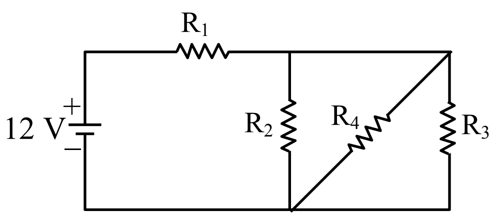
Sol. $\Delta U = 0$ (Cyclic process)

$\Delta Q = W$ = area of P-V curve.

$= \pi \times (140 \times 10^3 \text{ Pa}) \times (140 \times 10^{-6} \text{ m}^3)$

$\Delta Q = 61.6$ J

49. In the given figure $R_1 = 10\Omega$, $R_2 = 8\Omega$, $R_3 = 4\Omega$ and $R_4 = 8\Omega$. Battery is ideal with emf 12V. Equivalent resistant of the circuit and current supplied by battery are respectively.



(1) 12 Ω and 11.4 A (2) 10.5 Ω and 1.14 A

(3) 10.5 Ω and 1 A (4) 12 Ω and 1 A

Ans. (4)

Sol. Here R_2, R_3, R_4 are in parallel

$$\frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$R_{234} = 2\Omega$

R_{234} is in series with R_1 so

$R_{eq} = R_{234} + R_1 = 2 + 10 = 12\Omega$

$$i = \frac{12}{12} = 1\text{Amp}$$

50. An alternating voltage of amplitude 40 V and frequency 4 kHz is applied directly across the capacitor of 12 μF. The maximum displacement current between the plates of the capacitor is nearly:

(1) 13 A (2) 8 A

(3) 10 A (4) 12 A

Ans. (4)

Sol. Displacement current is same as conduction current in capacitor.

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$= \frac{1}{2\pi \times 4 \times 10^3 \times 12 \times 10^{-6}} = 3.317\Omega$$

$$I = \frac{V}{X_C} = \frac{40}{3.317} = 12\text{A}$$

SECTION-B

51. In Young's double slit experiment, carried out with light of wavelength 5000Å, the distance between the slits is 0.3 mm and the screen is at 200 cm from the slits. The central maximum is at x = 0 cm. The value of x for third maxima is .... mm.

Ans. (10)

Sol. $$\beta = \frac{\lambda D}{d} = \frac{5 \times 10^{-7} \times 2}{3 \times 10^{-4}} = \frac{10 \times 10^{-3}}{3} \text{ m}$$

For 3rd maxima $y_3 = 3\beta = 10 \times 10^{-3}$ m = 10 mm

52. A 2A current carrying straight metal wire of resistance 1 Ω, resistivity 2×10^{-6} Ωm, area of cross-section 10 mm^2 and mass 500 g is suspended horizontally in mid air by applying a uniform magnetic field $\vec{B}$. The magnitude of B is .... $\times 10^{-1}$ T (given, g = 10 m/s^2)

Ans. (5)

Sol. $R = \frac{\rho\ell}{A} \Rightarrow \frac{2\times10^{-6}\times\ell}{10^{-5}} = 1 \;\Rightarrow \ell = 5$

$mg = Bi\ell$

$B = \frac{mg}{i\ell} = \frac{5}{2\times5} = 0.5 = 5\times10^{-1}$ Tesla

53. The electric field between the two parallel plates of a capacitor of 1.5 μF capacitance drops to one third of its initial value in 6.6 μs when the plates are connected by a thin wire. The resistance of this wire is .... Ω. (Given, log 3 = 1.1)

Ans. (4)

Sol. $E = \frac{E_0}{3} \Rightarrow V = \frac{V_0}{3}$

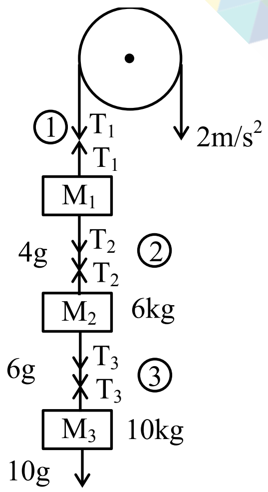
$\frac{V_0}{3} = V_0 e^{-\frac{t}{\tau}}$

$t = \tau \ell n 3$

$6.6\times10^{-6} = R\,(1.5\times10^{-6})(1.1)$

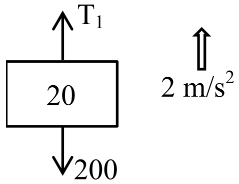
$R = \frac{6}{1.5} = 4\Omega$

54. Three blocks M_1, M_2, M_3 having masses 4 kg, 6 kg and 10 kg respectively are hanging from a smooth pully using rope 1, 2 and 3 as shown in figure. The tension in the rope 1, T_1 when they are moving upward with acceleration of $2ms^{-2}$ is .... N (if $g = 10\ m/s^2$)



Ans. (240)

Sol. FBD of M_1 :



$T_1 - 200 = (4 + 6 + 10)\times 2$

$\therefore T_1 = 240$

55. The density and breaking stress of a wire are $6\times10^4\ kg/m^3$ and $1.2\times10^8\ N/m^2$ respectively. The wire is suspended from a rigid support on a planet where acceleration due to gravity is $\frac{1^{rd}}{3}$ of the value on the surface of earth. The maximum length of the wire with breaking is .... m (take, $g = 10\ m/s^2$)

Ans. (600)

Sol.

$T = mg$

$\sigma = \frac{T}{A} = \frac{mg}{A}$

$\frac{(\sigma A\ell)g}{A}$

$\Rightarrow \ell = \frac{\sigma}{\rho g} = \frac{1.2\times10^8\times3}{6\times10^4\times10} = 600$

56. A body moves on a frictionless plane starting from rest. If S_n is distance moved between $t = n - 1$ and $t = n$ and S_{n-1} is distance moved between $t = n - 2$ and $t = n - 1$, then the ratio $\frac{S_{n-1}}{S_n}$ is $\left(1 - \frac{2}{x}\right)$ for $n = 10$. The value of x is ....

Ans. (19)

Sol. $S_n = \frac{1}{2}a(2n-1) = \frac{19a}{2}$

$S_{n-1} = \frac{1}{2}a(2n-3) = \frac{17a}{2}$

$\frac{S_{n-1}}{S_n} = \frac{17}{19} = 1 - \frac{2}{x} \Rightarrow x = 19$

57. If three helium nuclei combine to form a carbon nucleus then the energy released in this reaction is .... $\times 10^{-2}$ MeV. (Given 1 u = 931 MeV/c^2, atomic mass of helium = 4.002603 u)

Ans. (727)

Sol. Reaction :

$3\,{}_2^4He \longrightarrow {}_6^{12}C + \gamma$ rays

Mass defect = $\Delta m = (3m_{He} - m_C)$

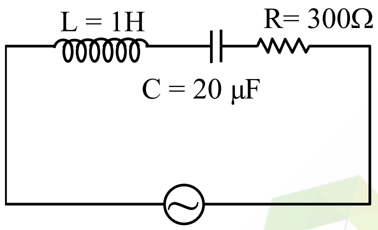
= (3 × 4.002603 – 12) = 0.007809 u

Energy released

= 931 Δm MeV

= 7.27 MeV = 727×10^{-2} MeV

58. An ac source is connected in given series LCR circuit. The rms potential difference across the capacitor of 20 μF is .... V.



Ans. (50)

Sol. $X_L = \omega L = 100 \times 1 = 100\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{100 \times 20 \times 10^{-6}} = 500\Omega$

$Z = \sqrt{(X_L - X_C)^2 + R^2}$

$\sqrt{(100-500)^2 + 300^2}$

Z = 500Ω

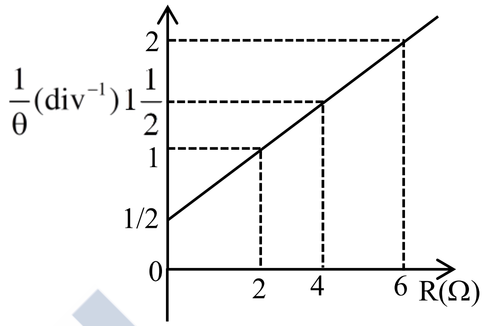
$i_{rms} = \frac{V_{rms}}{Z} = \frac{50}{500} = 0.1A$

rms voltage across capacitor

$V_{rms} = X_C\, i_{rms}$

=500 × 0.1 = 50V

59. In the experiment to determine the galvanometer resistance by half-deflection method, the plot of $\frac{1}{\theta}$ vs the resistance (R) of the resistance box is shown in the figure. The figure of merit of the galvanometer is .... $\times 10^{-1}$ A/division. [The source has emf 2V]



Ans. (5)

Sol. $i = K\theta$

$\frac{2}{G+R} = K\theta$

$\Rightarrow \frac{1}{\theta} = \frac{(G+R)K}{2} = R\left(\frac{K}{2}\right) + \frac{KG}{2}$

Slope = $\frac{K}{2} = \frac{1}{4} \Rightarrow K = 0.5 = 5 \times 10^{-1}$ A

60. Three capacitors of capacitances 25 μF, 30 μF and 45 μF are connected in parallel to a supply of 100 V. Energy stored in the above combination is E. When these capacitors are connected in series to the same supply, the stored energy is $\frac{9}{x}E$. The value of x is ....

Ans. (86)

Sol. In parallel combination : Potential difference is same across all

Energy = $\frac{1}{2}(C_1 + C_2 + C_3)V^2$

$= \frac{1}{2}(25+30+45) \times (100)^2 \times 10^{-6} = 0.5 = E$

In series combination: Charge is same on all.

$$\frac{1}{C_{equ}}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}=\frac{1}{25}+\frac{1}{30}+\frac{1}{45}$$

$$\frac{1}{C_{equ}}=\frac{(18+15+10)}{450}=\frac{43}{450}\ \Rightarrow C_{equ}=\frac{450}{43}$$

$$\text{Energy}=\frac{Q^2}{2C_1}+\frac{Q^2}{2C_2}+\frac{Q^2}{2C_3}$$

$$=\frac{Q^2}{2}\left[\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}\right]$$

$$\frac{(V\times C_{equ})^2}{2}\times\frac{1}{C_{equ}}=\frac{V^2C_{equ}}{2}$$

$$\frac{(100)^2}{2}\times\frac{450}{43}\times10^{-6}$$

$$\Rightarrow\frac{4.5}{86}=\frac{9}{x}E=\frac{9}{x}\times0.5\Rightarrow x=86$$