FINAL JEE–MAIN EXAMINATION – MARCH, 2021

(Held On Wednesday 17th March, 2021) TIME : 3 : 00 PM to 6 : 00 PM

PHYSICS — TEST PAPER WITH ANSWER & SOLUTION

SECTION-A

1. A rubber ball is released from a height of 5 m above the floor. It bounces back repeatedly, always rising to $\frac{81}{100}$ of the height through which it falls. Find the average speed of the ball. (Take $g = 10\ ms^{-2}$)

(1) $3.0\ ms^{-1}$ (2) $3.50\ ms^{-1}$
(3) $2.0\ ms^{-1}$ (4) $2.50\ ms^{-1}$

Official Ans. by NTA (4)

Sol. (4) $v_0 = \sqrt{2gh}$

$v = e\sqrt{2gh} = \sqrt{2gh}$

$\Rightarrow e = 0.9$

$S = h + 2e^2h + 2e^4\ h + ...$

$$t = \sqrt{\frac{2h}{g}} + 2e\sqrt{\frac{2h}{g}} + 2e^2\sqrt{\frac{2h}{g}} + ...$$

$$v_{av} = \frac{s}{t} = 2.5\ m/s$$

2. If one mole of the polyatomic gas is having two vibrational modes and β is the ratio of molar specific heats for polyatomic gas $\left(\beta = \frac{C_P}{C_V}\right)$ then the value of β is :

(1) 1.02 (2) 1.2
(3) 1.25 (4) 1.35

Official Ans. by NTA (2)

Sol. (2) $f = 4 + 3 + 3 = 10$

assuming non linear

$$\beta = \frac{C_p}{C_v} = 1 + \frac{2}{f} = \frac{12}{10} = 1.2$$

3. A block of mass 1 kg attached to a spring is made to oscillate with an initial amplitude of 12 cm. After 2 minutes the amplitude decreases to 6 cm. Determine the value of the damping constant for this motion. (take In 2 = 0.693)

(1) $0.69 \times 10^2\ kg\ s^{-1}$ (2) $3.3 \times 10^2\ kg\ s^{-1}$
(3) $1.16 \times 10^2\ kg\ s^{-1}$ (4) $5.7 \times 10^{-3}\ kg\ s^{-1}$

Official Ans. by NTA (NA)

Official Ans. by ALLEN (Bonus)

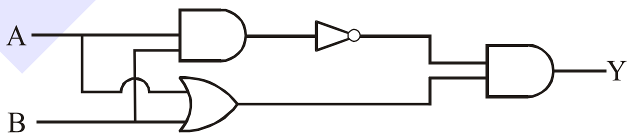
Sol. $A = A_0 e^{-\gamma t}$

$$\ln 2 = \frac{b}{2m} \times 120$$

$$\frac{0.693 \times 2 \times 1}{120} = b$$

1.16×10^{-2} kg/sec.

4. Which one of the following will be the output of the given circuit ?



(1) NOR Gate (2) NAND Gate
(3) AND Gate (4) XOR Gate

Official Ans. by NTA (4)

Sol. (4) Conceptual

5. An object is located at 2 km beneath the surface of the water. If the fractional compression $\frac{\Delta V}{V}$ is 1.36% , the ratio of hydraulic stress to the corresponding hydraulic strain will be ___________.

[Given : density of water is $1000\ kg\ m^{-3}$ and $g = 9.8\ ms^{-2}$.]

(1) $1.96 \times 10^7\ Nm^{-2}$ (2) $1.44 \times 10^7\ Nm^{-2}$
(3) $2.26 \times 10^9\ Nm^{-2}$ (4) $1.44 \times 10^9\ Nm^{-2}$

Official Ans. by NTA (4)

Sol. (4) $P = h\rho g$

$$\beta = \frac{p}{\frac{\Delta V}{V}} = \frac{2\times10^3\times10^3\times9.8}{1.36\times10^{-2}}$$

$= 1.44 \times 10^9\ \ N/m^2$

6. A geostationary satellite is orbiting around an arbitary planet 'P' at a height of 11R above the surface of 'P' , R being the radius of 'P'. The time period of another satellite in hours at a height of 2R from the surface of 'P' is_________.'P' has the time period of 24 hours.

(1) $6\sqrt{2}$ (2) $\frac{6}{\sqrt{2}}$ (3) 3 (4) 5

Official Ans. by NTA (3)

Sol. (3) $T \propto R^{3/2}$

$$\frac{24}{T} = \left(\frac{12R}{3R}\right)^{3/2} \Rightarrow T = 3hr$$

7. A sound wave of frequency 245 Hz travels with the speed of 300 ms^{-1} along the positive x-axis. Each point of the wave moves to and fro through a total distance of 6 cm. What will be the mathematical expression of this travelling wave ?

(1) $Y(x,t) = 0.03\ [\sin 5.1\ x - (0.2 \times 10^3)t]$

(2) $Y(x,t) = 0.06\ [\sin 5.1\ x - (1.5 \times 10^3)t]$

(3) $Y(x,t) = 0.06\ [\sin 0.8\ x - (0.5 \times 10^3)t]$

(4) $Y(x,t) = 0.03\ [\sin 5.1\ x - (1.5 \times 10^3)t]$

Official Ans. by NTA (4)

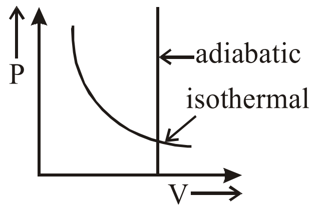
Sol. (4) $\omega = 2\pi f$

$= 1.5 \times 10^3$

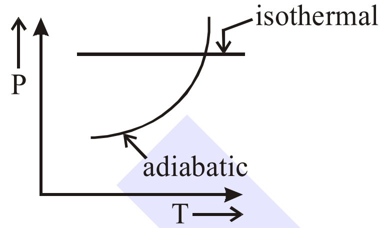
$A = \frac{6}{2} = 3\text{ cm} = 0.03\text{ m}$

8. Which one is the correct option for the two different thermodynamic processes ?

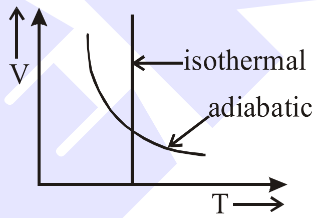
(a)



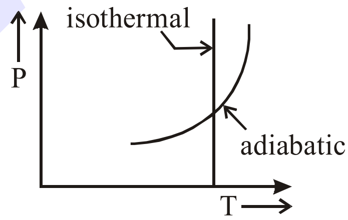
(b)



(c)



(d)



(1) (c) and (a) (2) (c) and (d)

(3) (a) only (4) (b) and (c)

Official Ans. by NTA (2)

Sol. (2) Option (a) is wrong ; since in adiabatic process $V \neq$ constant.

Option (b) is wrong, since in isothermal process T = constant

Option (c) & (d) matches isothermes & adiabatic formula :

$TV^{\gamma-1}$= constant & $\frac{T^{\gamma}}{P^{\gamma-1}}$ = constant

9. The velocity of a particle is $v = v_0 + gt + Ft^2$. Its position is $x = 0$ at $t = 0$; then its displacement after time $(t = 1)$ is :

(1) $v_0 + g + F$ (2) $v_0 + \frac{g}{2} + \frac{F}{3}$

(3) $v_0 + \frac{g}{2} + F$ (4) $v_0 + 2g + 3F$

Official Ans. by NTA (2)

Sol. (2) $v = v_0 + gt + Ft^2$

$$\frac{ds}{dt} = v_0 + gt + Ft^2$$

$$\int ds = \int_0^1 (v_0 + gt + Ft^2)dt$$

$$s = \left[v_0 t + \frac{gt^2}{2} + \frac{Ft^3}{3}\right]_0^1$$

$$s = v_0 + \frac{g}{2} + \frac{F}{3}$$

10. A carrier signal $C(t) = 25 \sin (2.512 \times 10^{10} t)$ is amplitude modulated by a message signal $m(t) = 5 \sin (1.57 \times 10^8 t)$ and transmitted through an antenna. What will be the bandwidth of the modulated signal ?

(1) 8 GHz

(2) 2.01 GHz

(3) 1987.5 MHz

(4) 50 MHz

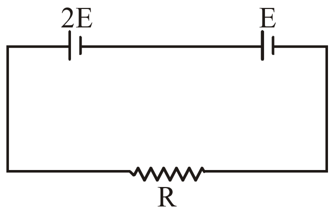
Official Ans. by NTA (4)

Sol. (4) Band width = $2 f_m$

$\omega_m = 1.57 \times 10^8 = 2\pi f_m$

$$BW = 2f_m = \frac{10^8}{2} Hz = 50 \text{ MHz}$$

11. Two cells of emf 2E and E with internal resistance r_1 and r_2 respectively are connected in series to an external resistor R (see figure). The value of R, at which the potential difference across the terminals of the first cell becomes zero is

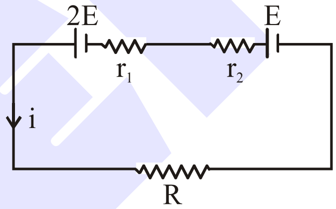


(1) $r_1 + r_2$ (2) $\frac{r_1}{2} - r_2$

(3) $\frac{r_1}{2} + r_2$ (4) $r_1 - r_2$

Official Ans. by NTA (2)

Sol. (2)



$$i = \frac{3E}{R + r_1 + r_2}$$

TPD = $2E - ir_1 = 0$

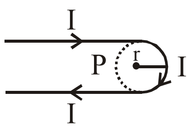
$2E = ir_1$

$$2E = \frac{3E \times r_1}{R + r_1 + r_2}$$

$2R + 2r_1 + 2r_2 = 3r_1$

$$R = \frac{r_1}{2} - r_2$$

12. A hairpin like shape as shown in figure is made by bending a long current carrying wire. What is the magnitude of a magnetic field at point P which lies on the centre of the semicircle ?



(1) $\frac{\mu_0 I}{4\pi r}(2 - \pi)$ (2) $\frac{\mu_0 I}{4\pi r}(2 + \pi)$

(3) $\frac{\mu_0 I}{2\pi r}(2 + \pi)$ (4) $\frac{\mu_0 I}{2\pi r}(2 - \pi)$

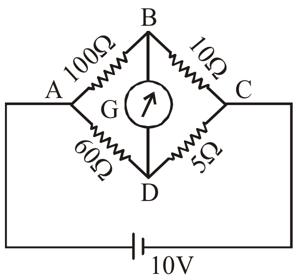
Official Ans. by NTA (2)

Sol. (2) $B = 2 \times B_{st.wire} + B_{loop}$

$$B = 2 \times \frac{\mu_0 i}{4\pi r} + \frac{\mu_0 i}{2r}\left(\frac{\pi}{2\pi}\right)$$

$$B = \frac{\mu_0 i}{4\pi r}(2+\pi)$$

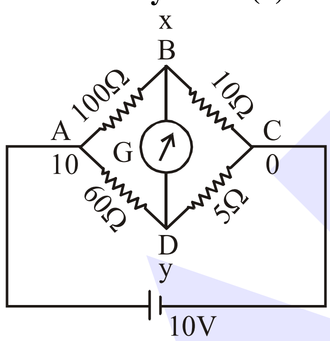
13. The four arms of a Wheatstone bridge have resistances as shown in the figure. A galvanometer of 15 Ω resistance is connected across BD. Calculate the current through the galvanometer when a potential difference of 10V is maintained across AC.



(1) 2.44 μA (2) 2.44 mA
(3) 4.87 mA (4) 4.87 μA

Official Ans. by NTA (3)

Sol. (3)



$$\frac{x-10}{100} + \frac{x-y}{15} + \frac{x-0}{10} = 0$$

$53x - 20y = 30$ .....(1)

$$\frac{y-10}{60} + \frac{y-x}{15} + \frac{y-0}{5} = 0$$

$17y - 4x = 10$ ......(2)

on solving (1) & (2)

$x = 0.865$

$y = 0.792$

$\Delta V = 0.073$ $R = 15\Omega$

$i = 4.87$ mA

14. Two particles A and B of equal masses are suspended from two massless springs of spring constants K_1 and K_2 respectively. If the maximum velocities during oscillations are equal, the ratio of the amplitude of A and B is

(1) $\frac{K_2}{K_1}$ (2) $\frac{K_1}{K_2}$ (3) $\sqrt{\frac{K_1}{K_2}}$ (4) $\sqrt{\frac{K_2}{K_1}}$

Official Ans. by NTA (4)

Sol. (4) $A_1\omega_1 = A_2\omega_2$

$$A_1\sqrt{\frac{k_1}{m}} = A_2\sqrt{\frac{k_2}{m}}$$

$$\frac{A_1}{A_2} = \sqrt{\frac{k_2}{k_1}}$$

15. Match List-I with List-II

List-I	**List-II**
(a) Phase difference between current and voltage in a purely resistive AC circuit	(i) $\frac{\pi}{2}$; current leads voltage
(b) Phase difference between current and voltage in a pure inductive AC circuit	(ii) zero
(c) Phase difference between current and voltage in a pure capacitive AC circuit	(iii) $\frac{\pi}{2}$; current lags voltage
(d) Phase difference between current and voltage in an LCR series circuit	(iv) $\tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

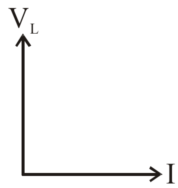
Choose the most appropriate answer from the options given below :

(1) (a)–(i),(b)–(iii),(c)–(iv),(d)–(ii)
(2) (a)–(ii),(b)–(iv),(c)–(iii),(d)–(i)
(3) (a)–(ii),(b)–(iii),(c)–(iv),(d)–(i)
(4) (a)–(ii),(b)–(iii),(c)–(i),(d)–(iv)

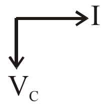
Official Ans. by NTA (4)

Sol. (4) (a)

(b)

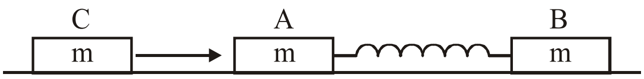


(c)



(d) $\tan\phi = \dfrac{V_L - V_C}{V_R} = \dfrac{X_L - X_C}{R}$

16. Two identical blocks A and B each of mass m resting on the smooth horizontal floor are connected by a light spring of natural length L and spring constant K. A third block C of mass m moving with a speed v along the line joining A and B collides with A. The maximum compression in the spring is



(1) $v\sqrt{\dfrac{M}{2K}}$ (2) $\sqrt{\dfrac{mv}{2K}}$

(3) $\sqrt{\dfrac{mv}{K}}$ (4) $\sqrt{\dfrac{m}{2K}}$

Official Ans. by NTA (1)

Sol. (1) C comes to rest

V_{cm} of A & B = $\dfrac{v}{2}$

$\Rightarrow \dfrac{1}{2}$ is $v_{ret}^2 = \dfrac{1}{2}kx^2$

$x = \sqrt{\dfrac{\mu \times v^2}{k}} = \sqrt{\dfrac{m}{2k}}v$

17. The atomic hydrogen emits a line spectrum consisting of various series. Which series of hydrogen atomic spectra is lying in the visible region ?

(1) Brackett series (2) Paschen series

(3) Lyman series (4) Balmer series

Official Ans. by NTA (4)

Sol. (4) Conceptual

18. Two identical photocathodes receive the light of frequencies f_1 and f_2 respectively. If the velocities of the photo-electrons coming out are v_1 and v_2 respectively, then

(1) $v_1^2 - v_2^2 = \dfrac{2h}{m}[f_1 - f_2]$

(2) $v_1^2 + v_2^2 = \dfrac{2h}{m}[f_1 + f_2]$

(3) $v_1 + v_2 = \left[\dfrac{2h}{m}(f_1 + f_2)\right]^{\frac{1}{2}}$

(4) $v_1 - v_2 = \left[\dfrac{2h}{m}(f_1 - f_2)\right]^{1/2}$

Official Ans. by NTA (1)

Sol. (1) $\dfrac{1}{2}mv_1^2 = hf_1 - \phi$

$\dfrac{1}{2}mv_2^2 = hf_2 - \phi$

$v_1^2 - v_2^2 = \dfrac{2h}{m}(f_1 - f_2)$

19. What happens to the inductive reactance and the current in a purely inductive circuit if the frequency is halved ?

(1) Both, inductive reactance and current will be halved.

(2) Inductive reactance will be halved and current will be doubled.

(3) Inductive reactance will be doubled and current will be halved.

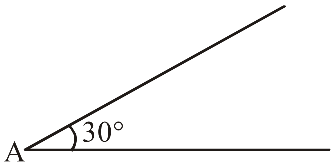
(4) Both, inducting reactance and current will be doubled.

Official Ans. by NTA (2)

Sol. (2) $X_L = \omega L$

$i = \dfrac{V_0}{\omega L}$

20. A sphere of mass 2kg and radius 0.5 m is rolling with an initial speed of 1 ms^{-1} goes up an inclined plane which makes an angle of 30° with the horizontal plane, without slipping. How low will the sphere take to return to the starting point A ?



(1) 0.60 s (2) 0.52 s
(3) 0.57 s (4) 0.80 s

Official Ans. by NTA (3)

Sol. (3) $a = \dfrac{g\sin\theta}{1+\dfrac{I}{mR^2}} = \dfrac{5}{7}\times\dfrac{10}{2} = \dfrac{25}{7}$

$t = \dfrac{2v_0}{a} = \dfrac{2\times1\times7}{25}$

$= 0.56$

SECTION-B

1. The electric field intensity produced by the radiation coming from a 100 W bulb at a distance of 3m is E. The electric field intensity produced by the radiation coming from 60 W at the same distance is $\sqrt{\dfrac{x}{5}}E$. Where the value of x =_________.

Official Ans. by NTA (3)

Sol. $c\in_0 E^2 = \dfrac{100}{4\pi\times3^2}$

$c\in_0\left(\sqrt{\dfrac{x}{5}}E\right)^2 = \dfrac{60}{4\pi\times3^2}$

$\Rightarrow \dfrac{x}{5} = \dfrac{3}{5}$

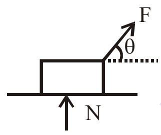
$\Rightarrow x = 3$

2. A body of mass 1 kg rests on a horizontal floor with which it has a coefficient of static friction $\dfrac{1}{\sqrt{3}}$. It is desired to make the body move by applying the minimum possible force F N. The value of F will be __________. (Round off to the Nearest Integer)

[Take g = 10 ms^{-2}]

Official Ans. by NTA (5)

Sol.



$F\cos\theta = \mu N$

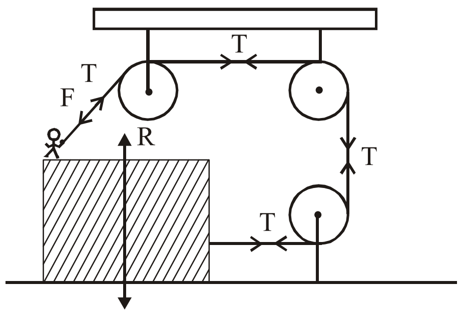
$F\sin\theta + N = mg$

$\Rightarrow F = \dfrac{\mu mg}{\cos\theta + \mu\sin\theta}$

$F_{min} = \dfrac{\mu mg}{\sqrt{1+\mu^2}} = \dfrac{\dfrac{1}{\sqrt{3}}\times10}{\dfrac{2}{\sqrt{3}}} = 5$

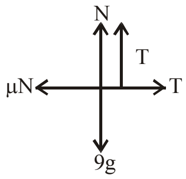
3. A boy of mass 4 kg is standing on a piece of wood having mass 5kg . If the coefficient of friction between the wood and the floor is 0.5, the maximum force that the boy can exert on the rope so that the piece of wood does not move from its place is ________N.(Round off to the Nearest Integer)

[Take g = 10 ms^{-2}]



Official Ans. by NTA (30)

Sol.



$N + T = 90$

$T = \mu N = 0.5\,(90 - T)$

$1.5\,T = 45$

$T = 30$

4. Suppose you have taken a dilute solution of oleic acid in such a way that its concentration becomes 0.01 cm^3 of oleic acid per cm^3 of the solution. Then you make a thin film of this solution (monomolecular thickness) of area 4 cm^2 by considering 100 spherical drops of radius $\left(\frac{3}{40\pi}\right)^{\frac{1}{3}} \times 10^{-3}$ cm. Then the thickness of oleic acid layer will be $x \times 10^{-14}$ m.

Where x is__________.

Official Ans. by NTA (25)

Sol. $4t_T = 100 \times \frac{4}{3}\pi r^3$

$= 100 \times \frac{4\pi}{3} \times \frac{3}{40\pi} \times 10^{-9} = 10^{-8}\ cm^3$

$t_T = 25 \times 10^{-10}$ cm

$= 25 \times 10^{-12}$ m

$t_0 = 0.01\ t_T = 25 \times 10^{-14}$ m

$= 25$

5. A particle of mass m moves in a circular orbit in a central potential field $U(r) = U_0 r^4$. If Bohr's quantization conditions are applied, radii of possible orbitals r_n vary with $n^{1/\alpha}$, where α is____________.

Official Ans. by NTA (3)

Sol. $F = \frac{-dU}{dr} = -4U_0 r^3 = \frac{mv^2}{r}$

$mv^2 = 4U_0 r^4$

$v \propto r^2$

$mvr = \frac{nh}{2\pi}$

$r^3 \propto n$

$r \propto n1/3$

$= 3$

6. The electric field in a region is given by $\vec{E} = \frac{2}{5}E_0\hat{i} + \frac{3}{5}E_0\hat{j}$ with $E_0 = 4.0 \times 10^3\ \frac{N}{C}$. The flux of this field through a rectangular surface area 0.4 m^2 parallel to the Y – Z plane is _________Nm^2C^{-1}.

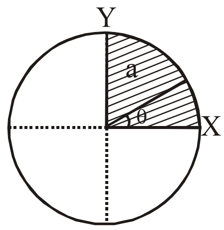
Official Ans. by NTA (640)

Sol. $\phi = E_x A \Rightarrow \frac{2}{5} \times 4 \times 10^3 \times 0.4 = 640$

7. The disc of mass M with uniform surface mass density σ is shown in the figure. The centre of mass of the quarter disc (the shaded area) is at the position $\frac{x}{3}\frac{a}{\pi}, \frac{x}{3}\frac{a}{\pi}$ where x is ________.

(Round off to the Nearest Integer)

[a is an area as shown in the figure]



Official Ans. by NTA (4)

Sol. C.O.M of quarter disc is at $\frac{4a}{3\pi}, \frac{4a}{3\pi}$

$= 4$

8. The image of an object placed in air formed by a convex refracting surface is at a distance of 10 m behind the surface. The image is real and is at $\frac{2^{rd}}{3}$ of the distance of the object from the surface .The wavelength of light inside the surface is $\frac{2}{3}$ times the wavelength in air. The radius of the curved surface is $\frac{x}{13}$ m. the value of 'x' is__________.

Official Ans. by NTA (30)

Sol. $\lambda_m = \frac{\lambda_a}{\mu} \Rightarrow \mu = \frac{3}{2}$

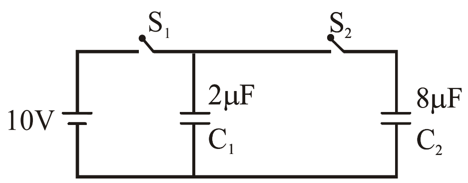
$$\frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{R}$$

$$\frac{3}{2 \times 10} + \frac{1}{15} = \frac{\frac{3}{2} - 1}{R}$$

$$R = \frac{30}{13}$$

$= 30$

9. A 2 μF capacitor C_1 is first charged to a potential difference of 10 V using a battery.Then the battery is removed and the capacitor is connected to an uncharged capacitor C_2 of 8μF. The charge in C_2 on equilibrium condition is_______μC. (Round off to the Nearest Integer)



Official Ans. by NTA (16)

Sol. $20 = (C_1 + C_2)\,V \Rightarrow V = 2$ volt.

$Q_2 = C_2 V = 16\mu C$

$= 16$

10. Seawater at a frequency f = 9 × 10^2 Hz, has permittivity $\varepsilon = 80\varepsilon_0$ and resistivity $\rho = 0.25\ \Omega$m. Imagine a parallel plate capacitor is immersed in seawater and is driven by an alternating voltage source $V(t) = V_0 \sin(2\pi ft)$. Then the conduction current density becomes 10^x times the displacement current density after time $t = \frac{1}{800}$ s. The value of x is ________

$$\left(\text{Given} : \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\,Nm^2C^{-2}\right)$$

Official Ans. by NTA (6)

Sol. $J_c = \frac{E}{\rho} = \frac{V}{\rho d}$

$$J_d = \frac{1}{A}\frac{dq}{dt}$$

$$= \frac{C}{A}\frac{dV_c}{dt}$$

$$= \frac{\in}{d}\frac{dV_c}{dt}$$

$$\Rightarrow \frac{V_0 \sin 2\pi ft}{\rho d} = 10^x \times \frac{80\varepsilon_0}{d} V_0 (2\pi f) \cos 2\pi ft$$

$$\tan\left(2\pi \times \frac{900}{800}\right) = 10^x \times \frac{40}{9 \times 10^9} \times 900$$

$= x = 6$