Strictly Confidential: (For Internal and Restricted use only)
Secondary School Examination September-2021
Marking Scheme – SUBJECT: PHYSICS THEORY (042)
CODE: 55/1/1

General Instructions: -

1. You are aware that evaluation is the most important process in the actual and correct assessment of the candidates. A small mistake in evaluation may lead to serious problems which may affect the future of the candidates, education system and teaching profession. To avoid mistakes, it is requested that before starting evaluation, you must read and understand the spot evaluation guidelines carefully. **Evaluation is a timed mission for all of us. Hence, it is necessary that you put in your best efforts in this process**
2. **"Evaluation policy is a confidential policy as it is related to the confidentiality of the examinations conducted, Evaluation done and several other aspects. Its' leakage to public in any manner could lead to derailment of the examination system and affect the life and future of millions of candidates. Sharing this policy/document to anyone, publishing in any magazine and printing in News Paper/Website etc may invite action under IPC."**
3. Evaluation is to be done as per instructions provided in the Marking Scheme. It should not be done according to one's own interpretation or any other consideration. Marking Scheme should be strictly adhered to and religiously followed. **However, while evaluating, answers which are based on latest information or knowledge and/or are innovative, they may be assessed for their correctness otherwise and marks be awarded to them**
4. The Head-Examiner must go through the first five answer books evaluated by each evaluator on the first day, to ensure that evaluation has been carried out as per the instructions given in the Marking Scheme. The remaining answer books meant for evaluation shall be given only after ensuring that there is no significant variation in the marking of individual evaluators.
5. If a question has parts, please award marks on the right-hand side for each part. Marks awarded for different parts of the question should then be totaled up and written in the left-hand margin and encircled.
6. Evaluators will mark(√) wherever answer is correct. For wrong answer 'X' be marked. Evaluators will not put right kind of mark while evaluating which gives an impression that answer is correct and no marks are awarded. **This is most common mistake which evaluators are committing.**
7. If a question does not have any parts, marks must be awarded in the left-hand margin and encircled.
8. If a student has attempted an extra question, answer of the question deserving more marks should be retained and the other answer scored out.
9. No marks to be deducted for the cumulative effect of an error. It should be penalized only once.
10. A full scale of marks 70 (example 0-70) has to be used. Please do not hesitate to award full marks if the answer deserves it.
11. Every examiner has to necessarily do evaluation work for full working hours i.e. 8 hours every day and evaluate 20 answer books per day in main subjects and 25 answer books per day in other subjects (Details are given in Spot Guidelines).
12. Ensure that you do not make the following common types of errors committed by the Examiner in the past:-
   - Leaving answer or part thereof unassessed in an answer book.
   - Giving more marks for an answer than assigned to it.

- Wrong transfer of marks from the inside pages of the answer book to the title page.
- Wrong question wise totaling on the title page.
- Wrong totaling of marks of the two columns on the title page.
- Wrong grand total.
- Marks in words and figures not tallying.
- Wrong transfer of marks from the answer book to online award list.
- Answers marked as correct, but marks not awarded. (Ensure that the right tick mark is correctly and clearly indicated. It should merely be a line. Same is with the X for incorrect answer.)
- Half or a part of answer marked correct and the rest as wrong, but no marks awarded.

13. While evaluating the answer books if the answer is found to be totally incorrect, it should be marked as cross (X) and awarded zero (0)Marks.

14. Any unassessed portion, non-carrying over of marks to the title page, or totaling error detected by the candidate shall damage the prestige of all the personnel engaged in the evaluation work as also of the Board. Hence, in order to uphold the prestige of all concerned, it is again reiterated that the instructions be followed meticulously and judiciously.

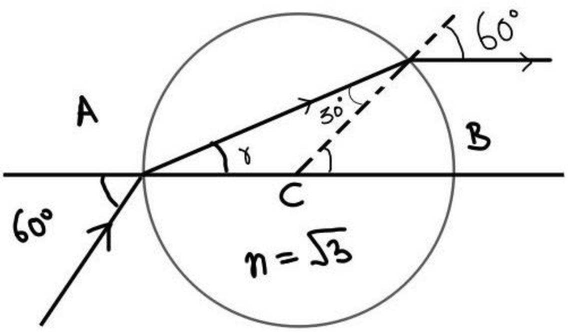
15. The Examiners should acquaint themselves with the guidelines given in the Guidelines for spot Evaluation before starting the actual evaluation.

16. Every Examiner shall also ensure that all the answers are evaluated, marks carried over to the title page, correctly totaled and written in figures and words.

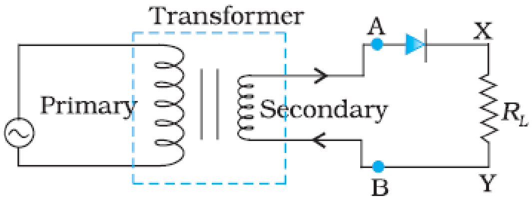
17. The Board permits candidates to obtain photocopy of the Answer Book on request in an RTI application and also separately as a part of the re-evaluation process on payment of the processing charges.

Marking Scheme: Physics (042)			
Code :55/1/1			
Q.No.	**VALUE POINTS/ EXPECTED ANSWERS**	**Marks**	**Total Marks**
	SECTION- A **All questions are compulsory. In case of internal choices, attempt any one of them.**		
1.	$\frac{Jx}{Jy}=1:1$ (Note: Award ½ mark if a student just writes formula $J = \frac{I}{A}$)		1
2.	Image moves away with increasing speed from the lens. Image is real/inverted/larger than object. (Note: Give full credit of ½ mark if a student just writes image moves away from the lens) OR $M.P = \frac{D}{f} = \frac{25}{5} = 5$ (Note: Award ½ marks if students write formula only)	½ + ½ ½ + ½	1
3.	$I_o = 10$ A, $I_{rms} = \frac{10}{\sqrt{2}}$ A $P_{av} = I^2_{rms} R = (\frac{10}{\sqrt{2}})^2 \times 20 = 1000$ watt (Note: Award full marks if the student writes answer directly. Award ½ mark for writing formula only)	½ + ½	1
4.	Electric field / magnetic field/ Electric and magnetic fields OR UV radiation	1 1	1
5.	$P = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{2}{R}\right)$ (Note: If student writes lens makers formula only without considering $R_1 = R_2$ award ½ mark only)	1	1
6.	Absence of repulsive force/ neutral particle / heavy particle.	1	1
7.	Stopping potential increases.	1	1
8.	$\lambda = \frac{12.27}{\sqrt{V}} A^0$ $\lambda = \frac{12.27}{\sqrt{100}} = 1.227$ A^o (Note: Award ½ marks for writing formula only) OR $\frac{\lambda_p}{\lambda_d} = \frac{h}{m_p v_p} \times \frac{m_d v_d}{h}$ $=> \frac{2m_p}{m_p} = \frac{2}{1}$	½ ½ ½ ½	1

9.	Energy gap decreases.	1	1
10.	It is because the diffusion current becomes equal to drift current. OR Depends on energy gap/band gap of the semiconductor.	1 1	1
11.	(A)	1	1
12.	(D)	1	1
13.	(A)	1	1
14.	(D)	1	1
	SECTION- B **Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.**		
15.	(i) (D) terminal potential difference of the cell is less than its EMF. (ii) (C) Protect the galvanometer from damage due to large current. (iii) (A) Increase. (iv) (B) Q, because potential gradient is less. (v) (C) of low value of its temperature coefficient of resistivity.	1 1 1 1 1	4
16.	(i) (B) $R=R_0A^{1/3}$ (ii) (C) 1:1 (iii) (C) X=93; Y=239 (iv) (D) short-range forces (v) (A) not suffer more than one scattering and gold nucleus is 50 times heavier than alpha particle.	1 1 1 1 1	4
	SECTION- C **All questions are compulsory. In case of internal choices, attempt any one.**		
17.	Definition 1 Part (i) ½ Part (ii) ½ Definition- It is defined as the average velocity with which all the electrons move inside a conductor under the external potential/ electric fields i) Slope= $\frac{v_d}{V} = \frac{e\tau}{m\,l}$ (Alternatively: slope = $\frac{v_d}{V}$) ii) Wire B is longer	1 ½ ½	2
18.	Part (i) ½ + ½ Part (ii) 1 i) Greater Britain is closer to magnetic North Pole ii) At both these places , a magnetic needle shows the true North quite accurately OR Finding the magnetic moment 2 N (2πr) = 2N($2\pi r'$) => $r' = \frac{r}{2}$ ∵ M = NIA = NI(πr^2) M′ = (2N) (I) ($\frac{\pi r^2}{4}$) = $\frac{M}{2}$	½ ½ 1 ½ ½ 1	2

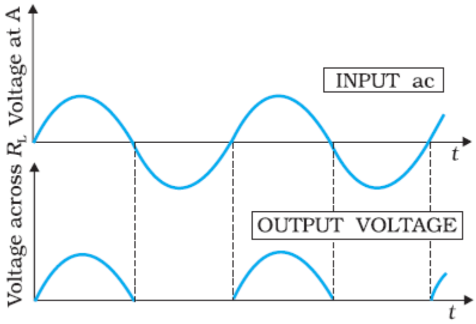
19.	Comparison of (i) induced EMF & justification ½ + ½ Comparison of (ii) induced current and justification ½ + ½ i) Induced EMF is same in both cases Induced emf $e = \frac{1}{2} Br^2\omega$ is independent of the resistivity / nature of material (**Note**: Give full credit of justification if a student justifies without using formula) ii) $I = \frac{e}{R}$ Since $\rho_{cu} < \rho_{Al}$, $R_{cu} < R_{Al}$ Hence Induced current is more in copper disc	 ½ ½ ½ ½	 2
20.	(a) (i) ½ (ii) ½ (b) Two characteristics ½ + ½ a) i) – z direction ii) YY ′direction / Y direction b) i) Electromagnetic waves do not require any medium to propagate ii) Electromagnetic waves are transverse in nature (award full credit for this part if the student write any other two properties)	 ½ ½ ½ ½	 2
21.	Calculation of angle of emergence 2 $n = \frac{\text{Sin}\, i}{\text{Sin}\, r}$ $\sqrt{3} = \frac{\text{Sin}\, 60^0}{\text{Sin}\, r} = \frac{\sqrt{3}/2}{\text{Sin}\, r}$ ⇨ $r = 30^o$ $\frac{1}{\sqrt{3}} = \frac{\text{Sin}\ 30^0}{\text{Sin}\ e}$ $\text{Sin}\ e = \sqrt{3} \text{ X } \frac{1}{2} = \frac{\sqrt{3}}{2}$ $e = 60^o$ **Alternatively:** Give full credit of this part if a student finds angle of emergence using geometry.  Angle of refraction when ray of light falls on the transparent sphere	 ½ ½ ½ ½ ½	

	$n = \frac{\sin i}{\sin r}$ $\sqrt{3} = \frac{\sin 60^0}{\sin r}$ ⇨ $r = 30^o$ from figure angle of emergence = 60^o	½ 1	2
22.	(i) Effect of width of slit and justification ½ + ½ (ii) Effect of polychromatic light and justification ½ + ½ (i) Angular width increases $\theta = \frac{\lambda}{a}$ when 'a' decrease , θ increases (ii) Angular width of central maximum will be different for different colours of light. Angular width α wavelength i.e $\theta = \frac{\lambda}{a}$ **OR** Expression for intensity of resultant wave 1 Expression for intensity of resultant wave for (i) Incoherent sources ½ (ii) Coherent sources ½ $I = 4I_o Cos^2 \frac{\phi}{2}$ (i) $< I > = 4 I_o < \cos^2 \frac{\phi}{2} >$ $= 4I_o \times \frac{1}{2}$ $= 2I_o$ (ii) $I = 4I_o \cos^2 \frac{\phi}{2}$ For constructive interference $\cos^2 \frac{\phi}{2} = 1$ $I = 4 I_o$ For constructive interference $\cos^2 \frac{\phi}{2} = 0$ $I = 0$	½ ½ ½ ½ 1 ½ ½	2
23.	Calculation of stopping potential 2 $\frac{hc}{\lambda} = \Phi_0 + eV_o$; $V_o = \frac{hc}{\lambda e} - \frac{\Phi_0}{e}$ $(V_{02} - V_{01}) = \frac{hc}{e} \left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)$ = -1.03 Volt $V_{02} = 6 - 1.03 = 4.97$ Volt	1 ½ ½	2
24.	Circuit diagram 1 Working 1 (a) Circuit diagram of half wave rectifier.		



When the voltage at A is positive, the diode is forward biased and it conducts. When A is negative, the diode is reverse-biased and it does not conduct. The reverse saturation current of a diode is negligible and can be considered equal to zero for practical purposes. Thus output is obtain only during positive half cycle. 1

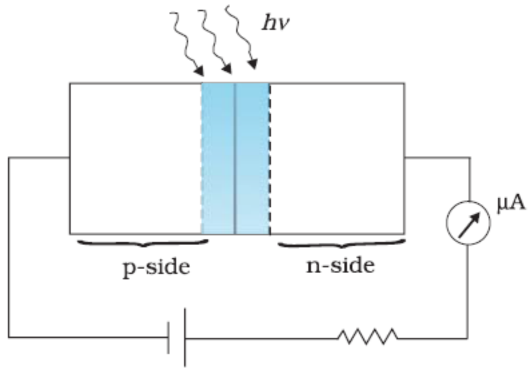
(Note :- Give full credit of explanation if a student just draws input and output waveform.) 1



OR

Circuit diagram	1
Working	1

(b) Circuit diagram of photo diode.



1

When the photodiode is illuminated with light (photons) with energy ($h\nu$) greater than the energy gap of the semiconductor, then electron-hole pairs are generated due to the absorption of photons. The diode is fabricated such that the generation of electron-hole pairs takes place in or near the depletion region of the diode. Due to electric field of the junction, electrons and holes are separated before they recombine. The direction of the electric field is such that electrons reach n-side and holes reach p-side. Electrons are collected on n-side and holes are collected on p-side giving rise to an emf. When an external load is connected, current flows. 1 2

25.

(a) (i)	½
(ii)	½
(b) Reason to operate photodiode in reverse Bias	1

a) (i) Reverse Biased ½

(ii) Reverse Biased ½

b) The fractional change due to the photo-effects on the *Minority carrier dominated reverse bias current* is more easily measurable than the fractional change in the forward bias current. 1

2

SECTION- D

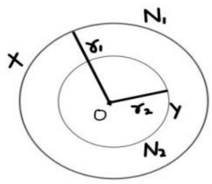
All questions are compulsory. In case of internal choices, attempt any one.

26.

Obtaining expression for mutual inductance	2
Obtaining expression for Magnetic Flux	1

(i) Magnetic field of coil 'X'

$B_1 = \frac{N_1 \mu_0 I_1}{2r_1}$ ½



As the inner coil placed co-axially has very small radius, therefore B_1 may be taken as constant over its cross-sectional area. Hence flux associated with inner coil is

$\Phi_2 = N_2 \pi r_2^2 B_1 = N_2 \pi r_2^2 \left(\frac{N_1 \mu_0 I_1}{2r_1}\right)$ ---- (1) ½

But $\Phi_2 = M_{21} I_1$ ---- (2) ½

From (1) & (2)

$M_{21} = \frac{\mu_o \pi N_1 N_2 r_2^2}{2r_1}$ ½

$M_{12} = M_{21} = \frac{\mu_o \pi N_1 N_2 r_2^2}{2r_1}$

ii) $\Phi_y = B_1 N_2 \pi r_2^2 = M_{21} I$ 1

OR

Definition of Eddy current	1
Cause of electromagnetic damping	½
Method to minimize eddy currents	1
Reason of smooth braking effect in trains	½

Eddy currents are the currents induced in the bulk piece of conductors when the amount of magnetic flux linked with the conductor changes. 1

Electromagnetic damping is reduced because due to slots (holes) , resistance of plate increases and therefore eddy current decreases. ½

By using laminated sheets in core of transformer. ½

No mechanical linkages 1

3

27.

a) Calculation of electric field	1
Identification of point	½
Justification	½
b) Calculation of new force	1

a) Electric field due to a uniformly charged sheet

$E = \frac{\sigma}{2\epsilon_o} = 1 \times 10^{-6}$ N/C outward — ½+½

At point Q — ½

For finite plane sheet, electric field is uniform in the middle. At the edges it will be curved. — ½

b) $q_1' = q'_2 = \frac{10+(-20)}{2} = -5\ \mu C$ — ½

$F' = \frac{F}{2}$ — ½ — **3**

(Note : Give full credit if student writes that electric field is same at all point , as electric field due to finite sheet is out of syllabus.

28.

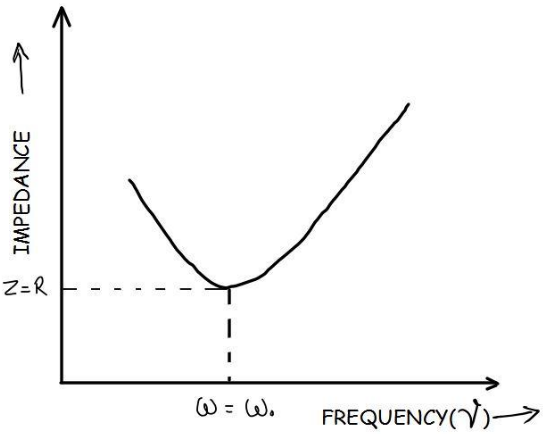
(i) Explanation of Part one	1
(ii) Reason of part two	1
(iii) Drawing of graph	1

i) C is increases; X_c decreases => $X_L > X_C$; As the circuit becomes inductive — ½

Therefore current lags the voltage — ½

ii) V & I are not in same phase — 1

iii)



— 1

OR

i) $\omega < \omega_o$; $X_c > X_L$ — ½

As circuit will become capacitive, current leads the voltage — ½

(ii) No change in magnetic flux for d.c. voltage, resulting no mutual induction — 1

iii) Resonance in a.c. circuit — 1 — **3**

29.

(a) Explanation of formation of fringes for	
(i) Path diff. = λ	1
(ii) Path diff. = 3λ/2	1
(b) Intensity distribution curve	1

(a) (i) In diffraction, for path diff. λ ; the light waves from two consecutive parts of the slit reach at a point with path diff. of λ/2 having a separation equal to half of the width of the slit. Therefore contribution from two halves of the slit gets cancelled, resulting Zero intensity. 1

(ii) For the path diff $\frac{3\lambda}{2}$, the light waves from two consecutive parts of the slit having separation equal to one third of the width of the slit reach a point on the screen with path diff. of $\frac{\lambda}{2}$. Therefore, contribution from two consecutive portion of the slit gets cancelled and illumination is due to only one third portion of the slit. 1

(b)

1 3

30.

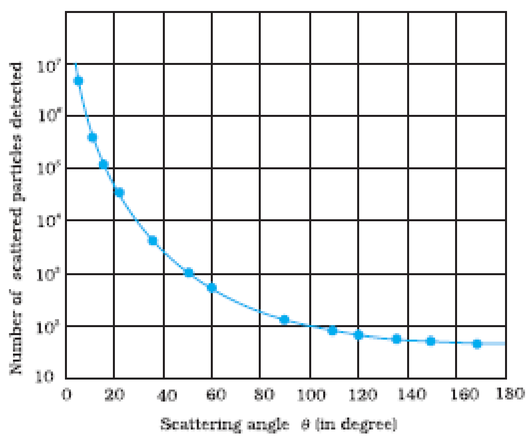
a) Calculation of distance of closest approach	1
Justification	½
b) Plotting a graph	1
Main assumption	½

$E_k = \frac{1}{4\pi\epsilon_o}\frac{(2e)(ze)}{d} = \frac{2ze^2}{4\pi\epsilon_o d}$ ½

$d = \frac{2X\,(9.0\,X\,10^9)(1.6\,X\,10^{-19})^2\,X79}{1.2\,X\,10^{-12}} \approx 30.4X10^{-15}$ m

d = 30 fm = 30 X 10^{-15} m $^1/_2$

Kinetic energy of α particle is not sufficient to touch the nucleus.
Radius of gold nucleus is 6 fm << 30 fm because α- particle does not collide with gold nuclei and therefore distance of closest approach is less than radius of gold nuclei. $^1/_2$



1

Atom has a small dense, positively charged nucleus ½ 3

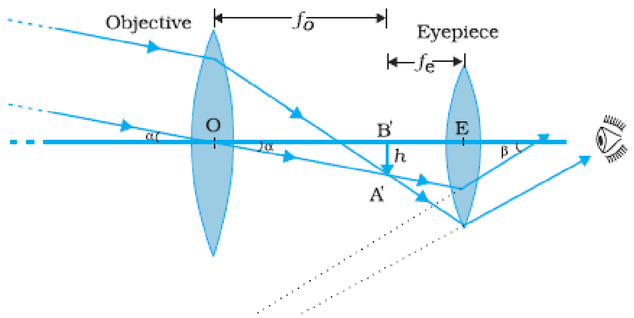
SECTION- E

All questions are compulsory. In case of internal choices, attempt any one.

31.

(a) (i) Ray diagram	1 ½
Derivation Expression for magnifying power	1
Method to increase magnifying power	½
(ii) Formula	½
Substitution and Calculation	1
Result	½

a) (i) Ray Diagram of Astronomical telescope



1½

(Deduct half mark for not showing direction of propagation of ray)

Magnifying power, m = $\frac{\tan\beta}{\tan\alpha}$

As angles, α and β are small, therefore, $\tan\alpha \approx \alpha$ and $\tan\beta \approx \beta$

then m = $\frac{\beta}{\alpha}$ ½

In $\Delta A'B'E$, $\tan\beta = \frac{A'B'}{EB'}$; In $\Delta A'B'O$, $\tan\alpha = \frac{A'B'}{OB'}$

$m = \frac{A'B'}{EB'} \times \frac{OB'}{A'B'}$ or $m = \frac{f_0}{-f_e}$ ½

Magnifying power of a telescope can be increased by increasing the focal length of objective lens and decreasing the focal length of eye piece. ½

(ii)

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ ½

u =+25m , v = ∞

∴ f=-25cm ½

P = - $\frac{1}{0.25}$ m ½

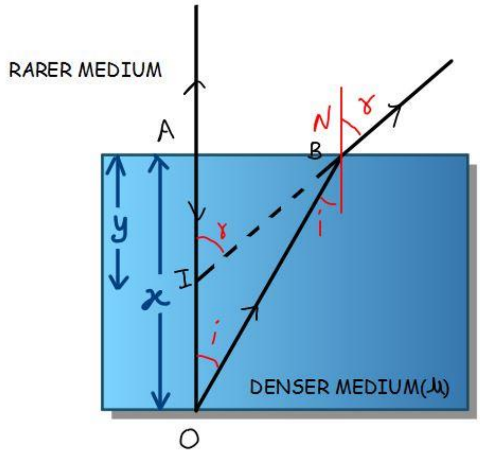
P =-4 D ½

OR

(b)

(a) (i) Reason for the apparent position of coin	½
Diagram	½
Derivation	1 ½
(ii) Calculation and objective distance	1 ½
Calculation of magnifying power	1

(i) Due to refraction of light ½



½

In ΔOAB,

$$\sin i = \frac{AB}{OB}$$

In ΔIAB, $\sin r = \frac{AB}{IB}$

According to Snell's law

$$\frac{1}{\mu} = \frac{\sin i}{\sin r} = \frac{IB}{OB}$$ ½

When angles are small, OB ≈ OA and IB ≈ IA

$$\mu = \frac{OA}{IA} = \frac{x}{y}$$ ½

Height through which object is raised = x-y

$$= x - \frac{x}{\mu}$$

$$= x\left(1 - \frac{1}{\mu}\right)$$ ½

	(ii) $f_0 = 2$ cm $f_e = 6.25$ cm $L = v_0 + \lvert u_e \rvert = 15$ cm $v_e = -25$ cm $\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$; $\frac{1}{-25} - \frac{1}{u_e} = \frac{1}{6.25}$ $u_e = -5$cm Now, $L = v_0 + \lvert -5 \rvert = 15$ cm $V_o = 10$ cm Now, $\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$ $u_o = 2.5$ cm MP = $\frac{v_o}{u_o}\left[1 + \frac{D}{f_o}\right]$ = - 20	½ ½ ½ ½ ½	5
32.	(i) Ratio of radii 3 (ii) Direction of magnetic field 1 (iii) Reason for using low resistance 1 $\frac{1}{2} m_\alpha v_\alpha^2 = \frac{1}{2} m_p v_p^2$ $\frac{V_\alpha}{V_p} = \sqrt{\frac{m_p}{m_\alpha}} = \frac{1}{2}$ Now , $\frac{1}{2} m_d v_d^2 = \frac{1}{2} m_p v_p^2$ $\frac{v_d}{v_p} = \frac{1}{\sqrt{2}}$ Radius of the circular path $r = \frac{mv}{Bq}$ $\frac{r_\alpha}{r_p} = \frac{1}{1}$ & $\frac{r_d}{r_p} = \frac{\sqrt{2}}{1}$ $\therefore r_\alpha : r_d : r_p = 1 : \sqrt{2} : 1$	½ ½ ½ ½ + ½ ½	

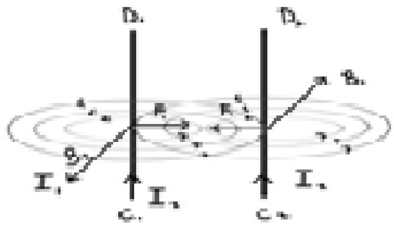
(**Note**: or any other relevant method)

ii) Magnetic field is along Z axis — 1

iii) Does not affect the net current drawn from the battery. — 1

OR

(i) Diagram	½
Derivation of Expression for force per unit length	1 ½
Definition	1
(ii) Showing magnetic field at the centre zero	2



B (i) — ½

Magnetic field induction at a point P on conductor C_2D_2 due to current I_1 passing through C_1D_1 is

$B_1 = \frac{\mu_o I_1}{2\pi r}$ where r is the separation between two conductors. — ½

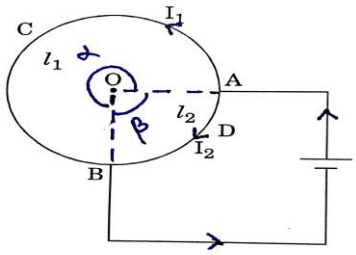
According to right hand thumb rule, the direction of magnetic field B_1 is perpendicular to the plane of paper, directed inwards.

As the current carrying conductor C_2D_2 lies in the magnetic field B_1 (produced by the current through C_1D_1) therefore, the length of C_2D_2 will experience a force given by

$F_2 = B_1 I_2 X l = B_1 I_2 l$ — ½

Putting the value of B_1, we have $\frac{F_2}{l} = \frac{\mu_o}{2\Pi} \cdot \frac{I_1 I_2}{r}$ — ½

The ampere is the value of that steady current which, when maintained in each of the two very long straight, parallel conductors of negligible cross section and placed in one meter apart in vacuum would produce of each of these conductors a force equal to $2 X 10^{-7}$ Newton per meter of length. — 1



(ii) $B_1 = \frac{\mu_o I_1 \alpha}{2r} = \frac{\mu_o I_1 l_1}{2r^2}$ vertically outward — ½

$B_2 = \frac{\mu_o I_2 \beta}{2r} = \frac{\mu_o I_2 l_2}{2r^2}$ vertically inward — ½

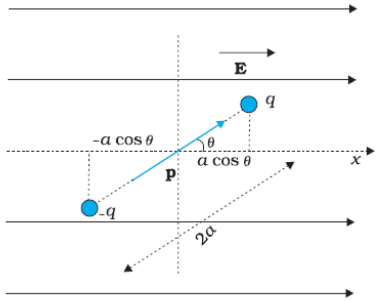
From calculation, using potential difference is same in parallel, $I_1 l_1 = I_2 l_2$

⇨ $B_1 = B_2$

⇨ Net magnetic field $\mathbf{B} = \mathbf{B_1} + \mathbf{B_2} = 0$ — 1 — 5

$B_{ACB} - B_{ADB} = 0$

33.	(i) (A) Reason for decrease in electric field 1 (B) Derivation for capacitance of capacitor with dielectric 2 (ii) Calculation of amount of work done. 1 (iii) Relation of polarization 1		
	(a) (i) (A) A dielectric material gets polarized when it is placed in an external electric field. The field produced due to the polarization of material reduces the effect of external electric field. Hence, the electric field inside a dielectric decreases.	1	
	(B) (i) Electric field in vacuum between the plates = $E_0 = \frac{\sigma}{\varepsilon_o}$ Electric field in dielectric between the plates, $E = \frac{E_0}{K}$	½	
	Potential difference between the capacitor plates $V = Et + E_0(d - t)$ where 't' is the thickness of dielectric slab. $V = \frac{E_0}{K} t + E_0 (d - t)$	½	
	$V = \frac{\sigma}{\varepsilon_o}[\frac{t}{K} + (d - t)]$ $V = \frac{\sigma}{\varepsilon_o}[\frac{t+K(d-t)}{K}]$	½	
	As $C = \frac{Q}{V}$ $\Rightarrow C = \frac{\varepsilon_0 AK}{t + K(d-t)}$	½	
	(ii) The surface of the sphere is equipotential. So, the work done in moving the charge from one point to the other is zero. $W = q\,\Delta V$ ($\because$ $\Delta V = 0$)	½	
	$= 0$	½	
	(iii) $\mathbf{P} = \chi\ \mathbf{E}$	1	
	OR		
	(i) Obtaining an expression potential energy 1½ (ii) Showing the total energy of combination equal to sum of the individual energy 1½ (iii) Effect on capacitance and justification ½ + ½ Effect on electric field and justification ½ + ½		
	(b)(i)		



½

Consider a dipole with charges $q_1 = +q$ and $q_2 = -q$ is placed in a uniform electric field **E**, as shown in Fig The dipole experiences no net force; but experiences a torque **τ** given by **τ =p×E**
which will tend to rotate it (unless **p** is parallel or antiparallel to **E)**. Suppose an external torque **τ** ext is applied in such a manner that it just neutralizes this torque and rotates it in the plane of paper from angle θ_o to angle θ_1 at an infinitesimal angular speed and *without angular acceleration*. The amount of work done by the external torque will be given by

$$W = \int_{\theta_0}^{\theta_1} \tau_{ext}(\theta)d\theta = \int_{\theta_0}^{\theta_1} pE\sin\theta d\theta$$ ½

W= U = $pE(\cos\theta_0 - \cos\theta_1)$ ½

(ii) $U = \frac{1}{2}\frac{Q^2}{C_{eff}}$ ½

$$\frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$ ½

½

$$U = \frac{1}{2}\frac{Q^2}{C_1} + \frac{1}{2}\frac{Q^2}{C_2} + \frac{1}{2}\frac{Q^2}{C_3}$$

U = $U_1 + U_2 + U_3$

(iii) When battery is disconnected then charge (q) remains constant.

(i)

Capacitance is halved ½

$$C' = \frac{\varepsilon_o A}{2d} = \frac{C}{2}$$ ½

(ii) ½

Electric field (E) is unaffected. ½

$$E = \frac{\sigma}{\varepsilon} = \frac{q}{\varepsilon_o A}$$

Alternatively for effect on electric field.

$$E = \frac{V}{d}$$

$$V' = \frac{Q}{C'} = \frac{Q}{C/2} = 2V$$

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$$E' = \frac{V'}{d'} = \frac{2V}{2d} = \frac{V}{d} = E$$