

vè; k; 11

fofdj.k rFkk n0;

dh }\$ i 00fr



11.1 Hkfredk

I u-1887 ea o\$ rppdh; fdj.ka dh mri fuk , oa l a puk ij fo| r p dRo o\$ eDl osy l ehdj.k rFkk gvZ'k o\$ iz kskaus izk'k dh rjxh; i 00fr dks vHkr i 00: i l sLFKfir fd; ka mluhl oha 'krkCh o\$ vfire pj.k ea fol tZ&ufydk ea x\$ ka ea de nlc ij fo| r&pkyu (fo| r&fol tZ) ij ik; k\$xd vto\$'k. ka l sdbZ , frgl d [k\$tagpA : a/xsu o\$ }kjk 1895 ea x-fdj.ka dh [k\$st rFkk ts ts VmE l u o\$ }kjk 1897 ea dh xbz byDVm dh [k\$st ijek. k&l j'puk dks l e>useaehy dk iRFkj Fkha yxHkx 0.001 mm i kjs o\$ Lrhlk o\$ vR; r de nlc ij ; g ik; k x; k fd , d snks byDVm/ka o\$ chp] ftuo\$ }kjk fol tZ&ufydk ea x\$ ij fo| r {k\$ LFkfir fd; k tkrk g\$, d fol tZ gk\$ g\$ o\$ LFkM o\$ l Ee[k dkp ij ifrnhr mRi l u gk\$ g\$ nhr dk jax dkp dh i 00fr ij fuHk\$ djrk g\$ t\$ p l kM/k&dkp o\$ fy, i hr&gjk jax dka bl ifrnhr dk dkj.k ml fofdj.k dks ekuk x; k tks o\$ LFkM l svk jgk FkA ; s o\$ LFkM fdj.ka 1870 ea fofy; e o\$ D l o\$ }kjk [k\$st xbz Fkha ftl usckn ea 1879 ea ; g l qk; k fd ; sfdj.ka hork l spyusokyh 1/2 .k&vko\$ kh d. ka dh ekjk l scuh g\$ fclV' k Hk\$rd 'kL=kh tsts VmE l u (1856 - 1940) usbl ifjdYiuk dh iq"V dha tsts VmE l u usigyh ckj fol tZ&ufydk o\$ vkj&ikj ijLij ycor fo| r , oa p d dh; {k\$ka dks LFkfir dj ik; k\$xd rlg ij o\$ LFkM&fdj.k d. ka o\$ osx rFkk vki \$ {kd vko\$ k 'vFkZ' vko\$ k vlg \$e0; eku dk vuqkr $(e/m)^0$ Kkr fd; ka ; g ik; k x; k fd ; s d.k izk'k o\$ osx $(3 \times 10^8 \text{ m/s})$ o\$

yxHlx 0.1 l s yd j 0.2 xps ox l s pyrs gá orðku ea e/m dk LohÑr eku 1.76×10^{11} C/kg gá ; g Hkh ik; k x; k fd e/m dk eku oFkM (mRI tð) oð inKFiz vFlók èkkrg ; k fol tð&ufydk eaHkjh xð dh iÑfr ij fuHkj ugha djrka bl iðk.k usofkM&fdj.k d.ka dh l kðodr dks l ðk; ka

yxHlx ml h l e; j 1887 eð ; g ik; k x; k fd tc oðN fuf'pr èkkrg/ka dks i jk&kuh izk'k }kjk fdj.f.kr djrs gá rks de ox okys $\frac{1}{2}$.k&vkoð'kr d.k mRI ftð gkrs gá bl h izdkj] tc oðN fuf'pr èkkrg/ka dks mPp rki rd xje fd; k tkrk gS rks ; s $\frac{1}{2}$.k&vkoð'kr d.k mRI ftð djrs gá bu d.ka oð fy, e/m dk eku mruk gh ik; k x; k ftruk fd oFkM fdj.k d.ka dk FkA bl izdkj bu iðk.k.ka us; g LFkfi r dj fn; k fd ; s l Hkh d.k] ; | fi fHku n'kvka ea mRI uu gq Fkð iÑfr ea l eku FkA tsts Vkk l u us 1897 eð bu d.ka dks byðVRU uke fn; k vð l ðk; k fd ; s æ0; oð ekðyd l koð=kd vo; o gá xð kaeaf | r oð l øgu ij muoð l S&krd rFkk ik; kðxd iðk.k.ka oð }kjk byðVRU dh bl ; q&kr dkh [kst oð fy, mlUga 1906 ea ukcsy ij Ldkj inku fd; k x; ka 1913 ea vesjdH HkðrdfoKkuh vkj-, - fefydu (1868–1953) us byðVRU ij vkoðk oð ifj'kð eku u oð fy, rý&çm dk iFk in'kd iz kx fd; ka mlUgk us; g ik; k fd rý&çm pd ij vkoðk l nð , d emy vkoðk] 1.602×10^{-19} C dk i w k z xqkæd gá fefydu oð iz kx us; g i LFkfi r dj fn; k fd oð r vkoðk Doka hÑr gá vkoðk (e) rFkk vki ð{kr vkoðk (e/m) oð eku l ð byðVRU dk æ0; eku (m) Kkr fd; k tk l dka

11.2 byðVRU mRI tð

ge tkurs gá fd èkkrg/ka ea eðr byðVRU ($\frac{1}{2}$.k vkoð'kr d.k) gkrs gá tks mudh pkydrk oð fy, mlUjnk; h gkrs gá rFkfi] eðr byðVRU l keku; r% èkkrg i "B l sckgj ughafudy l dra ; fn byðVRU èkkrg l sckgj vkrs gá rks bl dk i "B eku vkoðk i ktr dj yrk gS vð byðVRUka dks oki l èkkrg ij vkð'kz dj yrk gá bl izdkj eðr byðVRU èkkrg oð Hkhrj vk; uka oð vkð'kz k cyka oð }kjk jkcdj j [l s x, gkrs gá ifj.kæLo: i fl Hk os byðVRU ft l dh Átkz bl vkð'kz k dks vFkHkr dj l oð /krq i "B l sckgj vk i krs gá vr% byðVRUka dks èkkrg i "B l sckgj fudkyus oð fy, , d fuf'pr U; ure Átkz dh vko'; drk gksh gá bl U; ure Átkz dks èkkrg dk dk; & i ðyu dgrs gá bl s l kkkj.kr; k ϕ_0 oð }kjk 0; Dr djrs gá vð ev (byðVRU okV) ea eki rs gá , d byðVRU okV fd l h byðVRU dks 1 okV foHkokrj oð }kjk Rofjr djkus ij i ktr mðtkz dk eku gá vr% $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$

l kkkj.kr; k Átkz dh bl bdkbz dk iz kx i jek.krFkk ukFkdh; Hkðrdh eaf d; k tkrk gá dk; & i ðyu (ϕ_0) èkkrg oð xqkæa vð bl oð i "B dh iÑfr ij fuHkj djrk gá oðN èkkrg/ka oð dk; & i ðyu oð eku l kj.kh 11.1 eafn, x, gá ; seku vuøfur gá D; kðd buoð eku i "Bh; vind; ka ij cgr vf/d fuHkj djrs gá

l kj.kh 11.1 l s ; g è; ku fd; k tk l drk gS fd lyðVue dk dk; & i ðyu mPpre ($\phi_0 = 5.65 \text{ eV}$) gS tcd l hf'k; e dk U; ure ($\phi_0 = 2.14 \text{ eV}$) gá

èkkrg oð i "B l s byðVRU mRI tð oð fy, eðr byðVRUka dks U; ure vko'; d Átkz fuEu fd l h Hkh , d Hkðrd fofek oð }kjk nh tk l drh gS %

(i) rki k; fud mRI tð % mi ; ðr rki u oð }kjk eðr byðVRUka dks i ; kðr rki h; Átkz nh tk l drh gS ft l l s fd os èkkrg l sckgj vk l oð

I kj . kh 11.1 oñN /krq/ka oñ dk; &i Qyu

/krq	dk; &i Qyu ϕ_0 (eV)	/krq	dk; &i Qyu ϕ_0 (eV)
Cs	2.14	Al	4.28
K	2.30	Hg	4.49
Na	2.75	Cu	4.65
Ca	3.20	Ag	4.70
Mo	4.17	Ni	5.15
Pb	4.25	Pt	5.65

- (ii) {ksk mRI tZu % fdl h ðkkrij yxk; k x; k , d icy fo|qr {ksk (10^8 V m^{-1} dh dksV dk) byðVRNUka dks ðkk&i"B oñ ckj yk l drk gS ts k fd fdl h Likod lyx eð
- (iii) izk'k&fo|qr mRI tZu % mi ; ðr vkofuk dk izk'k tc fdl h ðkk&i"B ij iM&k gS rks byðVRNUka dk mRI tZu gsrk gð ; s izk'ktfur byðVRNU izk'kd byðVRNU (photo-electron) dgykrs gð

11.3 izk'k&fo|qr iHkko

11.3.1 gvZk oñ ijh{k.k

izk'k&fo|qr mRI tZu dh ifj?kVuk dh [kst gsfjp gvZk (1857-1894) oñ }kjk 1887 ea oñ rpp&dh; rj&ka oñ izk'ka oñ l e; dh xbz FkA LiQyx&fol tZu (spark discharge) oñ }kjk oñ rpp&dh; rj&ka dh mRI fuk oñ vius ik; ksd vlouk.k ea gvZk us; g iS{kr fd; k fd oñFkM dks fdl h vkoñ ys l s ijk&kuh izk'k oñ }kjk inhlr djus ij ðkk&byðVRNUka oñ ij mPp okVrk LiQyx vf/d gls tkrk gð

/kr&i"B ij pedus okyk izk'k eðr vkos'kr d.ka ftlga vc ge byðVRNU dgrsgð dks Lor&k djuseal gk; rk inku djrk gð tc /kr&i"B ij izk'k iM&k gS rks i"B oñ l ehi byðVRNU vki frr fofdj.k l sinkfz oñ i"B ea /ukRed vk; uka oñ vkd"lz.k dls ikj djus oñ fy, Åtkz vo'kks"kr dj yrs gð vki frr izk'k l s vko'; d Åtkz iklr djus oñ i'pkr] byðVRNU /kr&i"B l scgj ifjosk ea vk tkrsgð

11.3.2 gkyokMl rFk yhukMZ oñ ig{k.k

foygye gkyokMl rFk fi Qyi yhukMZ us 1886-1902 oñ chp izk'kfo|qr mRI tZu dh ifj?kVuk dk vlouk.k fd; ka

nk byðVRNUka (/kr&i f&dkv) okyh fdl h fuokfrr dlp dh uyh eamRI tZd if&dk ij ijk&kuh fofdj.ka dks vki frr djus ij yhukMZ (1862-1947) us ik; k fd ifji Fk ea /kjk izk'k gsrk gS (fp=k 11.1)A ts sgh ijk&kuh fofdj.ka dks jk&k x; k] oñ sgh /kjk izk'k Hk #d x; ka bu ijh{k.ka l s klr gsrk gS fd tc ijk&kuh fofdj.k mRI tZd if&dk c ij vki frr

glsrgÅ byDVm i fêdk l sckgj vk tkrsgÅrFk fo | r {lsk }kjk /ukRed l ætgd i fêdk A dh vlg vkdE"kr gsk tkrsgÅ fuokerr dkp dh uyh eabyDVmka o iDk o d kj.k /kjiDk gsh gÅ bl izdkj l } mri tD o i "B ij izk'k i Mus o d kj.k cká ifjiFk ea ekjkiDk gsh gÅ gkyokDl rFk yhuMzus l ætgd i fêdk o fohko] vkierr izk'k dh vkofuk rFk rhok o l kFk izk'k /kjk ea ifjorD dk vè; ; u fd; kA

gkyokDl us1888 ea bl vè; ; u dls vxsc<k; k vlg , d ½.kkos'kr tD i fêdk dls , d fo | r n'kZ l stkm+fn; kA ml us i f {kr fd; k fd tc i fêdk dls i jk&uh izk'k l sfdjf.kr fd; k x; k rls bl us viuk vkosk [k s fn; kA bl o vrfjDr tc , d vukos'kr tD i fêdk dls i jk&uh izk'k l sfdjf.kr fd; k x; k rls; g /ukos'kr g s x b A tD i fêdk dls i jk&uh izk'k l s i q% fdjf.kr d j u s i j] bl i fêdk i j /u vkosk vlg vf/d g s x; kA bu i g k. kA l s ml us; g fu" d "kz fudkyk fd i jk&uh izk'k o i Hkko l s tD i fêdk l s ½.kkos'kr d.k mri ftr glsrgÅ

1897 ea byDVm dh [kst o i 'pkr ; g fu'pr g s x; k fd mri tD i fêdk l s byDVmka o mri tD dk dkjd vkierr izk'k gÅ ½.k vkosk o d kj.k mri ftr byDVm fo | r {lsk }kjk l ætgd i fêdk dh vlg /o b s tkrsgÅ gkyokDl rFk yhuMzus; g Hk i f {kr fd; k fd tc mri tD i fêdk i j , d fu; r U; ure eku l s de vkofuk dk i jk&uh izk'k i Mf k g s rls d k b Z Hk byDVm mri ftr ugha g s kA bl fu; r U; ure vkofuk d s ngyh vkofuk (threshold frequency) dgrsgÅrFk bl dk eku mri tD i fêdk o i nFkz dh iDfr i j fuHkj djrk gÅ

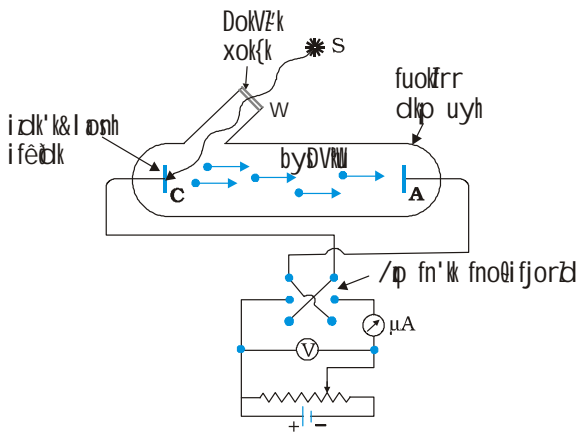
; g i k; k x; k fd tD] o s m f e; e] e x u h f' k; e t s h o q n /k r q; k a e a; g i Hkko o s o y de r j a n s; Z dh i j k & u h r j a k a o s f y , g l s k g Å r F k f i y h f f k; e] l k s m; e] i k s / s ' k; e] l h f t; e r F k : c h f m; e t s h {k j /k r q; n' ; izk'k o } j k Hk ; g i Hkko n' k z h g Å tc bu izk'k & l o n h i n k F k a d s izk'k l s i n h r fd; k t k r k g s r l s ; s b y D V m m r i f t r d j r s g Å b y D V m dh [k s t o i ' p k r - b u b y D V m k a d s i z k ' k d b y D V m u k e f n ; k x ; k A ; g i f j ? k v u k i z k ' k & f o | r i Hkko d g y k r h g Å

11.4 izk'k&fo | r i Hkko dk i k; k s x d vè; ; u

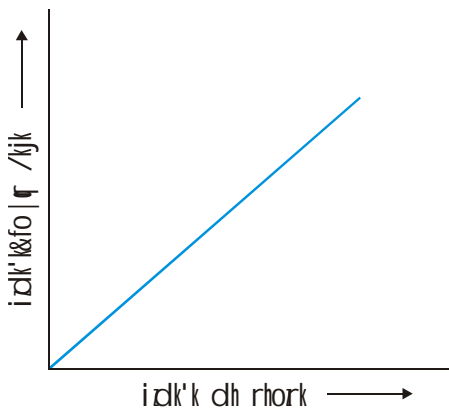
fp= 11.1 ea izk'k&fo | r i Hkko o i k; k s x d vè; ; u o s f y , m i ; l s e a y k b z x b z 0 ; o l F k d s n' k z k x; k g Å bl ea, d fuokerr dkp o d o k v z'k dh uyh g s f t l ea, d izk'k&l o n h i fêdk c vlg n i j h è k r q i fêdk A g Å l k r s l s i z k ' k j x o k { k (window) w l s i j g l s k g s v l g i z k ' k & l o n h i fêdk (mri tD) c i j i M f k g Å i k j n' k z D o k v z'k x o k { k (dkp&uyh i j e f n r) l s i j k & u h f o f d j . k i j g l s t k r k g s v l g i z k ' k & l o n h i fêdk c d l s f d j f . k r d j r k g Å i fêdk c l s b y D V m m r i f t r g l s r g Å t k s i fêdk A (l æ t g d) i j c s v j h } k j k m r i U u f o | r { l s k } k j k , d = d j f y , t k r s g Å c r F k A i fêdk v k a o s c h p f o H k o l a r j d l s c s v j h } k j k c u k , j [k t k r k g s r F k b l s i f j o f r z' d ; k t k l d r k g Å l y s' c r F k A o s / p f n' k k f n o s i f j o r z' d (Commutator) o s } k j k c n y s t k l d r s g Å b l i z k j m r i t D i fêdk c dh r g y u k e a i fêdk A d l s b P N k u d k j è k u v F k o k ½ . k f o H k o i j j [k t k l d r k g Å t c l æ t g d i fêdk A , m r i t D i fêdk c dh r g y u k e a / u k R e d g l s h r c b y D V m b l dh v l g v k d E " k r g l s b y D V m k a o s m r i t D o s d k j . k f o | r i f j i F k e a , d i D k m r i U u g l s k g s f t l l s i f j i F k e a , d f o | r è k j k l F k f i r g l s t k r h g Å

izk'k&fo | r i Hkko dk vupj . k
<http://www.eo.ucar.edu/rainbows>
<http://www.atoptics.co.uk/bows.htm>





fp-k 11.1 izdk'k&fo|q i Hkko oð vè; ; u oð fy, ik; k&sd 0; oLFKA



fp-k 11.2 izdk'k&fo|q /kjk vlg izdk'k dh rhork oð chip xki OA

byÐVRUka oð chip oð foHkolarj dks , d oðVehVj oð }kjk vlg ifj. MeLo: i ifji Fk eai okgr gksokyh izdk'k dð èkkjk dksokðs ehVj oð }kjk eki rs gð izdk'k d fo|q èkkjk dks l ætkgd ifeðdk A dk foHko mRI tð ifeðdk c oð l kiðk ifjoerr djoð c<k; k vFkok ?Kvk; k tk l drk gð vki frr izdk'k dh rhork rFk vkofuk dks Hk ifjofrr fd; k tk l drk gð sfd mRI tð c vlg l ætkgd A oð chip foHkolarj v dks ifjofrr fd; k tkrk gð

ge fp-k 11.1 dh ik; k&sd 0; oLFk dk mi ; l& izdk'k dð èkkjk oð (a) fofdj.k dh rhork] (b) vki frr fofdj.k dh vkofuk] (c) if^dkvA rFk c oð chip oð foHkolarj] rFk (d) if^dk c oð inkFkZ dh iÑfr oð l kFk ifjoru oð vè; ; u oð fy, dj l drsgð mRI tð c ij i Musokys izdk'k oð ekxz eami ; Ðr fi ÐVj vFkok jachu dko j[kdj fHku rj&ns; Zoð izdk'k dk mi ; l& dj l drsgð izdk'k l& dh mRI tð l snjh dksnyrsqg izdk'k dh rhork dks ifjofrr fd; k tk l drk gð

11.4.1 izdk'k&fo|q /kjk ij izdk'k dh rhork dk i Hkko

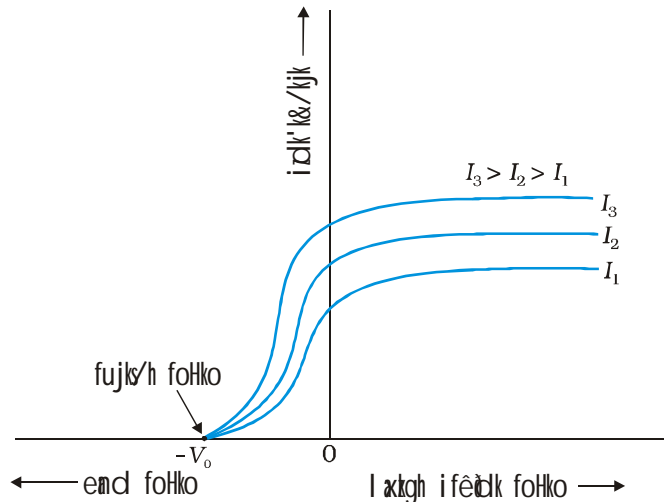
l ætkgd A dks mRI tð c dh ryuk ea, d èku foHko ij j[kk tkrk gðft l l s c l mRI ftð byÐVRU l ætkgd A dh vlg vkof'kz gksrgð vki frr fofdj.k dh vkofuk rFk Rojd foHko dks lFkj j[krgsq] izdk'k dh rhork dks ifjofrr fd; k tkrk gð vlg ifj. Meh izdk'k&fo|q èkkjk dks i R; sd ckj eki k tkrk gð ; g ik; k tkrk gðsd izdk'k dð èkkjk vki frr izdk'k dh rhork oð l kFk jð[kdr% c<fh gðtð k fd fp-k 11.2 eaxki Oh; : i ean'kz k x; k gð izdk'k dð èkkjk mRI ftð gksokys ifr l oðM byÐVRUka dh l æ; k oð vuðekuqkrh gð vr% mRI ftð gksokys ifr l oðM izdk'k dð byÐVRUka dh l æ; k vki frr fofdj.k dh rhork oð l ekuqkrh gð

11.4.2 izdk'k&fo|q /kjk ij foHko dk i Hkko

ge igys ifeðdk A dks ifeðdk c dh ryuk eafdl h èku Rojd foHko ij j[krgð vlg ifeðdk c dksuf'pr vkofuk v rFk fuf'pr rhork x_1 oð izdk'k l sinhr djrs gð fi Oj ge ifeðdk A oð èku foHko dks ekh&ekhjs ifjofrr djrs gð vlg i R; sd ckj ifj. Meh izdk'k&fo|q èkkjk dks eki rs gð ; g ik; k tkrk gðsd izdk'k&fo|q èkkjk Rojd (èku) foHko oð l kFk c<fh gð ifeðdk A oð , d fuf'pr èku foHko oð fy, , d , d h fLFkr vk tkrh gðft l ij l Hk mRI ftð byÐVRU ifeðdk A ij l æghr gks krgð rFk izdk'k&fo|q èkkjk mPpre gks tkrh gð vFkz l rtr gks tkrh gð ; fn ge fo|q ifeðdk A oð Rojd foHko dks vlg vfeð c<lrsgð rks izdk'k&fo|q /kjk ugha<fhA izdk'k&fo|q èkkjk oð bl mPpre eku dks l rtr èkkjk dgrs gð l rtr èkkjk ml fLFkr oð l ær gðtc mRI tð ifeðdk c oð }kjk mRI ftð l Hk izdk'k dð byÐVRU l ætkgd ifeðdk A ij igp tkrsgð

fótdj.k rFkk nD; dh }s iDfr

èkhj&èkhjsvfekd ½. kRed djrstkrsgà tc i fèdtkvka dh /prk cnyh tkrh gS rks byDVMM i frdE"kr gksrsgà rFkk oDoy oDn vfr Átkz okys byDVMM gh l átkgd A rd igpp ikrsgà ; g ik; k x; k fd izdkf'kd&èkjk r's'kh l sde gkrh tkrh gStc rd fd ; g i fèdtk A ij ½.k foHko v_0 oD fdl h fuf'pr rh{.k vS Li"V Økard eku ij 'kD; ughagks tkrhA vki frr fótdj.k dh , d fuf'pr vkofúk oD fy, i fèdtk A ij fn; k x; k fuEure ½.k (emd) foHko v_0 ftl ij izdkf'kd&èkjk 'kD; gks tkrh gS vrd (Cut-off) vFkok fujkèkh foHko (Stopping potential) dgykrk gD



fp=k 11.3 vki frr fótdj.k dh foHkoU rhorkvka oD fy, izdkf'kd&èkjk rFkk i fèdtk foHko oD chp vkys'kA

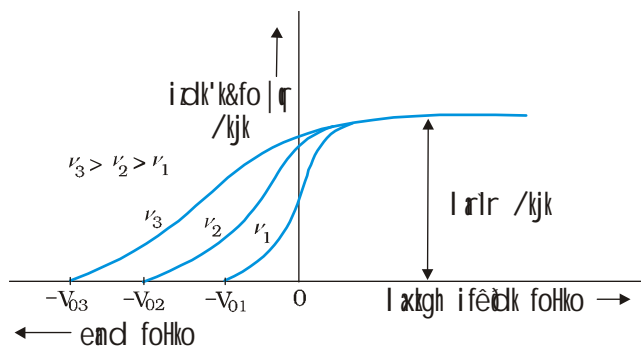
izdkf'kd byDVMM oD }kjk i gk.k dh 0; k[; k l èkhk gD èkkrq l smRI ftZ l Hk izdkf'kd byDVMM l eku Átkz okys ughagksà izdk'k&fo | r èkjk rc 'kD; gksr gStc fujkèkh foHko vf/dre Átkz okys izdkf'kd byDVMMk ftudh mPpre xfrt Átkz (K_{mp}) gS dks i frdE"kr djus dh volFk ea gD vFkZ

$$K_{mp} = e V_0 \tag{11.1}$$

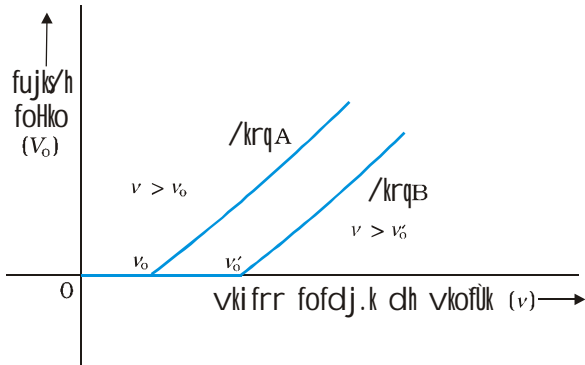
vc ge bl iz'kx dks vki frr fótdj.k dh , dl eku vkofúk i jrqmPp rhork I_2 rFkk I_3 ($I_3 > I_2 > I_1$) oD fy, nkgjk l drsgà ge ; g uk/ djrs gDfd vc l rlr èkjkvka oD eku c+ tkrsgà bl l sKkr gksk gSfd vki frr fótdj.k dh rhork oD vuqkr ea i fr l oDm vf/d byDVMM mRI Ètr gksrsgà i jrqfujkèkh foHko mruk gh jgrk gSftruk fd I_1 rhork oD vki frr fótdj.k oD fy, gksk gS tS k fd fp=k 11.3 ea xki 0 oD }kjk n'kZ k x; k gD bl izdkj vki frr fótdj.k dh , d fuf'pr vkofúk oD fy, fujkèkh foHko bl dh rhork l sLorak gksk gD n'js 'kcnkaeD izdkf'kd byDVMM dh mPpre xfrt Átkz vki frr fótdj.k dh rhork ij fuHkz ugha djrh gD

11.4.3 fujks/h foHko ij vki frr fótdj.k dh vkofúk dk i Hkko

vc ge vki frr fótdj.k dh vkofúk v vS fujkèkh foHko v_0 oD eè; l ákèk dk vè; ; u djka ge izdk'k fótdj.k dh foHkoU vkofúk; kà ij mi ; pr izdkj l s, d gh rhork dks l ek; kÈtr djrs gD vS l átkgh i fèdtk foHko oD l kFk izdk'k&fo | r èkjk oD i jorZu dk vè; ; u djrs gD i j. kkeh i jorZu dks fp=k 11.4 ea n'kZ k x; k gD gea vki frr fótdj.k dh fHkoU vkofúk; kà oD fy, fujkèkh foHko oD fHkoU eku i jqr l rlr èkjk dk , d gh eku i ktr gksk gD mRI Ètr byDVMMkadh Átkz vki frr fótdj.kkadh vkofúk ij fuHkz gD vki frr fótdj.k dh mPprj vkofúk oD fy, fujkèkh foHko dk eku vfekd ½. kRed gksk gD fp=k 11.4 l s; g Kkr gksk gSfd ; fn vkofúk; k $v_3 > v_2 > v_1$ oD Øe eagla



fp=k 11.4 vki frr fótdj.k dh foHkoU vkofúk; kà oD fy, i fèdtk foHko rFkk izdk'k&fo | r /kjk oD chp vkys'kA



fp-k 11.5, d fn, gq izk'k l onsh inkFiz oð fy, vki frr fofdj.k dh vkofuk v oð l kfk fujks/h foHko v_0 dk i fforzA

rkfujkæh foHkoka dk Øe $v_{03} > v_{02} > v_{01}$ gærk gA bl ea; g varufgr gSfd vki frr izk'k dh vkofuk ftruh vfeð gærk] izk'k dk byðvRnka dh mPpre xfrt Åtkz mruh gh vfeð gærkA iðyLo: ij blga i wæz : i l s jkæus oð fy, vfeð fujkæh foHko dh vko'; drk gærkA ; fn ge fHku ækkrvka oð fy, vki frr fofdj.k dh vkofuk vS l æfækr fujkæh foHko oð chp xki-è [khparksgea, d l hekh jSkk i ktr gærk gS tS k fd fp-k 11.5 ea n' kæz k x; k gA xki-è ; g n' kæz k gSfd

- (i) fujkæh foHko v_0 , d fn, gq izk'k l onsh inkFiz oð fy,] vki frr fofdj.k dh vkofuk oð l kfk jS[kæd-% i fforz gærk gA
- (ii) , d fuf'pr fuEure vrd vkofuk v_0 gærk gSftl oð fy, fujkæh foHko 'H; gærk gA

bu i gk. kka ea nks rF; varufgr gA %
 (i) izk'k dk byðvRnka dh mPpre xfrt Åtkz vki frr fofdj.k dh vkofuk oð l kfk jS[kæd-% i fforz gærk gS tæfd ; g bl dh rhork ij fuHkij ugha gærkA
 (ii) vki frr fofdj.k dh vkofuk v oð fy,] tæfd bl dk eku vrd vkofuk v_0 l sde gS dæbz izk'k æfo|q mRl tæ l Hkko ugha gS (rhork vfeð gærk dh fLFkr ea Hkh)A
 bl U; wære vrd vkofuk v_0 dks ngyh vkofuk dgrs gA ; g fHku ækkrvka oð fy, fHku gærk gA

fHku izk'k l onsh inkFiz izk'k oð fy, fofHku vuqø;k; n' kæz gA l fyfu; e] tæ vFkok dæw j dh ngyk ea vf/d l onsh gA , d gh izk'k l onsh inkFiz fofHku rjæns; Z oð izk'k oð fy, fHku vuqø;k n' kæz gA mnkgj.k oð fy,] dæw j ea ij kæxuh izk'k l s izk'k æfo|q i Hkko gærk gS tæfd gjs vFkok yky jæ oð izk'k l s; g i Hkko ugha gærkA è; ku nafd Åij oð l Hkh iz kæka ea; g ik; k x; k gSfd ; fn vki frr fofdj.k dh vkofuk ngyh vkofuk l s vfeð gærk tærk gS rks fæuk fdl h dky&i'prk oð rRdky izk'k æfo|q mRl tæ i kækk gærk tærk gS rc Hkh tæ vki frr fofdj.k cqr em gæ vc ; g kkr gSfd 10^{-9} s dh dæv oð ; k bl l sde l e; ea mRl tæ i kækk gærk tærk gA

- vc ge bl vuqø;k ea o. kæ fd, x, ik; kæx d y{k. kka, oa i gk. kka dk ; gk l kækk næks %
- (i) fdl h fn, x, izk'k l onsh inkFiz vS vki frr fofdj.k dh vkofuk (ngyh vkofuk l s vfeð) oð fy,] izk'k æfo|q ækkj vki frr izk'k dh rhork oð vuqøkuq krh gærk gS (fp-k 11.2)A
- (ii) fdl h fn, x, izk'k l onsh inkFiz vS vki frr fofdj.k dh vkofuk oð fy,] l ær ækkj vki frr fofdj.k dh rhork oð vuqøkuq krh i kæz tærk gS tæfd fujkæh foHko rhork ij fuHkij ugha gærk gS (fp-k 11.3)A
- (iii) fdl h fn, x, izk'k l onsh inkFiz oð fy,] , d fuf'pr U; wære vrd vkofuk gærk gSftl s ngyh vkofuk dgrs gA ftl oð uhs izk'k dk byðvRnka dk dæbz mRl tæ ugha gærk pgs vki frr izk'k færuk Hkh rhoz D; ka u gæ ngyh vkofuk oð Åij] fujkæh foHko vFkok rF; r% mRl ftæ izk'k dk byðvRnka dh mPpre xfrt Åtkz vki frr fofdj.k dh vkofuk oð l kfk jS[kæd-% c<rh gS i jæq; g bl dh rhork l s Loræ gærk gS (fp-k 11.5)A

(iv) iðk'k&fo|q mRI tzu fcuk fdh dky&i'prk oð (~10⁻⁹s vFkok de) , d rR{kf.kd ifð; k gð rc Hkh tc vkifrr fofdj.k dls vR; fêd em dj fn; k tkrk gð

11.5 iðk'k&fo|q i Hkko rFkk iðk'k dk rjx fl ¼kr

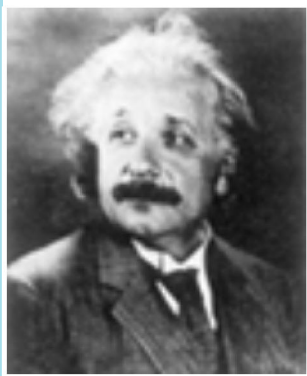
iðk'k dh rjx i Ñfr mluhl oha 'krkCnh oð var rd vPNh rjg LFkfr gis xbz FkA iðk'k oð rjx&fp=k oð }kjk 0; frdj.k] foorzu rFkk êk. k dh ?kVukvka dh LokHkfoð , oð l rRkktud : i ea0; k[; k dh tk pph FkA bl fp=k oð vuq kj] iðk'k , d oS ppeðh; rjx gð tksfo|q , oapeðh; {tsk l sfeydj cuh gsrh gsrFk ft l vkdk'kh; {tsk ea i ðyh gsrh gð ogk} Åtkz dk l arr forj.k gsrk gð vc ge ; g n[ksfd D; k iðk'k dk ; g rjx&fp=k.k fi Nys vubHkx eafn, x, iðk'k&fo|q mRI tzu l ækth i {k.kka dh 0; k[; k dj l drk gð

iðk'k&fo|q mRI tzu oð rjx&fp=k.k oð vuq kj êkkrq oð i"B (tgk fofdj.k dh fdj.k&iq; i MfH gð) ij Lorak byðVRU fofdjr Åtkz dls l arr : i ea vo'kks"kr djrs gð ftruh vfêd iðk'k dh rhork gsrh mrus gh vfêd oS q rFkk ppeðh; {tska oð vk; ke gkæð ijf.kkeLo: i] rhork ftruh vfêd gsrh mruk gh vfêd i R; d byðVRU oð }kjk Åtkz&vo'kks.k gskuk pkfg, A bl fp=k.k oð vuq kj] iðk'k dk byðVRU dh mPpre xfrt Åtkz rhork ea of¼ oð l kFk c<uh pkfg, A l kFk gh] pkgs iðk'k dh vkofuk oqN Hkh gkð , d i; klr rhoz fofdj.k fdj.k&iq; (i; klr l e; eð) byðVRUka dls bruh i; klr Åtkz nus ea l eFz gsrk tks buoð êkkrq; i"B l sckgj fudyus oð fy, vko' ; d fuEure Åtkz l s vfêd gsrhA bl fy,] , d ngyh vkofuk dk vflRro ugha gskuk pkfg, A rjx fl ¼kr dh bu i kxðDr; ka l s vubHkx 11.4.3 eafn, x, i {k.kka (i), (ii) rFkk (iii) dk l hêk fojkêk gsrk gð

vkxs gea è; ku j [kuk gsrk fd rjx&fp=k.k eð byðVRU }kjk Åtkz dk l arr vo'kks.k fofdj.k oð ijs rjxkx ij gsrk gð pfid , d cMh l q; k ea byðVRU Åtkz vo'kks"kr djrs gð vr% ifr byðVRU ifr bdkbz l e; ea vo'kks"kr Åtkz cgr de gsrhA Li "V x.kuk l s; g vkdyu fd; k tk l drk gsfð , dy byðVRU oð fy, dk; &iOyu dls i kj dj êkkrq l sckgj fudy vkus oð fy, i; klr Åtkz tðkus ead b?kvs vFkok vlg Hkh vfêd l e; yx l drk gð ; g fu"d"l Hkh i {k.k (iv), ft l oð vuq kj iðk'k&fo|q mRI tzu (yxHkx) rR{kf.kd gsrk gð oð fcyoðy foi jhr gð l {k i eð rjx&fp=k.k oð }kjk iðk'k&fo|q mRI tzu oð vR; r ewy y {k.kka dh 0; k[; k ugha gsk l drhA

11.6 vkbLvkbu dk iðk'k&fo|q l ehdj.k % fofdj.k dk Åtkz Dokæ

l u~1905 eavYcVZ vkbL vkbu (1879 – 1955) us iðk'k&fo|q i Hkko dh 0; k[; k oð fy, oS ppeðh; fofdj.k dk , d eðyd : i l su; k fp=k.k i Lrkfor fd; ka bl fp=k.k eð iðk'k&fo|q mRI tzu fofdj.k l s l arr Åtkz&vo'kks.k oð }kjk ugha gsrhA fofdj.k Åtkz fofodr bdkb; ka l s cuh gsrh gð tks fofdj.k dh Åtkz oð Dokæ/k dgykrs gð fofdj.k Åtkz oð i R; d Dokæ dh Åtkz nv gsrh gð tgk n lykæd flFkjæd gs vlg v iðk'k dh vkofuk iðk'k&fo|q i Hkko eð , d byðVRU fofdj.k oð , d Dokæ dh Åtkz (nv) vo'kks"kr djrk gð ; fn Åtkz dk ; g vo'kks"kr Dokæ byðVRU oð fy, êkkrq dh l rg l sckgj fudy vkus



vYcVZ vkbhVkbv (1879 - 1955)

vYcVZ vkbhVkbv (1879 - 1955)
 I u-1879 ea tezh eamYe uked LFkku ij tlesvYcVZ vkbhVkbv vkt rd oð fo'o oð HKSrdfonka ea lokE/d egku HKSrdfon oð : i ea tkustkrsgð mudk fole; dkhj oðkrfud thou muoð I u-1905 ea izdk'kr rhu Økardkhj 'ks/i-ka I s vkjðk gq/vA mlglaus vius i Fie 'ks/i-ka ea izdk'k Dokk (vc i-ks/vkU dgk tkrk g) dh /kj.k dks i Lrj fd; k vlg izdk'k oðs q i Hkko oð ml y{k.k dh 0; k[; k dh ft I s fofdj.k dk fpji rfr"Br rjæ fl ¼ar ugha I e>k I dka vius ml js'ks/i-ka eamlglaus clmuh xfr dk fl ¼ar fodfl r fd; k ft I dh oðN o"kecln iz lskRed i q"V gbZ vlg ft I us nð; oð vkf.od fp-k.k dk fo'okl k i knd I k[; mi yC/ djk; ka muoð rrrh; 'ks/i-ka us vki f{kdrk oð fo'k"V fl ¼ar dks tle fn; ka I u-1916 eamlglaus vki f{kdrk oð 0; ki d fl ¼ar dks izdk'kr fd; ka vkbhVkbv oð oðN vU; egROI wIz ; lsknku gð% mihfir mRI tzu dh /kj.k tks lykæd Ñf".kdk fofdj.k fu; e oð , d oðs fyi d 0; ði lu eai Lrj dh xbz gð fo'o dk LFrd ifr: i ft I usvk/þud oðeðVdh dk vkjðk fd; kj fdl h xð oð LFoy clk wU dh Dokk/e&I k[; dh rFk Dokk/e&; k-ð dh I ðFki uk dk vlykpuRed fo'ySk. ka I ¼ard HKSrdh ea muoð ; lsknku rFk izdk'k&fo|q i Hkko oð fy, 1921 eamlgla ukcsy ij Ldkj I s I Eekfur fd; k x; ka

oð fy, fuEure vko' ; d ÅtkI svfæd gsk gS (dk; &i Øyu] φ₀) rc mRI ftr byðVRU dh vf/dre xfrt ÅtkI gskh %

$$K_{mp} = hv - \phi_0 \tag{11.2}$$

vf/d n<fk I s vlc¼ byðVRUka oð mRI ftr gskus ij mudh xfrt ÅtkI viusvf/dre eku I s de gskh gð è; ku nafd fdl h vkofuk oð izdk'k dh rhork] ifr I oðM vkifrr i-ks/vkUka dh I ð; k }kjk fu/kEjr gskh gð rhork c<kus ij ifr I oðM mRI ftr byðVRUka dh I ð; k c<fh gð rFkfi] mRI ftr izdk'kd byðVRUka dh vf/dre xfrt ÅtkI iR; d i-ks/vkU dh ÅtkI }kjk fu/kEjr gskh gð

I ehdj.k (11.2) dks vkbhVkbv dk izdk'k&fo|q I ehdj.k dgrsgð vc ge ; g n[k I drsgðfd fdl izdkj ; g I ehdj.k vuðkx 11.4.3 ea fn, izdk'k&fo|q i Hkko I s I æfækr I Hk iðk.ka dks , d I jy , oð ifj"Ñr <x I s i Lrj djrk gð

- I ehdj.k (11.2) oð vuq kj] iðk.k oð vuq i] K_{mp} vkofuk v ij jð[kdr% fuHkj djrh gS vlg fofdj.k dh rhork ij fuHkj ugha djrh gð , d k bl fy, gqk gSD; k d vkbhVkbv oð fp-k.k eð izdk'k&fo|q i Hkko , dy byðVRU }kjk fofdj.k oð , dy Dokk/e oð vo'ksk.k I s mRI lu gskh gð fofdj.k dh rhork (tks ÅtkI Dokk/eka dh I ð; k ifr bdkbz {tski Øy ifr bdkbz I e; oð vuðekuq krh g) bl ey; ifø; k oð fy, vl ær gð

- D; k d $K_{mp} = \frac{1}{2} k jk'$ k ugha gskh] I ehdj.k (11.2) ea; g varfuZgr gSfd izdk'k&fo|q mRI tzu rHk I Hkko gS tc

$$hv > \phi_0$$

$$vFkok \quad v > v_0, \text{ tgl}$$

$$v_0 = \frac{\phi_0}{h} \tag{11.3}$$

I ehdj.k (11.3) oð vuq kj] dk; &i Øyu φ₀ oð vf/d eku oð fy,] izdk'kd byðVRU mRI ftr djus oð fy, vko' ; d U; ure vFkok ngyh vkofuk v₀ dk eku vf/d gskhA bl izdkj] , d ngyh vkofuk v₀ (= φ₀/h) vflrro ea gskh gS ft I s de vkofuk ij dkbZ izdk'k&fo|q mRI tzu I Hkko ugha gð pks fofdj.k dh rhork oðN Hk D; ka u gS vFkok og i"B ij fdruh Hk nj D; ka u i Mð

- bl fp-k.k eð fofdj.k dh rhork] tð k Åij ifjyf{kr gð ÅtkI Dokk/ dh I ð; k ifr bdkbz {tski Øy ifr bdkbz I e; oð vuðekuq krh gskh gð ftruh vfæd I ð; k ea ÅtkI Dokk/ mi yCek gskh] mruh gh vfæd I ð; k eabyðVRU ÅtkI Dokk/ dk vo'ksk.k djæsvlg bl fy, (v > v₀ oð fy,) èkkq I s ckj vkus okys byðVRUka dh I ð; k mruh gh vfæd gskhA bl I s ; g Li"V gsk tkrk gS fd D; ka v > v₀ oð fy, izdk'k&fo|q èkkj rhork oð vuðekuq krh gskh gð
- vkbhVkbv oð fp-k.k eð izdk'k&fo|q i Hkko ea , d byðVRU oð }kjk

izk'k oð , d Dokk/e dk vo'kkk.k eyw iKkfed iFØ; k gksh gð ; g iFØ; k rR{Kf.kd gksh gð bl izk] rhork vFkkz fótdj.k Dokk/k dh I ð; k pkgs ftruh Hkh gkð izk'k&fo|q mRI tzu rR{Kf.kd gh gksh de rhork l smRI tzu eafoyæ ughagksh D; kðd eyw iKkfed iFØ; k ogh jgsxA rhork l sooy ; g fuèkzjr gksh gsfð fdrusbyDVVV bl iKkfed iFØ; k (, d , dy byDVVV }kjk , d izk'k Dokk/e dk vo'kkk.k) eaHkkx ys l dus okys byDVVV dh I ð; k l sgh izk'k&fo|q /kjk oð ifjek.k dk fu/kj.k gksh gð l ehdj.k (11.1) dk mi ; l x dj] izk'k&fo|q l ehdj.k (11.2) dks bl izk] fy [kk tk l drk gð

$$e \mathbf{v}_0 = \mathbf{h} \mathbf{v} - \phi_0 ; \text{ oð } fy, v \geq v_0$$

$$vFkok \mathbf{v}_0 = \left(\frac{h}{e}\right) \mathbf{v} - \frac{\phi_0}{e} \tag{11.4}$$

; g , d egRo iwiz ifj.kke gð bl l s; g iKkDr gksh gsfð \mathbf{v}_0 oð fo#¼ v dk oð , d l jy jçkk gð ftl dk < yku = (h/e) , tks fd inkFkz dh iðfr ij fuHkz ugha djrk 1906&1916 oð eè;] fefydu us vkba.Vkbu oð izk'k&fo|q l ehdj.k dks vl R; kfir djus oð fy, izk'k&fo|q iHkko ij iz, ksh dh kçkyk dh fp=k 11-5 ea n'kkz, vuq kj] ml us l kM; e oð fy, iKk l jy jçkk dk < yku eki kA e oð Kkr eku dk mi ; l x dj ml us l ykð flFkjkd h dk eku fuèkzjr fd; k FkA ; g eku l ykð flFkjkd oð ml eku (= 6.626×10^{-34} J s) oð fudV Fk ftl sfcy oð gh fHku l mHkz eaKkr fd; k x; k FkA bl izk] l s 1916 eafefydu us vkba.Vkbu oð izk'k&fo|q l ehdj.k dks vl R; kfir djus oð LFkku ij ml dh l R; rk dks LFkkfir fd; kA

izk'k Dokk/k dh ifjdYiuk , oah rFkk ϕ_0 oð eku (tks vl; iz, ksh l s iKk eku l sesy j [krs gð) oð fuèkz.k oð mi ; l x l s izk'k&fo|q iHkko oð vkba.Vkbu oð fp=k.k dks Lohdkjk x; kA fefydu us izk'k&fo|q l ehdj.k dks cMh ifj'kçrk l s dbz {kjh; èkkrq/k oð fy, fótdj.k&vkofuk; k oð foLrr ijkl oð fy, l R; kfir fd; kA

11.7 izk'k dh d.kh; iðfr % Hkks/kW

izk'k&fo|q iHkko us bl foy{k.k rF; dks iæf.kr fd; k fd izk'k fd l h æ0; oð l kFk vl; k; fØ; k eabl izk] 0; ogkj djrk gStS s; g Dokk/k vFkok Åtkz oð iðv (ftuea i R; d dh Åtkz $h v$ g) dk cuk gkð

D; k izk'k Åtkz oð Dokk/e dks fd l h d.k l s l æ¼ fd; k tk l drk gð vkba.Vkbu , d egRo iwiz ifj.kke ij igpsfd izk'k Dokk/e dks l x ($h v/c$) l s l æ¼ fd; k tk l drk gð Åtkz oð l kFk l kFk l x dk fu'pr eku bl dk izy l pd gsfð izk'k Dokk/e dks d.k l s l æ¼ fd; k tk l drk gð bl d.k dks ckn ea iðv uke fn; k x; kA izk'k oð d.k tS s 0; ogkj dks, - , p- dka Vu (1892-1962) oð byDVVV oð }kjk x-fdj.kk oð izh.kz oð iz, ksh l s l u-1924 ea i q% i qv fd; k x; kA l s krd Hksh dh ea; kshnu rFkk izk'k&fo|q iHkko oð vius dk; Z oð fy, vkba.Vkbu dks 1921 ea Hksh dh dk uksey ij Ldkj inku fd; k x; kA fo|q oð eyw vkosk rFkk izk'k&fo|q iHkko ij fd, x, dk; Z oð fy, l u-1923 ea fefydu dks Hksh dh dk uksey ij Ldkj inku fd; k x; kA

ge oð rppd; fótdj.k oð iðv fp=k.k dk l kjk k fuEkuq kj ns l drs gð %

- (i) fofdj.k oð æ0; oð l kfk vU; kð; fØ; k eþ fofdj.k bl izdkj 0; ogkj djrk gsekuls; g , d s d. ka l s cuk gks ftUga i-eks/kU dgrs gð
- (ii) i R; d i-eks/kU dh Åtkiz $E (=hv)$ gksh gSVkð l oð $p (=hv/c)$ rFkk pky c gksh gð tglk c izdk'k dh pky gð
- (iii) , d fuf'pr vkofük v, vFkok rjxnð; $Z\lambda$, oð l Hkh i-eks/kU dh Åtkiz $E (=hv = hc/\lambda)$ vð l oð $p (=hv/c = h/\lambda)$, , dl eku gkrs gð (fofdj.k dh rhork pkgstks Hkh gk) A fdl h nh xbz rjxnð; Z oð izdk'k dh rhork $c < \lambda$ us ij oðoy fdl h fn, x, {sk l s xfkjus okys ifr l oðm i-eks/kU dh l ð; k gh $c < \lambda$ h gS (l Hkh i-eks/kU dh Åtkiz, dl eku gksh gð) A vr% i-eks/kU dh Åtkiz fofdj.k dh rhork ij fuHkj ugha djrha
- (iv) i-eks/kU fo|q mnkl hu gkrs gð vð fo|q rFkk pðdh; {skka oð }kjk fo{kfir ugha gkrs
- (v) i-eks/kU d.k l ðkêð (ts sfd i-eks/kU byDVU l ðkêð) eaofy Åtkiz rFkk ofy l oð l jf{kr jgrs gð rFkfi] fdl h l ðkêð ea i-eks/kU dh l ð; k Hkh l jf{kr ugha jg l drh gð i-eks/kU vo'kk"kr gks l drk gS vFkok , d u; k i-eks/kU l ftr gks l drk gð

mngj.k 11.1

mngj.k 11.1 6.0×10^{14} Hz vkofük dk , do.kh izdk'k fdl h yd j oð }kjk mRi lu fd; k tkrk gð mRi tU {kerk 2.0×10^{-3} W gð (a) izdk'k fdj.k&ið ea fdl h i-eks/kU dh Åtkiz fdruh gð (b) l kr oð }kjk vð r rð ij ifr l oðm fdrus i-eks/kU mRi ftr gkrs gð

gy

(a) i R; d i-eks/kU dh Åtkiz gksh
 $E = hv = (6.63 \times 10^{-34} \text{ J s}) (6.0 \times 10^{14} \text{ Hz})$
 $= 3.98 \times 10^{-19} \text{ J}$

(b) ; n l kr oð }kjk ifr l oðm mRi ftr i-eks/kU dh l ð; k N gS rks fdj.k&ið ea l pfjr {kerk P ifr i-eks/kU Åtkiz E oð N xuk gksh ft l l sfd $P = NE$ A rc

$$N = \frac{P}{E} = \frac{2.0 \times 10^{-3} \text{ W}}{3.98 \times 10^{-19} \text{ J}}$$

$$= 5.0 \times 10^{15} \text{ i-eks/kU ifr l oðm}$$

mngj.k 11.2

mngj.k 11.2 ; n l hf"k; e dk dk; &iðyu 2.14 eV gS rks ifjdyu dhft, % (a) l hf"k; e dh ngyh vkofük rFkk (b) vki frr izdk'k dk rjxnð; ; n izdk'k d ðkkj dks 0.60 V dk , d fujksh foHko yxkdj 'k; fd; k tk, A

gy

(a) vrd vFkok ngyh vkofük oð fy,] vki frr fofdj.k dh Åtkiz $h\nu_0$ dk; Ziðyu ϕ_0 oð l eku gksh gð vr%

$$\nu_0 = \frac{\phi_0}{h} = \frac{2.14 \text{ eV}}{6.63 \times 10^{-34} \text{ J s}}$$

$$= \frac{2.14 \times 1.6 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ J s}} = 5.16 \times 10^{14} \text{ Hz}$$

bl izdkj $\nu_0 = 5.16 \times 10^{14}$ Hz l sde vkofük; ka oð fy,] dks izdk'k d byDVU eðr ugha gkrs gð

(b) mRi ftr izdk'k d byDVU dh mPpre xfrt Åtkiz $e\nu_0$ fLFkrt Åtkiz (emu&foHko ν_0 oð }kjk) oð l eku gks dh fLFkr ea izdk'k d ðkkj 'k; gk tkrh gð vkblvku dk izdk'k&fo|q l ehdj.k fuEu gS%

fof dj. k rFkk n0; dh }f i0fr

$$eV_0 = hv - \phi_0 = \frac{hc}{\lambda} - \phi_0$$

vFlok $\lambda = hc/(eV_0 + \phi_0)$

$$= \frac{(6.63 \times 10^{-34} \text{ J s}) \times (3 \times 10^8 \text{ m/s})}{(0.60 \text{ eV} + 2.14 \text{ eV})}$$

$$= \frac{19.89 \times 10^{-26} \text{ J m}}{(2.74 \text{ eV})}$$

$$\lambda = \frac{19.89 \times 10^{-26} \text{ J m}}{2.74 \times 1.6 \times 10^{-19} \text{ J}} = 454 \text{ nm}$$

mnkgj. k 11.2

mnkgj. k 11.3 n'; {lsk ea c&uh j& ihy&gjs j& rFkk yky j& o0 idk'k dh rj&nS; Z 0e'k% yxHkx 390 nm, yxHkx 550 nm (v& r rj&nS;) rFkk yxHkx 760 nm g& (a) n'; {lsk o0 fuEu idk'k o0 fy, i0v& dh &tlz (eV) D; k g&h% (i) c&uh fl jk (ii) ihy&gjs j& dh v& r rj&nS; ; Z rFkk (iii) yky fl jk ($h = 6.63 \times 10^{-34} \text{ J s}$ rFkk $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$) (b) idk'k&l 0nh inkFkz o0 fy, l kj. h 11.1 esfn, x, dk; &i0yu o0 eku rFkk (a) iz u o0 (i), (ii) rFkk (iii) Hkx&o0 ifj. k&e& d&mi ; l& ea ykrsgg D; k vki n'; idk'k o0 l Fk dk; Zdj l dusokyh idk'k fo l r ; 0Dr dk l tu dj l drsg&

gy

(a) vkifrr i0v& dh &tlz $E = hv = hc/\lambda$

$$E = \frac{(6.63 \times 10^{-34} \text{ J s}) (3 \times 10^8 \text{ m/s})}{1.989 \times 10^{-25} \text{ J m}} = \frac{\lambda}{\lambda}$$

(i) c&uh idk'k o0 fy, $\lambda_1 = 390 \text{ nm}$ (fuEu rj&nS; ; Z fl jk)

$$\begin{aligned} \text{vkifrr i0v& dh } \hat{A} \text{tlz } E_1 &= \frac{1.989 \times 10^{-25} \text{ J m}}{390 \times 10^{-9} \text{ m}} \\ &= 5.10 \times 10^{-19} \text{ J} \\ &= \frac{5.10 \times 10^{-19} \text{ J}}{1.6 \times 10^{-19} \text{ J/eV}} \\ &= 3.19 \text{ eV} \end{aligned}$$

(ii) ihy&gjs idk'k o0 fy, $\lambda_2 = 550 \text{ nm}$ (v& r rj&nS; ;)

$$\begin{aligned} \text{vkifrr i0v& dh } \hat{A} \text{tlz } E_2 &= \frac{1.989 \times 10^{-25} \text{ J m}}{550 \times 10^{-9} \text{ m}} \\ &= 3.62 \times 10^{-19} \text{ J} = 2.26 \text{ eV} \end{aligned}$$

(iii) yky idk'k o0 fy, $\lambda_3 = 760 \text{ nm}$ (mPp rj&nS; ; Z fl jk)

$$\begin{aligned} \text{vkifrr i0v& dh } \hat{A} \text{tlz } E_3 &= \frac{1.989 \times 10^{-25} \text{ J m}}{760 \times 10^{-9} \text{ m}} \\ &= 2.62 \times 10^{-19} \text{ J} = 1.64 \text{ eV} \end{aligned}$$

(b) fdl h idk'k&fo l r ; 0Dr o0 dk; Z o0 fy, vkifrr idk'k &tlz E dk eku iz 0r inkFkz o0 dk; &i0yu o0 eku o0 l eku ; k vf/d g&ik p&fg, A vr% c&uh idk'k ($E = 3.19 \text{ eV}$) o0 fy, dk; Zdj l dusokyh idk'k&fo l r ; 0Dr o0 idk'k&l 0nh inkFkz Na (dk; Z i0yu $\phi_0 = 2.75 \text{ eV}$), K (dk; &i0yu $\phi_0 = 2.30 \text{ eV}$) rFkk Cs (dk; &i0yu $\phi_0 = 2.14 \text{ eV}$) g&l drsg& ; g ; 0Dr ihy&gjs idk'k ($E = 2.26 \text{ eV}$) o0 fy, idk'k&l 0nh inkFkz Cs (dk; &i0yu $\phi_0 = 2.14 \text{ eV}$), o0 mi ; l& l sgh dk; Zdj l drh g& rFkfi ; g ; 0Dr yky idk'k ($E = 1.64 \text{ eV}$) o0 fy, mi j&Dr rhuk&e&l s&dl h idk'k&l 0nh inkFkz o0 mi ; l& l s& ; Zugh&dj l o0x&

mnkgj. k 11.3

11.8 n0; dh rjx i0fr

izk'k (0; ki d rlg ij os rppdh; fofdj.k) dh }s iNfr (rjx&d.k) or2ku rFk i0z v0;k; ka ea fd, x, v0; ; u }kjk Li"V : i ls izdV gsrh gA izk'k dh rjx iNfr 0; frdj.k] foorZu rFk 0p.k dh ifj?kVukvka eanf"Vxkpxj gsrh gA nu jh vlg] izk'k&fo| r i Hko rFk dKvi Vu i Hko ftuea Atkz vlg l 0x dk varj.k gsrk g\$ fofdj.k bl izdkj 0; ogkj djrk g\$ fd ekuls ; g d.ka 00 xPN vFkz i-0s/KUka ls cuk gla d.k vFkok rjx&fp=k.k ea l s dks fdl h iz lxx dks le>usea l 0k0kd mi ; 0r g\$; g iz lxx dh iNfr ij fuHk] gA mnkgj.k 00 fy,] vius uska l s fdl h 0Lrq dks n\$kus dh l qjfr ?kVuk ea nskaka gh fp=k.k egroiwlz gA usk yd }kjk izk'k dks , d= dj i-0kd l djus dh if0; k dks rjx&fp=k.k l s Hkyh&Hkfr fo0spr fd; k x; k gA i jarqbl dk 'kykdkvkarFk 'k0qvka (jSVuk 00) }kjk vo'kSk.k ea i 0s/KU fp=k.k dh vko' ; drk gsrh gA

, d LokHk0fod izu ; g mBrk g\$fd ; fn fofdj.k dh }s iNfr (rjx rFk d.k) g\$rls D; k iNfr 00 d.k (byDVRU] i 0s/KU vlfm) Hk rjx&t\$ k y{k.k inE'kr djrs gA l u-1924 ea, d i 0kd hl h HKSRdoKk0fud y0l f0DVj nscMlyh (i 0p mPpkj.k eabl sy0z f0DVj nsc, i 0dkj tkrk g\$) (1892 – 1987) us, d fuHk0d ifjdYiuk dks iLrq fd; k fd inkFkz 00 xfreku d.k mi ; 0r ifjLFkr; ka earjx l n'k xqk inf'kz dj l drsgA ml us; g ro0 fn; k fd iNfr l efer g\$ vlg nls ey HkSRd l 0k vlg 00; , 0a Atkz dk Hk l efer y{k.k gskuk plfg, A ; fn fofdj.k dk }s y{k.k g\$rls 00; dk Hk gskuk plfg, A nscMlyh us iLrfor fd; k fd l 0x p 00 d.k 00 l kFk t0l rjxn\$; Z l fuEu izdkj n'kz h tk l drh g\$ %

$$\lambda = \frac{h}{p} = \frac{h}{mv} \tag{11.5}$$

tgk m d.k dk 00; eku rFk v bl dh pky gA l ehdj.k (11.5) dks nscMlyh dk l 00k vlg 00; &rjx 00 rjxn\$; Z l dks nscMlyh rjxn\$; Z dgrs gA 00; dk }s Lo: i nscMlyh 00 l 00k ea Li"V gA l ehdj.k (11.5) dh 0k0±vlg] l rjx dk y{k.k g\$ tcf d n0±vlg l 0x p d.k dk fof"V y{k.k gA lyk0d fLFkj0d n nskaka y{k.k ka dks l a kstr djrk gA

l ehdj.k (11.5) , d inkFkz d.k 00 fy, eyr% , d ifjdYiuk g\$ftl dh ro0l xfr 00oy iz lxx 00 }kjk gh ij [kh tk l drh gA rFkfi] ; g n\$kus jk0d g\$fd ; g , d i-0s/KU 00 }kjk Hk l r0V gsrk gA , d i-0s/KU 00 fy,] t\$ k fd geus n\$kk g\$

$$p = hv / c \tag{11.6}$$

bl fy,]

$$\frac{h}{p} = \frac{c}{v} = \lambda \tag{11.7}$$

vFkz] , d i-0s/KU dk nscMlyh rjxn\$; Z tks l ehdj.k (11.5) }kjk fn; k x; k g\$ ml 0s rppdh; fofdj.k 00 rjxn\$; Z 00 l eku gsrk g\$ rFk i-0s/KU fofdj.k dh Atkz rFk l 0x dk , d Dok0e gA

Li"Vr% l ehdj.k (11.5) 00 }kjk l , d " ; knk Hkjh d.k (cMk m) vFkok vfeld AtLoh d.k (cMk v) 00 fy, Nk/k gskka mnkgj.k 00 fy,] , d 0.12 kg 00; eku dh xm tks 20 m s⁻¹ dh pky l s py jgh g\$ dh nscMlyh rjxn\$; Z dk l jyrk l s ifjdyu fd; k tk l drk gA

fodj.k rFkk nD; dh }f idfrr

lkoS/ks l sy

lkoS/ks l sy (izk'k l sy) izk'k&fo|q i Hko dk , d f'kyi i kS kSxdh; vuqz, l x gB ; g , d , d h ; qDr gStks izk'k&AtkZ dksos q&AtkZ eacny nrh gB bl sdHh&dHh fo|q usk Hh dgrsgB , d lkoS/ks l sy ea, d vek&csyukdj izk'k&l dsh ekkrq ifeZk C (mRI tZl) gsrh gsvlS , d rkj dk ik'k (yui) A (l xkgd) , d fuokZrr dlp ; k DokVZ'k cYc ea yxsglsgB bl sfp=k ean'kZ, vuq kj fd l h ckA ifji Fk ea, d mPp&foHko cSjh B rFkk ekbDks eHVj (μA) oD l kFk l a kStr fd; k tkrk gS dHh&dHh ifeZk C oD LFku ij izk'k&l dsh inkFkZ (c) dh , d iryh ijr cYc dh Hkrjh lrg ij fpidk nh tkrh gB cYc oD , d Hkx dls l kHQ NkM+fn; k tkrk gSft l l sfd izk'k bl ea idSk dj l oB

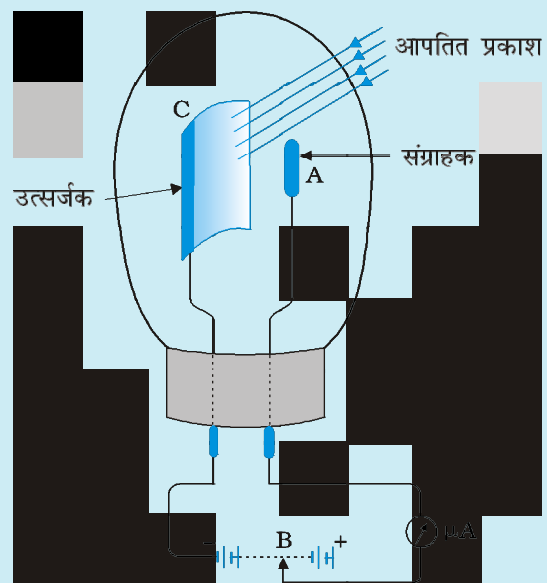
tc mi; qDr rjxnS; Zdk izk'k mRI tZl C ij iMfK gS rks byDVWU mRI ftZ gsrsgB ; sidk'kd byDVWU l xkgd ij vkdf'kr gS tkrsgB fd l h izk'k l sy l soqN ekbDks fEi ; j dh dksV dh izk'k&l ekjk ikr dh tkrh gB

, d izk'k l sy inhkr&rhok ea ifjorZu dj izk'k&l ekjk ea ifjorZu dj l drk gB ; g ekjk fu; ak.k rak oD pkyu vlS izk'k ekid ; qDr; ka ea mi; l x ea ykbZ tk l drh gB vojDr fodj.k oD fy, l dsh yM l YifkM oD izk'k l sya dk mi; l x byDVWUud iToyu ifji Fka eafd; k tkrk gB

oBkrfud dk; l x eD izk'k dh rhok dskedi us oD l Hh vuqz, l x ea izk'k l sya dk mi; l x fd; k tkrk gB i fK/kski dh oBjka ea izk'k ekid izk'k l sy dk mi; l x vkfrr izk'k dh rhok eki us ea djrsgB Lopkyr }kj fu; akd ea izk'k l sy dk iz, l x }kj&izk'k fo|q ifji Fk ea gsrk gB }kj dh vlS c<fsgg 0; fDr }kj izk'k l sy ij iMusokys izk'k i qd ckf/r gS l drsgB izk'k&l /kj ea vpkud gksokyscnyko dk mi; l x }kj [kysu oD fy, ekSj dls i kjbk djusea; k vykeZctkuseafd; k tk l drk gB budk mi; l x ml x.kuk; qDr oD fu; ak.k ea Hh fd; k tkrk gStks izk'k fdj.k&i qd dh iR; d #dkoV] tksfdj.k&i qd oD i k fd l h 0; fDr vFkok oLrqoD tkusoD dkj.k mRI lu gsrh gS dks vdr djrk gB bl fy,] izk'k l sy fd l h i fKxg ea idSk djusokys 0; fDr; ka dh x.kuk djusea l gk; rk djrk gS ; fn osfo'ky d{k ea, d&, d djoD idSk djrsgB budk mi; l x ; krk; kr fu; e rksMusokyka dh i gpk oD fy, fd; k tkrk gB tc Hh fodj.k oD , d fdj.k&i qd dks vojkskr fd; k tkrk gS rks, d , ykeZctk; k tk l drk gB

plS , ykeZ eD ijk&kuh izk'k (vn';) dks lrr idSk&}kj ij LFkfir izk'k l sy ij Mky tkrk gB dkbZ 0; fDr tks }kj ea idSk djrk gSog izk'k l sy ij iMusokysfdj.k&i qd dks vojkskr djrk gB izk'k&l fo|q&ekjk ea vkdf'led ifjorZu dk mi; l x , d fo|q ?k/h oD ctus l i kjbk fd; k tkrk gB vFku&, ykeZ eD Hkou eami; qDr LFkku ij dbZ izk'k l sy LFkfir dj fn, tkrsgB vx yxus ij izk'k fodj.k izk'k l sy ij iMfsgB bl l s, d fo|q ?k/h vFkok , d Hkai w lsgkdj tkus okyk ifji Fk iwZ gS tkrk gS vlS ; g , d prkouh&l dDr oD : i ea dk; Z djuk i kjbk dj nrk gB

izk'k l sya dk mi; l x py fp=k.k ea eofu oD i q#Ri knu rFk Vsyfo"ku oBjsean"; oD Oeoh{k.k (scanning) rFk Vsyfo"ku iZ kj.k (telecasting) eafd; k tkrk gB budk iz, l x m | ksk ea /krq dh pknjka ea NkS/h =qV; ka rFk fNnta dks [kst us ea Hh fd; k tkrk gB



lkoS/ks l sy

$$p = m v = 0.12 \text{ kg} \times 20 \text{ m s}^{-1} = 2.40 \text{ kg m s}^{-1}$$

$$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34} \text{ J s}}{2.40 \text{ kg m s}^{-1}} = 2.76 \times 10^{-34} \text{ m}$$



yφl foDVj ns cMlyh (1892 - 1987) i dld hl h HKSrdfon ftUglaus nð; dh rjæ i Ñfr dk Økærdkjh fopkj i Lrø fd; kA ; g fopkj bjfou JksMxj }kj k Dokve&; kA-dh oð , d l äwzfl ¼kr oð : i eafodfl r fd; k x; kj ftl sl keW; r% rjæ&; kA-dh dgrs gð byðVRM d h rjæ i Ñfr dh [kæst oð fy, blgø l u-1929 ea ukæsy ijLdkj l sl Eekfur fd; k x; kA

; g rjæns; Zbruh NKS h gSfd ; g fdl h eki u dh l hek l sckgj gð ; gh dkj.k gSfd LFloy oLrq; gekjs nðud thou earjæ&l n'k xqk ugha n'kæz-ha nu jh vlgj] vo&i jekf.od Mkesu (Sub-atomic domain) eð d. kA dk rjæ y{k.k egROI wLz gS rFkk eki us; kA; gð , d byðVRM (æ0; eku m , vkoš k e) ftl sfojkekolLFk l s, d foHko v }kj k Roj r fd; k tkrk gð dk fopkj dja byðVRM dh xfrt Åtkz K bl ij fo| r {kæ }kj k fd, x, dk; Z($v e$) oð cjkj gæsk %

$$K = e V \tag{11.8}$$

; gkj $K = \frac{1}{2} m v^2 = \frac{p^2}{2m}$, ftl l s

$$p = \sqrt{2 m K} = \sqrt{2 m e V} \tag{11.9}$$

rc byðVRM dk ns cMlyh rjæns; Zl gæsk

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2 m K}} = \frac{h}{\sqrt{2 m e V}} \tag{11.10}$$

h, m rFkk e oð l kA; d eku dks LFkkuki uu djus ij ge fuEu eku i krs gð

$$\lambda = \frac{1.227}{\sqrt{V}} \text{ nm} \tag{11.11}$$

tgk v Rojd foHko dk oKV ea eku gð , d 120 v Rojd foHko oð fy, l ehdj.k (11.11) l s $\lambda = 0.112 \text{ nm}$ i klr gæsk gð ; g rjæns; Z ml h dkV dh gSftruh njh fØLVyka ea i jek.oh; ryka oð chip gæsk gð

bl l s; g l oðr feyrk gSfd , d byðVRM l s tðh inkFkZ rjæ dks x-fdj.k foorzu tS s fØLVy foorzu iz kæka l s ij [kæ tk l drk gð ge vxys vuðkæx ea ns cMlyh dh ifjdYi uk oð i k; kæxd ij h{k.k dk o.ku djæa byðVRM dh rjæh; i oðr dh [kæst oð fy, ns cMlyh dks 1929 ea HKSrdh oð ukæsy ijLdkj l sl Eekfur fd; k x; kA

æ0; & rjæ fp=k.k us gk"kuæz l oð vfuf' prrk fl ¼kr dks ifj"Ñr : i ea l ekfo"V fd; kA bl fl ¼kr oð vuð kj] , d gh l e; ij fdl h byðVRM (vFkok dksZ vlš d.k) dh flFkr , oal oæ nkska dks ifj' kq4 : i l seki uk vl ilko gð geš k gh oðN vfuf' prrk (Δx) flFkr oð fofunž k vlš oðN vfuf' prrk (Δp) l oæ oð fofunž k ea gæsk gð Δx rFkk Δp oð xqlui oý dh , d fuEurj l hek gæsk gð tks o* (tgk $\delta = h/2\pi$) dh dksV dh gæsk gð vFkkZ-

$$\Delta x \Delta p \approx \delta \tag{11.12}$$

l ehdj.k (11.12) bl l ilkkouk dh vuæfr ns k gSfd Δx 'kA; gæ i jærc Δp dks vuæ gæsk pfg, ftl l sfd xqlui oý 'kA; u gð bl h i d kj ; fn Δp 'kA; gæsk gð rc Δx vuæ gæsk l keW; r; kj nkska Δx rFkk Δp 'kA; ugha gæsf l l sfd mudk xqlui oý o dksV dk gð vc ; fn , d byðVRM fuf' pr l oæ p (vFkkZ $\Delta p = 0$) gæsk rc ns cMlyh l æk oð }kj k

* , d vfekd ifj' kq4 foopu l s $\Delta x \Delta p \geq \delta/2$ i klr gæsk gð

fof dj.k rFkk nD; dh }s iDfr

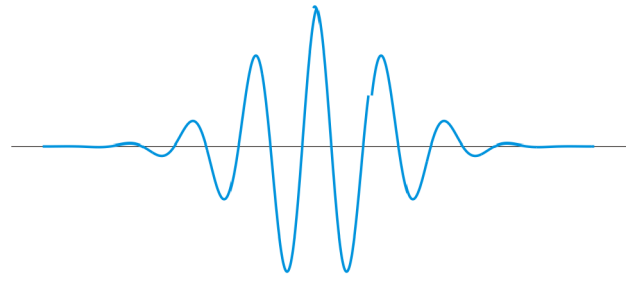
bl dk rjxnS; $L(\lambda)$ fuf'pr gLskA ,d fuf'pr (,dy) rjxnS; L dh rjx dk foLrkj l a wLz LFku ea gLsk gA cMIZ dh i kf; drk 0; k[; k l sbl dk vFkZ; g gq/k fd byDVNUI LFku oD fdl h fuf'pr {lsk ea LFkuhf; r ughagLskA vFkZ} bl dh fLFkfr vfuf'prrk vuar gLsk ($\Delta x \rightarrow \infty$) tks vfuf'prrk oD fl 1/4kr oD l kfk l xkr gA

l kedu; r% byDVNUI oD l kfk tMh i nkFkZ;rjx l a wLz vkdk'k ea folrR ugha gLskA ; g ,d rjx&iDdV oD : i ea vkdk'k ea ,d fuf'pr {lsk ea folrR gLsk gA ml fLFkfr ea Δx vuar ughagLsk gScfyd rjx&iDdV oD foLrkj ij fuHkj bl dk dksZ ijfer eku gLsk gA vki dls; g Hk tkuuk pkfg, fd ijfer foLrkj dh fdl h rjx&iDdV dk rjxnS; L , dy ugha gLskA ; g fdl h oDdh; rjxnS; L oD vki ikl foLrR rjxnS; L l s cuh gLsk gA

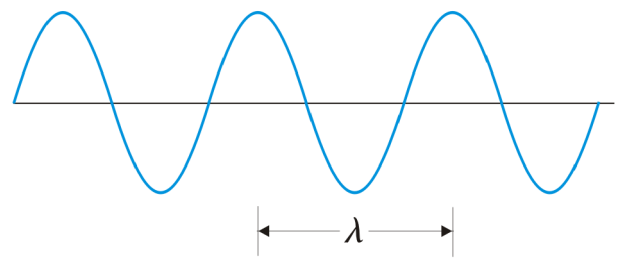
rc] ns cMlyh oD l cDk oD }kjk] byDVNUI oD l Ds dk Hk ,d foLrkj gLsk $\mu \Delta p$ dh vfuf'prrkA ; g vfuf'prrk oD l cDk l s vi f{kr gA xf. krh; $\langle x \rangle$ (mi i fUk NkM+nh xBZ gS) l s ; g n'kZ k tk l drk gS fd rjx&iDdV foj.k ns cMlyh l cDk rFk cMIZ i kf; drk 0; k[; k oD l kfk gLbt sxcZ vfuf'prrk l cDk dk ifj'kq; : i ea i q#Ri l u d jrk gA

vè; k; 12 e] ns cMlyh l cDk dks fdl h i jek.kq ea byDVNUI oD dks h; l Ds oD Dok/ehdj.k ij dks dh ifjdYiuk dh l eFkZk dks n'kZ s gq ik, xA

fp=k 11.6(a) ea ,d LFkuhf; r rjx&iDdV rFk fp=k 11.6(b) ea fuf'pr rjxnS; L oD fy, foLrR rjx dk 0; oLFk&fp=k n'kZ k x; k gA



(a)



(b)

fp=k 11.6 (a) ,d byDVNUI dk rjx&iDdV foj.kA fdl h fcmq oD vk; ke oD oxZ dks ml fcmq ij byDVNUI dh i kf; drk ?kuRo oD l kfk l cDkr fd; k x; k gA rjx&iDdV fdl h oDdh; rjxnS; L oD vki ikl rjxnS; L oD foLrkj (vLs bl i dks ns cMlyh l cDk oD }kjk] l Ds oD foLrkj) oD l kfk esy j[krk gA ifj.ker% ; g fLFkfr ea vfuf'prrk (Δx) vLs l Ds ea vfuf'prrk (Δp) l s tMh gA (b) fdl h byDVNUI oD fuf'pr l Ds l esy [krh nD; &rjx l a wLz vkdk'k ea folrR gLsk gA bl mnkgj.k ea $\Delta p = 0$ vLs $\Delta x \rightarrow \infty$

mnkgj.k 11.4 (a) ,d byDVNUI tks 5.4×10^6 m/s dh ply l s xfr dj jgk gS (b) 150 g æ0; eku dh ,d xn tks 30.0 m/s dh ply l s xfr dj jgh gS l s tMh ns cMlyh rjxnS; L ; k gLsk \

gy

(a) byDVNUI oD fy,

æ0; eku $m = 9.11 \times 10^{-31}$ kg, oX $v = 5.4 \times 10^6$ m/s

rc l Ds $p = mv = 9.11 \times 10^{-31}$ (kg) $\times 5.4 \times 10^6$ (m/s)

$$p = 4.92 \times 10^{-24} \text{ kg m/s}$$

ns cMlyh rjxnS; ; $\lambda = h/p$

$$\begin{aligned} &= \frac{6.63 \times 10^{-34} \text{ Js}}{4.92 \times 10^{-24} \text{ kg m/s}} \\ \lambda &= 0.135 \text{ nm} \end{aligned}$$

(b) xn oD fy,

æ0; eku $m' = 0.150$ kg, oX $v' = 30.0$ m/s

rc l Ds

$$p' = m'v' = 0.150 \text{ (kg)} \times 30.0 \text{ (m/s)}$$

$$p' = 4.50 \text{ kg m/s}$$

ns cMlyh rjxnS; ; $\lambda' = h/p'$

mnkgj. k 11.4

$$= \frac{6.63 \times 10^{-34} \text{ Js}}{4.50 \times 10^6 \text{ m/s}}$$

$$\lambda' = 1.47 \times 10^{-10} \text{ m}$$

byðvnu óð fy, nscðnyh rjxnþ; Lx-fdj.k rjxnþ; Zoð l eku gð i jgqxm óð fy, ; g i ðvnu óð vðkj óð yxHkx 10^{-19} xþk gð tks ik; kðxd ekiu dh l hek óð fcyoðy ckgj gð

mnkgj. k 11.5

mnkgj. k 11.5, d byðvnu, d α -d.k rFkk, d i ðvnu dh xfrt Átkl l eku gð bueal s fdl d.k dh nscðnyh rjxnþ; LU; ure glskh

gy
fdl h d.k óð fy, nscðnyh rjxnþ; $\lambda = h/p$ gð
xfrt Átkl $K = p^2/2m$

vr% $\lambda = h/\sqrt{2mK}$
l eku xfrt Átkl óð fy, fdl h d.k l sl ð¼ nscðnyh rjxnþ; Zml óð nð; eku óð oxþy óð 0; Þðekuj krh gð i ðvnu (^1_1H) byðvnu l s1836 xþk Hkjh gð rFkk α -d.k (^4_2He) i ðvnu l spkj xþk Hkjh gð
vr% α - d.k dh nscðnyh rjxnþ; LU; ure glskh

nð; rjxnþ dk i kf; drk vfk

; gk bl ckr ij fopkj djuk mfpr glsk fd fdl h d.k (tþ s byðvnu) l sl ðf/r æ0; &rjxnþ dk D; k vfk gð oklro eð vHk rd æ0; rFkk fofdj.k óð }þ i ðfr dh, d olrþ% l rskktud Hkrd l e> fodfl r ughagk l dh gð Dokve& kðdh óð egku l ðFki dka (uhYl ckgj) vYcvZ vkbvkbv vfg dbZvU;) usbl rFkk bl l sl ðfkr l ðYiukvka óð l kfk cgr l e; rd l ðk'k'fd; ka vc Hk Dokve& kðdh dh xgu Hkrd 0; k[; k l fð; 'kðk dk fo'k; cuk gþk gð bl óð glrsgg Hkjh æ0; &rjxnþ dh l ðYiuk dksclMh l i þyrk óð l kfk vkeþud Dokve& kðdh ea xf.krh; rfg ij ifo"V fd; k x; k gð bl l ðk ea, d egROIwK miyfcèk ; g gðfd tc eðl cKwZ (1882-1970) us æ0; &rjxnþ óð vk; ke dh, d i kf; drk&0; k[; k l þkð bl óð vuð kj] fdl h fcmq ij æ0; &rjxnþ dh rhork (vk; ke dk oxð) ml fcmq ij d.k dk i kf; drk-?kuRo fuekZjr djrk gð i kf; drk ?kuRo dk vfk i kf; drk ifr bðkðZ vk; ru gð bl iðkj] ; fn fdl h fcmq ij A rjxnþ dk vk; ke gð rks |A|² ΔV ml fcmq óð þkja vfg ΔV y'q vk; ru eaml d.k óð ik, tkus dh i kf; drk gð vr% fdl h fof'k"V {kðk ea ; fn æ0; &rjxnþ dh rhork vfekd gð rc ml dh rþuk ea tgl rhork de gð d.k óð ik, tkus dh i kf; drk vfekd glskh

mnkgj. k 11.6

mnkgj. k 11.6, d d.k byðvnu dh viðk rhu xþk vf/d þky l sxfr dj jgk gð bl d.k dh nscðnyh rjxnþ; Z dk byðvnu dh nscðnyh rjxnþ; Z l svuq kr 1.813×10^{-4} gð d.k óð nð; eku dk ifjdyu dhft, rFkk d.k dks igþkfu, A

gy
xfr djrs gq d.k (nð; eku m rFkk ox v) dh nscðnyh rjxnþ; Z

fofdj.k rFkk n0; dh }s idOr

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

n0; eku $m = h/\lambda v$

byDVNU dk n0; eku $m_e = h/\lambda_e v_e$

gea Kkr gSfd $v/v_e = 3$ rFkk

$$\lambda/\lambda_e = 1.813 \times 10^{-4}$$

d.k dk n0; eku] $m = m_e \left(\frac{\lambda_e}{\lambda}\right) \left(\frac{v_e}{v}\right)$

$$m = (9.11 \times 10^{-31} \text{ kg}) \times (1/3) \times (1/1.813 \times 10^{-4})$$

$$m = 1.675 \times 10^{-27} \text{ kg}$$

bl n0; eku dk d.k i kV/m; k U; W gS l drk gS

mnkgj.k 11.6

mnkgj.k 11.7 100 v oS fohkora; }kjk Rofjr fd l h byDVNU l s l af/r ns chMyh rjxnS; l dk ifjdyu dhft, A gy Rojd fohko $v = 100$ v ns chMyh rjxnS; l gksh

$$\lambda = \frac{h}{p} = \frac{1.227}{\sqrt{V}} \text{ nm}$$

$$\lambda = \frac{1.227}{\sqrt{100}} \text{ nm} = 0.123 \text{ nm}$$

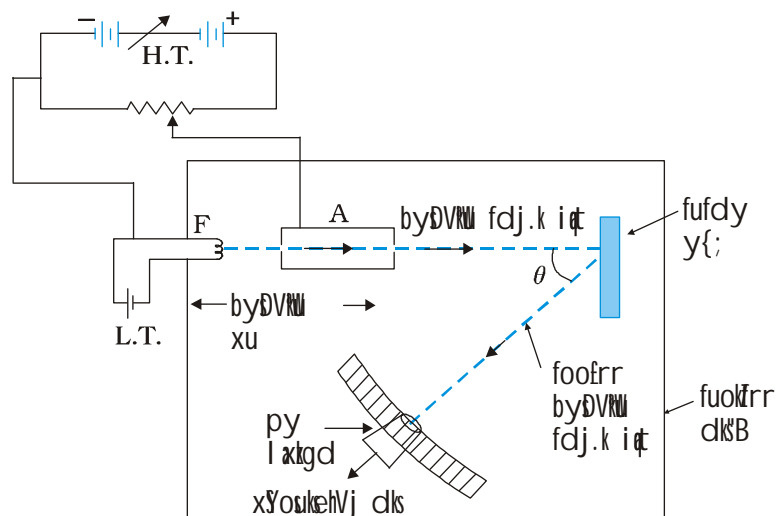
byDVNU l s l af/r ns chMyh rjxnS; l x-fdj.k rjxnS; l dh dkV dh gS

mnkgj.k 11.7

11.9 Mfolu rFkk tej iz kx

byDVNU dh rjxn iNfr ik; kSxd rS ij l oFke l h-ts Mfolu rFkk , y-, p- tej oS }kjk 1927 earFkk Lorak : i l s th-i- VKE l u oS }kjk 1928 ea l R; kfir dh xbZ FWA bu oKkfuoka us byDVNUka oS fdj.k i q; dk fDLVyk l s izh.k u oS }kjk fooru i Hko dk i k.k fd; k FWA l h-ts Mfolu (1881-1958) vS th-i- VKE l u (1892-1975) us fDLV oS }kjk byDVNUka oS fooru dh ik; kSxd [kSt oS fy, 1937 ea l a q; : i l sukSy ij l dkj i k r fd; k

Mfolu rFkk tej dh ik; kSxd 0; oLFkk fp=k 11.7 ea n'kz h xbZ gS bl ea, d ^byDVNU xu* gksh gS tks, d VakLVu rirq F dh cuh gksh gS ftl ij cfj; e vKI l kM dk yS gksh gS bl s de fohko (L.T. cSjh) l s xel fd; k tkrk gS fd l h mPp oKVRk Atk l k (HT cSjh) }kjk mi; q; fohko oKVRk



fp=k 11.7 Mfolu & tej byDVNU fooru 0; oLFKA

oð vuuqz lxx l s r r q } j k m r l e t r b y D V R M U k a d l s , s P N d o x r d R o f j r f d ; k t k r k g a b l g a , d c y u f t l e a b l o ð v { k o ð l e k r j i r y s f N æ g l s r s g ð l s i k f j r d j o ð , d i r y s f d j . k & i e t o ð : i e a l e k r j r d j f y ; k t k r k g a b l f d j . k & i e t d l s , d f u f d y f Ø L V y o ð i " B i j M k y k t k r k g a f Ø L V y o ð i j e k . k a v l a o ð } j k b y D V R M U l H k h f n ' k v l a e a i z d h f . k r g l s r s g a f d l h f n ' k k e a i z d h f . k r b y D V R M U f d j . k & i e t d h r h o r k d l s b y D V R M U l a p d (l a k t g d) o ð } j k e k i k t k r k g a l a p d d l s o ð k k d j e k i u h i j ? k e k ; k t k l d r k g s v l g , d l a k t g h x Y o s u k e h v j o ð l k f k l a k f t r d j f n ; k t k r k g ð t l s e k j k d l s v a d r d j r k g a x Y o s u k e h v j e a f o z k i l a k t g d e a i o s k d j u s o k y s b y D V R M U f d j . k & i e t d h r h o r k o ð v u o ð e k u i k r h g l s r k g a b l m i d j . k d l s , d f u o k f r r d l s B e a i f j c ¼ d j n r s g a l a p d d l s o ð k k d j e k i u h i j f o f H k U u f l F k r ; k a e a ? k e k d j j i z d h f . k r b y D V R M U f d j . k & i e t d h r h o r k d l s f o f H k U u v { k a k d l s k o ð e k u o ð f y , (v F k o k i z d h . k u o ð d l s k) e d l s e k i r s g ð t l s f d v k i f r r v l g i z d h f . k r b y D V R M U f d j . k i e t k a o ð c h p d k d l s k g l s r k g a i z d h f . k r b y D V R M U k a d h r h o r k (x) e a i z d h . k u d l s k e o ð l k f k i f j o r z u d l s f o f H k U u R o j . k f o H k o k a o ð f y , i k l r f d ; k t k r k g a

Rojd foHko oð 44 v l s 68 v oð i j k l o ð f y , b l i z l x d l s l a l u f d ; k x ; k M s o l u & t e j i z l x o ð i f j . k k e k a d l s n ' k z k x ; k g a ; g i k ; k x ; k f d , d r h { . k f o o r z u m f P p " B o ð l a r , d i z y f ' k [k j] R o j d f o H k o 54 v r f k i z d h . k u d l s k e = 50° i j b y D V R M U f o r j . k e a i z d v g l s r h g a , d f o f ' k ' V f n ' k k e a f ' k [k j d k ; g i z d v u f Ø L V y o ð i j e k . k a v l a o ð l e k u v a r j k y d h i j r k a l s b y D V R M U k a o ð l a k s k h 0 ; f r d j . k o ð d k j . k g l s r k g a b y D V R M U f o o r z u e k i u l s a e 0 ; & r j a k d k r j a n s ; 7 0 . 1 6 5 n m i k l r f d ; k x ; k a

n s c h m y h r j a n s ; 7 λ 1 l e h d j . k (1 1 . 1 1) o ð m i ; l x l s l e v = 54 v o ð f y , b y D V R M U d k e k u f u e u g l s r k %

$$\lambda = h / p = \frac{1.227}{\sqrt{V}} \text{ nm}$$

$$\lambda = \frac{1.227}{\sqrt{54}} \text{ nm} = 0.167 \text{ nm}$$

v r % n s c h m y h r j a n s ; 7 o ð l s a k i r d r f k i z l x } j k i k l r e k u k e a m l k e l g e f r g a M s o l u & t e j i z l x b l i z d j i H k k o ' k y h : i l s b y D V R M U k a d h r j a k i n f r r f k n s c h m y h l a e k d h i q ' V d j r k g a i z d k ' k d h r j a k - i n f r o ð f y , f d , x , f } f > j h i z l x o ð l e : i b y D V R M U i e t d h r j a k & i n f r d l s l u - 1 9 8 9 e a i k ; k s x d : i l s i n f ' k r f d ; k x ; k a l u - 1 9 9 4 e a H k h v k ; k a l h u v . k a v l a (t l s b y D V R M U k a d h r g y u k e a y x H k x n l y k [k x a k H k j h g ð) o ð l k f k 0 ; f r d j . k i i t a i k l r d h t k p a h g a

n s c h m y h d h i f j d Y i u k v l e k i u d D o k e ; k a k d h o ð f o d k l e a v l e k j j g h g a b l u s b y D V R M U & i z d k ' k d h f o " k ; d l s H k h f o d f l r f d ; k g a b y D V R M U o ð r j a h ; x q k a d k m i ; l x b y D V R M U & l e n ' k z o ð f u e l z k e a f d ; k x ; k g ð t l s i z d k ' k & l e n ' k z d h r g y u k e a m P p r j f o H k o u o ð d k j . k , d c g r c m k l e k j g a

by D V R M U & l e n ' k z d k f o d k l
http://www.nobelprize.org



I kjk k

1. fdl h byðvnu dls èkrq l scgj fudkyus oð fy, U; ure Átz dls èkrq dk dk; & i ðyu dgrs gð èkrq i "B l s byðvnu mri tð oð fy, vko'; d Átz (dk; & i ðyu ϕ_0 l s vfkð) dls mi; ðr rkiu vfkok icy fo | r {k sk vfkok mi; ðr vkofúk oð izk'k }kjk fódfjr djus l snh tk l drh gð
 2. izk'k-fo | r i Hko èkrq ka l smi; ðr vkofúk oð izk'k l sinhr djus ij byðvnu ka oð mri tð dh ifj? vuk gð oðN èkrq ij k skuh izk'k l s ifrð; k djrs gð tcfð nu l s n'; & izk'k oð fy, Hh l xkgh gð izk'k & fo | r i Hko ea izk'k Átz dk oð r Átz ea : i k rj . k gsk gð ; g Átz oð l j {k . k oð fu; e dk i kyu djrk gð izk'k & fo | r mri tð , d r r {k . k d i fð; k g s v l s b l oð oðN fo f' k' v y {k . k g s gð
 3. izk'k & fo | r èkkj (i) vki frr izk'k dh rhorkj (ii) nls byðvnu ka oð chp yxk; k x; k fo h k o r j j v l s (iii) mri tð oð in k f l z dh i Ñfr ij fu Hk j djrk gð
 4. jkðd fo hko (\mathbf{v}_0) (i) vki frr izk'k dh vkofúk v l s (ii) mri tð in k f l z dh i Ñfr ij fu Hk j djrk gð vki frr izk'k dh fdl h nh gð z vkofúk oð fy,] ; g bl dh rhork ij fu Hk j ugha djrk gð jkðd fo hko dk mri tð byðvnu ka dh m ppre xfrt Átz l s l æ f e k r g %

$$\mathbf{e} \mathbf{V}_0 = \frac{1}{2} \mathbf{m} \mathbf{v}_{mp}^2 = \mathbf{K}_{mp}$$
 5. , d fuf' pr vkofúk (ngyh vkofúk) v_0 oð u hps tks èkrq dk v f h k y {k . k g s d k b z izk'k & fo | r mri tð ugha gsk p k g s vki frr izk'k dh rhork f d r u h Hh v f / d D; k a u gð
 6. Dyk l dh r j a k & l ¼ k r izk'k & fo | r i Hko oð e l ; y {k . k a dh 0; k [; k ugha dj l d k a b l dk fó d j . k l s Átz dk l r r v o' k s k . k dk f p = k . k \mathbf{K}_{mp} dh rhork l s L o r a k r j j v_0 oð v f l r k o v l s b l i fð; k dh r r {k . k d i Ñfr dh 0; k [; k ugha dj l d k a v k b a v k b u u s b u y {k . k a dh 0; k [; k izk'k oð i f s / k u & f p = k . k oð v k e k j ij d h a b l oð v u d k j izk'k j m o t k z oð f o f o d r i s o v k a l s c u k g s f t l g a D o l a k v f k o k i f s / k u d g r s gð i R; d i f s / k u dh Átz $\mathbf{E} (= \mathbf{h} \nu)$ v l s l o x $\mathbf{p} (= \mathbf{h} / \lambda)$ gsk g s t k s f d vki frr izk'k dh vkofúk (ν) ij fu Hk j djrs gð i j r q b l dh rhork ij fu Hk j ugha dj r a èkrq oð i "B l s izk'k & fo | r mri tð , d byðvnu oð }kjk i f s / k u oð v o' k s k . k l s g s k gð
 7. v k b a v k b u dk izk'k-fo | r l e h d j . k m o t k z l j {k . k fu; e oð l x r g s t s k f d èkrq e a , d byðvnu oð }kjk i f s / k u v o' k s k . k e a y l x w g s k gð m p p r e x f r t m o t k z ($\frac{1}{2} \mathbf{m} \mathbf{v}_{mp}^2$) i f s / k u & m o t k z ($\mathbf{h} \nu$) r F k k y { ; èkrq dk; & i ð y u $\phi_0 (= \mathbf{h} \nu_0)$ oð v r j oð c j k c j g s k gð

$$\frac{1}{2} \mathbf{m} \mathbf{v}_{mp}^2 = \mathbf{V}_0 \mathbf{e} = \mathbf{h} \nu - \phi_0 = \mathbf{h} (\nu - \nu_0)$$
- bl izk'k & fo | r l e h d j . k l s izk'k-fo | r i Hko oð l Hh y {k . k a dh 0; k [; k g s k gð f e f y d u d s i f k e i f j' k ¼ izk'k & fo | r e k i u k a u s v k b a v k b u d s izk'k & fo | r l e h d j . k d l s l a q v f d ; k v l s l y b l & f l f k j k d (\mathbf{h}) oð ; F k f l z e k u d l s i k l r f d ; k a b l l s v k b a v k b u }kjk i ð f r t oð r p p d h ; fó d j . k dk d . k v f k o k i f s / k u o . k u (i Ñfr) L o h Ñ r g q / k a
8. fó d j . k dh }f i Ñfr g s k g s % r j a k r F k k d . k a i z k x oð L o : i j ; g f u e k k z j r g s k g s f d r j a k v f k o k d . k oð : i e a o . k u i z k x oð i f j . k e d l s l e > u s oð fy, l o k z e k d m i ; ð r gð b l r o d oð l f k f d fó d j . k r F k k i n k f l z i Ñfr e a l e f e r gð y q l n s c h l y h oð i n k f l z (i n k f l z d . k a) d l s r j a k t s k y {k . k i n k u f d ; k a x f r e k u i n k f l z d . k a l s t p h r j a k a d l s i n k f l z r j a k v f k o k n s c h l y h r j a k d g r s gð

9. xfreku d.k. l sl æfækr nscáhyh rjxnS; $Z(\lambda)$ bl oð l ox p l sbl iðkj l æfækr gS% $\lambda = h/p$ A inkfíð d k }S nscáhyh l ææk] ft l earjæ l æðYiuk (λ) vís d.k. l æðYiuk (p) l fæfyr gþ ea vrfuZB gþ nscáhyh rjxnS; Z inkfíð d.k. oð vkoš k rFk bl dh i Ñfr l s Loræk gþ ; g l kfíð rí% oðoy mi & ijekf. od d. k kþ tS sþ byðVNU l kS/KU vkfn (buoð æ0; eku vFkZ l ox dh y?kþk oð dkj.k) oð fy, gh ifjæs (fØLVykæa ijek.oh; l erylæ oð chp dh njh dh dKv dk) gþ rFkfi ; g okLro eamu LFkoy olrþ/ka oð fy, tks l keld; r% ifrfnu thou eafeyrh gþ vís eki u dh l hek oð fcyoðy ckj gþ cgr Nk/k gþ
10. Mfol u&tej oð rFk th- ih- Vhæ l u oð }kj k byðVNU foorú iz kskærFk ckn oð dbz iz kskæus byðVNU dh rjæ&i Ñfr dks l R; kfi r rFk i qV fd; k gþ inkfíð rjæ dh ns áhyh ifjðYiuk] ckj dh LFk; h d{kk dh l æðYiuk dk l æFkú djrh gþ

Hkkárd jkf'k	irhd	foek, j	ektd	fVi . kh
lykð fLFkj kð	h	$[ML^2 T^{-1}]$	J s	$E = hv$
fujkð fohko	v_0	$[ML^2 T^{-3} A^{-1}]$	V	$e V_0 = K_{mp}$
dk; & i ðyu	ϕ_0	$[ML^2 T^{-2}]$	J; eV	$K_{mp} = E - \phi_0$
ngyh vkofuk	v_0	$[T^{-1}]$	Hz	$v_0 = \phi_0 / h$
nscáhyh rjxnS; Z	λ	[L]	m	$\lambda = h/p$

fopkj. kh; fo" k;

1. fdl h ækkraqææðr byðVNU bl vFízææðr gþfd osækkraqoð Hkhrj , d fLFkj fohko oð vaxt xfreku gksr gþ (; g oðoy , d l fludVu gS) A osækkraqoð ckj fudyus oð fy, eðr ughaglsr gþ mlga ækkraq l sckj tkus oð fy, vrfjDr mótíz dh vko'; drk gksh gþ
2. fdl h ækkraqæ l Hk h eðr byðVNUka dh mótíz l eku ughaglsr h fdl h xS tkj ea v. kþ/ka oð tS } , d fn, x, rki ij byðVNUka dk , d fuf' pr Átkíz forj. k gksr gþ ; g forj. k ml l keld; eðl osy forj. k l s fhklu gksr gS ft l svki xS ka oð xfrt fl ¼kr oð vé; ; u ea i <+pþ oð gþ bl oð fo" k; eavki ckn oð i k B; Øelæa tkus } i j r q fhklu r k dk l ææk bl rF; l s gSfd byðVNU i kþyh oð viotú oð fl ¼kr dk vuð j. k djrs gþ
3. fdl h ækkraqææðr byðVNUka oð mótíz forj. k oð dkj. k] ækkraq l sckj vkus oð fy, byðVNU oð }kj k ví s(kr Átkíz fhklu byðVNUka oð fy, fhklu gksh gþ mPprj Átkíz okys byðVNUka dh ækkraq l sckj vkus oð fy, de mótíz okys byðVNUka dh rgyuk ea de vrfjDr mótíz

fofdj.k rFkk nD; dh }\$ iDfr

dh vko'; drk gksh gA dk; &i Qyu ekrqI scgj fudyusD fy, fdl h byDVNU oD }kjk vi\$kr U; wre mDtKz gA

4. izdk'k&fo|q iHko lsl ekr iZ kskaeaooy ; gh varfuZgr gSfd nD; oD l kFk izdk'k dh vU; kD; fD; k eamDtKz dk vo' kSk.k hV dh fofodr bdkb; kaeagkrk gA ; g fcyoDy gh , d k dgusD l eku ugha gSfd izdk'k , d s d. kka l scuk gSftuea iR; d dh mDtKz hV gA
5. fujksh foHko ij iZk.k (bl dh rhork ij vfuHjrk vS vkofuk ij fuHjrk) izdk'k&fo|q iHko oD rj&fp=k.k vS iQs/KU&fp=k.k oD chp fu. kZ d foHndkj d gA
6. l k $\lambda = \frac{h}{p}$ oD }kjk fn; k x; k inkFk&rj& dk rj&ns; Z dk HkSrdh; eglo g\$ bl oD dyk&ox v, dk dkbZ HkSrdh; eglo ugha gkrk gA rFkfi] inkFk&rj& dk l eY&ox HkSrdh; k vFkZ wLz gS vS d.k oD ox oD cjkj gkrk gA

vH; kl

- 11.1** 30 kV byDVNUka oD }kjk mRi lu X-fdj. ka dh (a) mPpre vkofuk rFk (b) fuEure rj&ns; Z iklr dhft, A
- 11.2** l hf'k; e ekrqdk dk; &i Qyu 2.14 eV gA tc 6×10^{14} Hz vkofuk dk izdk'k ekr&i"B ij vkifrr gkrk g\$ byDVNUka dk izdk'kd mRi tU gkrk gA
(a) mRi ftZ byDVNUka dh mPpre xfrt mDtKz
(b) fujksh foHko] vS
(c) mRi ftZ izdk'kd byDVNUka dh mPpre pky fdruh gS
- 11.3** , d fof'k'V iz kx ea izdk'k-fo|q iHko dh vrd okVrk 1.5 V gA mRi ftZ izdk'kd byDVNUka dh mPpre xfrt AtKz fdruh gS
- 11.4** 632.8 nm rj&ns; Z dk , d ghfy; e&fu; KU yd j oD }kjk mRi lu fd; k tkrk gA mRi ftZ 'kDr 9.42 mW gA
(a) izdk'k oD fdj. k&it ea iR; d iQs/KU dh mDtKz rFk l ox iklr dhft,]
(b) bl fdj. k&it oD }kjk fofdj r fdl h y{; ij vS ru fdus iQs/KU ifr l oM igp&S (; g eku yhft, fd fdj. k&it dh vuqLFk dV , dl eku gStk y{; oD {ski Qy l sde g\$} rFk
(c) , d gkbMStu ijek. kdls iQs/KU oD cjkj l ox iklr djusD fy, fdruh r'sk pky l spyuk gsk
- 11.5** iFoh oD i"B ij igpus oky l w&izdk'k dk mDtKz-vfHkkg (YyDI) 1.388×10^3 W/m² gA yxHx fdus iQs/KU ifr oxZehVj ifr l oM iFoh ij vkifrr gkrsgA ; g eku yafd l w&izdk'k ea iQs/KU dk vS r rj&ns; Z 550 nm gA
- 11.6** izdk'k&fo|q iHko oD , d iz kx eJ izdk'k vkofuk oD fo#¼ vrd okVrk dh <yku 4.12×10^{-15} V s iklr gksh gA lykd fLFkjkd dk eku ifjdfyr dhft, A
- 11.7** , d 100 W l kM; e cYc (y) l Hh fn' kvkæa, dl eku mDtKz fofdj r djrk gA yd dls, d , d scM&xlys oD oE ij j [k x; k gStk bl ij vkifrr l kM; e oD l a wLz izdk'k dls vo' kSk'kr djrk gA l kM; e izdk'k dk rj&ns; Z 589 nm gA (a) l kM; e izdk'k l s tM& ifr iQs/KU dh AtKz fdruh gS (b) xlys dlsfdl nj l siQs/KU inku fd, tk jgsgA

- 11.8** fdl h ekkrqdh ngyh vkofúk 3.3×10^{14} Hz gá ; fn 8.2×10^{14} Hz vkofúk dk izdk'k ekkrqij vkifrr gš rks izdk'k&fo|qr mRI tÚ oð fy, vrd okVrk Kkr dhft, A
- 11.9** fdl h ekkrqoð fy, dk; &i Qyu 4.2 eV gá D; k ; g ekkrq 330 nm rjxnš; Zoð vkifrr fofdj.k oð fy, izdk'k&fo|qr mRI tÚ nskl
- 11.10** 7.21×10^{14} Hz vkofúk dk izdk'k ,d ekkrq i" B ij vkifrr gá bl i" B l s 6.0×10^5 m/s dh mPpre xfr l s byðvnu mRI ftÚ gš jgs gá byðvnuka oð izdk'k mRI tÚ oð fy, ngyh vkofúk D; k gš
- 11.11** 488 nm rjxnš; Zdk izdk'k , d vkkú yd j l smri lu fd; k tkrk gš ftl s izdk'k&fo|qr i Hko oð mi ; l x eayk; k tkrk gá tc bl Liðveh&jškk oð izdk'k dlsMRI tÚ ij vkifrr fd; k tkrk gšrc izdk'k d byðvnuka dk fujksh (vrd) foHko 0.38 V gá mRI tÚ oð inKfz dk dk; &i Qyu Kkr djá
- 11.12** 56 V foHkora j oð }jkj Rofjr byðvnuka dk
(a) l oðx] vlg
(b) nscðlyh rjxnš; Zifjdfyr dhft, A
- 11.13** , d byðvnu ftl dh xfrt Átkz 120 eV gš ml dk
(a) l oðx] (b) ply vlg (c) nscðlyh rjxnš; ZD; k gš
- 11.14** l km; e oð Liðveh mRI tÚ jškk oð izdk'k dk rjxnš; 589 nm gá og xfrt Átkz Kkr dhft, ftl ij
(a) , d byðvnu] vlg (b) , d l; vnu dk nscðlyh rjxnš; Zl eku gškk
- 11.15** (a) , d 0.040 kg nð; eku dk cgv/ tš 1.0 km/s dh ply l spy jgk gš (b) , d 0.060 kg nð; eku dh xm tš 1.0 km/s dh ply l spy jgh gš vlg (c) , d eky&d.k ftl dk nð; eku 1.0×10^{-9} kg vlg tš 2.2 m/s dh ply l svuxfer gš jgk gš dk nscðlyh rjxnš; Zfdruk gškk
- 11.16** , d byðvnu vlg , d iðvnu i R; d dk rjxnš; 1.00 nm gá
(a) budk l oðx]
(b) iðvnu dh mðtk] vlg
(c) byðvnu dh xfrt mðtk] Kkr dhft, A
- 11.17** (a) l; vnu dh fdl xfrt mðtk] oð fy, nscðlyh rjxnš; 1.40×10^{-10} m gškk
(b) , d l; vnu] tš inKfz oð l Kf rki h; l K; eagsvlg ftl dh 300 K ij vlg r xfrt mðtk] $\frac{3}{2} k T$ gš dk Hk nscðlyh rjxnš; ZKkr dhft, A
- 11.18** ; g n'wð, fd oð rppcdh; fofdj.k dk rjxnš; Zbl oð Doka/e (iðvnu) oð rjxnš; Zoð cjkj gá
- 11.19** ok; qea 300 K rki ij , d ukvřtu v. kq dk nscðlyh rjxnš; Zfdruk gškk ; g ekuafd v. kq bl rki ij v. kq/ka oð ply oxleke; l s xfreku gá (ukvřtu dk ijek. kq nð; eku = 14.0076 u)

vfrfjDr vH; kl

- 11.20** (a) , d fuokÚ uyh oð rkifir oðFKM l smri ftÚ byðvnuka dh ml ply dk vkdyu dhft, ftl l s smri tÚ dh rgyuk ea 500 V oð foHkora j ij j [l s x, , ukM l s v djrs gá byðvnuka oð y?k i j a Hkd pkyka dh miškk dj nð byðvnu dk vki šškd vkosk vFKÚ e/m 1.76×10^{11} C kg⁻¹ gá
(b) l xtd foHko 10 MV oð fy, byðvnu dh ply Kkr djusoð fy, ml h l w dk iz l x djá tš (a) eadke eayk; k x; k gá D; k vki bl l w dlsxyr i krs gá bl l w dls fdl izklj l qkjk tk l drk gá

- 11.21** (a) , d l ektiz byðvnu fdj.k&ið ftl ea byðvnu dh pky $5.20 \times 10^6 \text{ m s}^{-1}$ gð ij , d pædh; {lsk $1.30 \times 10^{-4} \text{ T}$ fdj.k&ið dh pky oð yæor yxk; k tirk gð fdj.k&ið }kjk vkjð [kr oðk dh f=Ë; k fdruh gksh] ; fn byðvnu oð e/m dk eku $1.76 \times 10^{11} \text{ C kg}^{-1}$ gð
- (b) D; k ftl l wk dls (a) eami ; lœ ea yk; k x; k gSog ; gk Hkh , d 20 MeV byðvnu fdj.k&ið dh f=Ë; k ifjdfyr djusoð fy, ; ðrijd gð ; fn ugharkfdl izlkj bl ea l ðæku fd; k tk l drk gð
- ¹ukv % vH; kl 11.20 (b) rFlk 11.21 (b) vki dksvki f{kdh; ; k=kdh rd ystkrsgð tksbl iðrd oð fo"k; oð ckj gð ; gk ij blgabl fcmq ij cy nus oð fy, l fefyr fd; k x; k gSfd ftu l wk dls vki (a) eami ; lœ ea ykrs gð os cgr mPp pky l vFlk mÔtk/ka ij ; ðrijd ugha gk=ð ; g tkuus oð fy, fd ^cgr mPp pky vFlk mÔtk dk D; k vFlz gð vr eafn, x, mÛjka dks nð kð
- 11.22** , d byðvnu xu ftl dk l ætgð 100 V foHko ij gð , d de nk (~ 10^{-2} mm Hg) ij gkbMktu l s Hkjs xly/kdkj cYc ea byðvnu NkM/rh gð , d pædh; {lsk ftl dk eku $2.83 \times 10^{-4} \text{ T}$ gð byðvnu oð ekxZ dls 12.0 cm f=Ë; k oð oðk; d {kk ea ofðr dj nrk gð (bl ekxZ dks nð k tk l drk gS; k=kd ekxZ ea xð vk; u fdj.k&ið dls byðvnu ka dks vld f"kr dj oð vð byðvnu izxg.k oð }kjk izk'k mRl tû dj oð iðkdl djrs gð bl fofek dls ^ifj"Ñr fdj.k&ið uyh* fofek dgrs gð) vkðM/ka l s e/m dk eku fuèkðjr dhft, A
- 11.23** (a) , d x-fdj.k uyh fodj.k dk , d l ær LiðVè ftl dk y?kq rjæns; Z fl jk 0.45 Å ij gð mRi l u djrk gð fodj.k eafdl h iðvnu dh mPpre mÔtk fdruh gð
- (b) vius (a) oð mÛkj l svuæku yxkb, fd fdl dksV dh Rojd oksVrk (byðvnu oð fy,) dh bl uyh ea vko'; drk gð
- 11.24** , d Roj= (accelerator) iz lœ ea i f"kvnuka (e^+) oð l kfk byðvnu ka oð mPp&mÔtk l ækèu ij] , d fof"kv ?kuk dh 0; k [; k oðy mÔtk 10.2 BeV oð byðvnu & i f"kvnu ; ðe oð cjkj mÔtk dh nks ã-fdj. ka ea fo yk i u oð : i eadh tirk gð i R; ð ã-fdj.k l sl æðekr rjæns; lœ oð eku D; k glæð (1 BeV = 10^9 eV)
- 11.25** vxks vkus okyh nls l æ; kvka dk vkdyu jkpd gls l drk gð igyh l æ; k ; g crk, xh fd jsm; lsvfhk; k=kd Hkks/vnu dh vfekd fpark D; ka ugha djrð nu jh l æ; k vki dls ; g crk, xh fd gekjs usk ^iðvnu ka dh fxurh* D; ka ugha dj l drð Hkysgh izk'k l ki-ð l ki-ð l ð pu ; kð; gkð
- (a) , d eè; rjæ (medium wave) 10 kW l keF; Zoð i skh] tks 500 m rjæns; Zdh jsm; lsrjæ mRl ftz djrk gð oð }kjk ifr l oðM mRl ftz iðvnu ka dh l æ; ka
- (b) fuEure rhork dk 'or izk'k ftl sge nð k l drs gð (~ $10^{-10} \text{ W m}^{-2}$) oð l ær iðvnu ka dh l æ; k tks ifr l oðM gekjs uska dh i rpyh ea iðk djrh gð i rpyh dk {lski Oy yxHlx 0.4 cm² vð 'or izk'k dh vð r vkofl k dls yxHlx $6 \times 10^{14} \text{ Hz}$ ekfu, A
- 11.26** , d 100 W ikjn (Mercury) Ìkr l smRi l u 2271 Å rjæns; Z dk ijkc&uh izk'k , d efyCMæse èkrq l s fufeð izk'k l sy dls fodfjr djrk gð ; fn fujkèh foHko -1.3 V gð rksèkrq oð dk; & i Oyu dk vkdyu dhft, A , d He-Ne yð j }kjk mRi l u 6328 Å oð mPp rhork (~ 10^5 W m^{-2}) oð yky izk'k oð l kfk izk'k l sy fdl izlkj vuqð; k djxk\

- 11.27** , d fu; $\lambda = 640.2 \text{ nm}$ ($1 \text{ nm} = 10^{-9} \text{ m}$) rjans; λ d, do. λ fofdj. k $V_{01} = 1.28 \text{ V}$, $V_{02} = 0.95 \text{ V}$, $V_{03} = 0.74 \text{ V}$, $V_{04} = 0.16 \text{ V}$, $V_{05} = 0 \text{ V}$
- 11.28** , d ikjn yd] izdk'k&fo| η mri t \dot{z} dh vkof \ddot{u} k fuHj \ddot{r} k o \ddot{e} v \ddot{e} ; ; u o \ddot{e} fy, , d l f \ddot{o} e \ddot{e} ktud l \ddot{r} g \ddot{s} D; k \ddot{i} d ; g n' ; &Li \ddot{D} Ve o \ddot{e} ijk \ddot{c} kuh (UV) l syky Nkj rd db \ddot{z} o. k \ddot{z} j \ddot{s} k, ; mri ft \ddot{r} djrk g \ddot{a} : ch \ddot{M} ; e izdk'k l sy o \ddot{e} gekjsiz l \ddot{x} e \ddot{i} ikjn (Mercury) l \ddot{r} dh fuEu o. k \ddot{z} j \ddot{s} k l \ddot{v} la o \ddot{d} iz l \ddot{x} fd; k x; k %
- $\lambda_1 = 3650 \text{ \AA}$, $\lambda_2 = 4047 \text{ \AA}$, $\lambda_3 = 4358 \text{ \AA}$, $\lambda_4 = 5461 \text{ \AA}$, $\lambda_5 = 6907 \text{ \AA}$, fujk \ddot{e} h o \ddot{v} r \ddot{k} , j \ddot{O} e'k \ddot{o} fuEu eki h x \ddot{b} ±%
- $V_{01} = 1.28 \text{ V}$, $V_{02} = 0.95 \text{ V}$, $V_{03} = 0.74 \text{ V}$, $V_{04} = 0.16 \text{ V}$, $V_{05} = 0 \text{ V}$
- (a) l y \ddot{d} l f \ddot{L} kj \ddot{a} d h dk eku K \ddot{r} dh \ddot{f} t, A
- (b) e \ddot{k} r \ddot{q} o \ddot{e} fy, ng \ddot{y} h vkof \ddot{u} k r \ddot{F} k dk; &i \ddot{O} yu dk vk \ddot{d} yu dh \ddot{f} t, A
- 1 \ddot{u} k \ddot{v} % mi ; \ddot{O} r vk \ddot{d} M \ddot{a} l s h dk eku K \ddot{r} d \ddot{j} us o \ddot{e} fy, vki d \ddot{s} $e = 1.6 \times 10^{-19} \text{ C}$ dh vk \ddot{o} ' ; drk gl \ddot{x} h \ddot{a} bl iz \ddot{k} j o \ddot{e} iz l \ddot{x} Na, Li, K vk \ddot{f} n o \ddot{e} fy, fe \ddot{y} du us fd, F \ddot{a} fe \ddot{y} du us v \ddot{i} us \ddot{r} y&cm iz l \ddot{x} l s i \ddot{k} l \ddot{r} e o \ddot{e} eku dk mi ; l \ddot{x} dj vk \ddot{b} a vk \ddot{b} u o \ddot{e} izdk'k& fo| η l e \ddot{h} d \ddot{j} . k d \ddot{s} l R; k \ddot{f} i r fd; k r \ddot{F} k bl \ddot{g} h \ddot{a} i \ddot{x} k. k \ddot{a} l s h o \ddot{e} eku o \ddot{e} fy, i f \ddot{k} o \ddot{e} v \ddot{u} e \ddot{k} u y \ddot{x} k; k \ddot{o}
- 11.29** fuEu e \ddot{k} r \ddot{q} o \ddot{e} dk; &i \ddot{O} yu fuEu iz \ddot{k} j fn, x, g \ddot{s} %
Na: 2.75 eV; K: 2.30 eV; Mo: 4.17 eV; Ni: 5.15 eV A bu \ddot{e} a e \ddot{k} r \ddot{q} o \ddot{e} ea l s d \ddot{k} u izdk'k l sy l s 1 m nj j l \ddot{s} x, He-Cd y \ddot{d} j l s mri l \ddot{u} 3300 \AA rjans; λ o \ddot{e} fofdj. k o \ddot{e} fy, izdk'k&fo| η mri t \dot{z} u \ddot{g} h \ddot{n} s \ddot{k} l y \ddot{d} j d \ddot{s} l sy o \ddot{e} fu \ddot{d} V 50 cm njh ij j l \ddot{k} us ij D; k gl \ddot{x} s \ddot{k} l
- 11.30** 10^{-5} Wm^{-2} rhok dk izdk'k , d l k \ddot{M} ; e izdk'k l sy o \ddot{e} 2 cm^2 l \ddot{s} ki \ddot{O} y o \ddot{e} i" B ij i M \ddot{r} k g \ddot{a} ; g eku yaf \ddot{d} \ddot{A} ij dh l k \ddot{M} ; e dh i \ddot{k} p i \ddot{j} ravki \ddot{r} r \ddot{A} t \ddot{z} d \ddot{s} vo' k \ddot{e} " \ddot{r} djrh g \ddot{s} r \ddot{i} s fofdj. k o \ddot{e} rj \ddot{a} &f \ddot{p} -k. k ea izdk'k&fo| η mri t \dot{z} o \ddot{e} fy, vk \ddot{o} ' ; d l e; dk vk \ddot{d} yu dh \ddot{f} t, A /k \ddot{r} qo \ddot{e} fy, dk; &i \ddot{O} yu y \ddot{x} H \ddot{x} 2 eV fn; k x; k g \ddot{a} vki o \ddot{e} m \ddot{u} kj dk D; k fu \ddot{g} r \ddot{k} l \ddot{z} g \ddot{a}
- 11.31** X-fd \ddot{j} . k \ddot{a} o \ddot{e} iz l \ddot{x} vk \ddot{f} ok mi ; \ddot{O} r o \ddot{v} r \ddot{k} l s \ddot{r} of \ddot{j} r by \ddot{D} V \ddot{r} u \ddot{a} l s \ddot{f} o \ddot{L} Vy&foor \ddot{z} u iz l \ddot{x} fd, tk l drs \ddot{g} h d \ddot{k} u&l h t \ddot{k} p v \ddot{f} ek \ddot{d} m \ddot{u} t \ddot{z} l \ddot{e} ¼ g \ddot{s} (i \ddot{f} jek \ddot{d} k \ddot{d} r \ddot{y} uk o \ddot{e} fy,) t \ddot{k} p o \ddot{e} fy, rjans; λ d \ddot{s} 1 \AA y \ddot{h} ft,) t \ddot{s} fd t \ddot{y} yd (y \ddot{v} l) ea v \ddot{r} j&i \ddot{j} ek. l \ddot{q} v \ddot{r} j. k dh d \ddot{k} v dk g \ddot{s} ($m_e = 9.11 \times 10^{-31} \text{ kg}$) A
- 11.32** (a) , d U; $\lambda = 11.31$ e \ddot{a} n \ddot{s} l \ddot{k} g \ddot{s} bruh m \ddot{u} t \ddot{z} dk by \ddot{D} V \ddot{r} u fd \ddot{j} . k&i \ddot{q} f \ddot{O} L \ddot{V} y foor \ddot{z} u iz l \ddot{x} o \ddot{e} fy, mi ; \ddot{O} r g \ddot{a} D; k l eku m \ddot{u} t \ddot{z} dk , d U; $\lambda = 11.31$ e \ddot{a} n \ddot{s} l \ddot{k} g \ddot{s} bl iz l \ddot{x} o \ddot{e} fy, l eku : i ea mi ; \ddot{O} r gl \ddot{x} s \ddot{k} l Li"V dh \ddot{f} t, A ($m_p = 1.675 \times 10^{-27} \text{ kg}$)
(b) de \ddot{j} so \ddot{e} l ke \ddot{U} ; rki (27 $^{\circ}\text{C}$) ij \AA "eh; U; $\lambda = 11.31$ e \ddot{a} n \ddot{s} l \ddot{k} g \ddot{s} rjans; λ K \ddot{r} dh \ddot{f} t, A bl iz \ddot{k} j Li"V dh \ddot{f} t, fd D; k \ddot{a} , d rho \ddot{x} keh U; $\lambda = 11.31$ e \ddot{a} n \ddot{s} l \ddot{k} g \ddot{s} foor \ddot{z} u iz l \ddot{x} eami ; l \ddot{x} ea ykus l s i \ddot{g} ys ok \ddot{r} ko \ddot{j} . k o \ddot{e} l k \ddot{f} k rki h \ddot{N} r fd; k t \ddot{r} k g \ddot{a}
- 11.33** , d by \ddot{D} V \ddot{r} u l \ddot{v} en' k \ddot{z} ea 50 kV o \ddot{v} r \ddot{k} o \ddot{e} }kj \ddot{k} Rof \ddot{j} r by \ddot{D} V \ddot{r} u \ddot{a} dk mi ; l \ddot{x} fd; k t \ddot{r} k g \ddot{a} bu by \ddot{D} V \ddot{r} u \ddot{a} l s t \ddot{p} l \ddot{s} ns \ddot{c} h \ddot{y} h rjans; λ K \ddot{r} dh \ddot{f} t, A ; fn v \ddot{U} ; c \ddot{r} ka (t \ddot{s} s \ddot{f} d l \ddot{q} ; k \ddot{r} ed }kj \ddot{d} vk \ddot{f} n) d \ddot{s} y \ddot{x} H \ddot{x} l eku fy; k tk,) by \ddot{D} V \ddot{r} u l \ddot{v} en' k \ddot{z} dh fo \ddot{H} ku {kerk dh r \ddot{y} uk i \ddot{h} ys izdk'k dk iz l \ddot{x} d \ddot{j} us ok \ddot{y} s izdk'k l \ddot{v} en' k \ddot{z} l s \ddot{f} d l iz \ddot{k} j gl \ddot{x} s \ddot{k} l g \ddot{a}
- 11.34** fd l h t \ddot{k} p dh rjans; λ m \ddot{l} o \ddot{e} }kj \ddot{k} o \ddot{q} N fo \ddot{L} r \ddot{k} j ea t \ddot{k} p dh tk l dusok \ddot{y} h l \ddot{j} puk o \ddot{e} vk \ddot{d} kj dh y \ddot{x} H \ddot{x} vk \ddot{e} ki g \ddot{a} i \ddot{k} s \ddot{r} u \ddot{a} r \ddot{F} k U; $\lambda = 11.31$ e \ddot{a} n \ddot{s} l \ddot{k} g \ddot{s} foor \ddot{z} u iz l \ddot{x} eami ; l \ddot{x} ea ykus l s i \ddot{g} ys ok \ddot{r} ko \ddot{j} . k o \ddot{e} l k \ddot{f} k rki h \ddot{N} r fd; k t \ddot{r} k g \ddot{a}
- H \ddot{k} de y \ddot{c} ko \ddot{z} o \ddot{e} y \ddot{q} i \ddot{e} ku \ddot{s} dh g \ddot{a} bl l \ddot{j} puk d \ddot{s} l o \ddot{e} F \ddot{I} e 1970 n'k \ddot{d} o \ddot{e} i \ddot{k} j \ddot{k} e \ddot{i} , d

fótdj.k rFkk nð; dh }f iðfr

jstkh; Rofj=k (Linear accelerator) l smri lu mPp mótíz byðvnu ka oð fdj. k&iqt ka oð mi ; lsk }kjkj LV&i&M& l a ðr jkt; vesjck ea t&pk x; k Fkk bu byðvnu fdj. k&iqt ka dh mótíz dh d&v dk v&ku y&kb, A (byðvnu dh fojke nð; eku mótíz 0.511 MeV gð)

11.35 dejs oð rki (27 °C) v& 1 atm nlc ij He ijek. kq l st&is ik; ih nsc&lyh rj&n& ; Z Kkr dhft, v& bu ifjfl&fr; ka eabl dh r&yuk nls ijek. k& ka oð chp v& r njh l schft, A

11.36 fdl h èkkrqea (27 °C) ij , d byðvnu dk ik; ih nsc&lyh rj&n& ; Z ifjdfyr dhft, v& bl dh r&yuk èkkrqea nls byðvnu ka oð chp v& r i F&D; l schft, t&syx Hlx 2 × 10⁻¹⁰ m fn; k x; k gð

1uk&v % vH; kl 11.35 v& 11.36 inf'kz djrs gð fd t&g& l ke& ; ifjfl&fr; ka ea x& h; v. k& ka l st&is rj& i ð&v v&vfr0; kih gð fdl h èkkrqea byðvnu rj& i ð&v izy : i l s, d&n& js l s vfr0; kih gð ; g l &krk g&fd t&g& fdl h l ke& ; x& ea v. k& ka dh v&yx igpku g& l drh g& fdl h èkkrqea byðvnu dh , d&n& js l s v&yx igpku ugha g& l drh& bl vi&ks&rk oð dbz&ny fufgr&f&zk, ; g&ftlga vki H&ðrdh oð v&ekd mPp ik& ; Ø&ka ea t&ka&ð

11.37 fuEu iz&ka oð m&lkj nhft, %

(a) , ð k fopkj fd; k x; k g&fd i k&vnu v& U; w&nu oð H&krj Dok&ð ij v&ka' kd vk&sk gl&rs gð [(+2/3)e ; (-1/3)e]A ; g f&fydu r&y&c&pm iz lsk ea D; ka ugha iz&v gl&rs

(b) e/m l a lsk dh D; k fo' k'Vrk g& ge e rFkk m oð fo'k; ea v&yx&v&yx fopkj D; ka ugha dj&rs

(c) x& a l ke& ; nlc ij oð&kyd g&rs g& i j&rcg& de nlc ij pkyu i k&bl& dj n&rh g& D; ka

(d) i R; d èkkrq&dk , d fuf'pr dk; & i ð&y&u g&rk g& ; fn vki fr& f&fdj.k , do. k&z g&sr&ks l H&h iz&kf' kd byðvnu l eku mótíz oð l k&f& ck&j D; ka ugha v&kr&sg& iz&kf' kd byðvnu ka dk , d mótíz for&j.k D; ka g&rk g&.

(e) , d byðvnu dh mótíz rFkk bl dk l &sx bl l st&is i nk&f& rj& dh vk&f&lk rFkk bl oð rj&n& ; Z oð l k&f& fuEu iz&kj l &è&kr& gl&rs g&%

$$E = h\nu, p = \frac{h}{\lambda}$$

i j&rc&λ dk eku t&g& H&ðrd eg&lo dk g& v oð eku (v& bl fy, dyk pky v&λ dk eku) dk d&bz H&ðrd eg&lo ugha g& D; ka

i f j f ' k ' V

11-1 rjæ rFkk d.k oð myV&iyV dk bfrgkl

izdk'k D; k gS ; g izu ekuo tkr dks yæsl e; rd ijs kku djrk jgk gâ yxHlx pj j 'krkCnh igy} oKkfud rFkk vSj kSxd ; q oð i j k k oð l e; l sgh oKkfudka }kj k Øec¼ iz kx fd, x, A yxHlx ml h l e;] izdk'k D; k gS bl l æk eal Sækrd ekmy fodfl r fd, x, A foklu dh fd l h Hh 'kk[tk eadkæz ekmy fodfl r djrs l e; ; g n[uk vko' ; d gSfd ; g ml l e; fo | eku l Hh ik; kSxd i k k. kæadh 0; k[; k dj l oð bl fy,] l ægoha 'krkCnh ea izdk'k oð fo'k; ea Kkr oðN i k k. kæadh l æki . k mi ; Ør jgsæA

ml l e; Kkr izdk'k oð xqkæeal fæfyr Fkpu (a) izdk'k dk l j y j æh; i Fk i j xeu] (b) l ery rFkk xlyh; i "Bkæ l s j koru] (c) nksæke; eka oð v r j k i "B i j v i o r u] (d) fo f H k u o . k æ e a i z d k ' k d k f o { k i . k j (e) m P p p l y A i g y h p l j i f j ? V u k v k a o ð f y , m f p r f u ; e k a d k s i f r i k f n r f d ; k x ; k A m n k g j . k o ð f y ,] L u s y u s l u - 1 6 2 1 e a v i o r u o ð f u ; e k a d k s l æ c ¼ f d ; k A x s y f y ; k s o ð l e ; l s g h v u s d o K k f u d k a u s i z d k ' k d h p l y d k s e k i u s d k i z R u f d ; k A y s d u o s , d k d j u s e a v l e f k z j g a o s o ð b o y ; g f u " d " l z f u d k y i k , f d i z d k ' k d h p l y m u d h e k i d h l h e k l s v f e k d g a

l ægoha 'krkCnh ea izdk'k oð nksækmy i L r r f d , x, A l ægoha 'krkCnh oð i k j æ h k d n ' k d k a e a n d k r z u s i f r i k f n r f d ; k f d i z d k ' k d . k a l s c u k g s t c f d l u - 1 6 5 0 & 6 0 o ð v k l i k l g l o x d u s i L r r f d ; k f d i z d k ' k r j æ k a l s c u k g a n d k r z d k i L r k o e k e k , d n k ' k f u d e k m y F k f t l e a i z k æ a v f k o k o K k f u d r d k e d k v H k o F k A ' k h ? k g h y x H l x 1 6 6 0 & 7 0 o ð v k l i k l U ; W u u s n d k r z o ð d f . k d k f l ¼ k a r d k o K k f u d f l ¼ k a r o ð : i e a f o l r k j f d ; k r F k k b l d h l g k ; r k l s i z d k ' k o ð v u s d x q k æ a d h 0 ; k [; k d h x b a r j æ k a o ð : i e a r F k k d . k a o ð : i e a i L r r d j u s o k y s ; s e k m y , d n l j s o ð f c y o ð y f o i j h r g a y s d u n s k a g h e k m y i z d k ' k o ð l H h K k r x q k æ a d h 0 ; k [; k d j u s e a l { k e F k a b u n s k a e a l s f d l h d k s H h N k v u k d f B u F k A

v l x k e h o ð N ' k r k f C n ; k a e a b u e k m y k a o ð f o d k l d k b f r g k l e u l æ t d g a l u - 1 6 6 9 e j k j F k s y u l u s o ð N f Ø L V y k a e a i z d k ' k o ð f j v i o r u d h [k s t d h r F k k ' k h ? k g h l u - 1 6 7 8 e a g l o x d l u s v i u s r j æ f l ¼ k a r o ð v k e k j i j b l d h 0 ; k [; k d h a b l o ð k o t m] , d l l s o " l z l s H h v f e k d l e ; r d U ; W u d k d f . k d k e k m y v f e k d f o ' o l u h ; e k u k t k r k j g k r F k k r j æ e k m y d h v i s k v f e k d i l m f d ; k t k r k j g a

bl dk , d v æ k r % d k j . k r l s b l e k m y d h l j y r k F h r F k k v æ k r % m l l e ; o ð l e d k y h u H k s r d ' k f l æ k ; k a i j U ; W u d k i H k o F k A

l u - 1 8 0 1 e a ; æ u s v i u s f } f > j h i z k x } k j k 0 ; f r d j . k f i æ t k a d k i æ k . k f d ; k A b l i f j ? V u k d h 0 ; k [; k o ð b o y r j æ f l ¼ k a r } k j k g h d h t k l d r h g a ; g H h v u h k o f d ; k x ; k f d f o o r u , d v l ; i f j ? V u k g S f t l d h 0 ; k [; k o ð b o y r j æ f l ¼ k a r } k j k g h d h t k l d r h g a o k L r o e a ; g i z d k ' k o ð i F k e a i R ; d f c m q l s f u x æ u g k s o k y h g l o x d o ð f j r h ; d r j æ x d k d k L o k H k f o d f u " d " l z g a b u i z k æ a d h i z d k ' k o ð d f . k d k f l ¼ k a r } k j k 0 ; k [; k u g a d h t k l d r h a y x H l x l u - 1 8 1 0 e a / p . k d h i f j ? V u k d h [k s t g h a b l i f j ? V u k d h 0 ; k [; k H h r j æ f l ¼ k a r } k j k g h L o k H k f o d : i l s d h t k l d r h g a b l i z d j g l o x d d k r j æ f l ¼ k a r v x H l x e a v k x ; k r F k k U ; W u d k d f . k d k f l ¼ k a r i " B H k æ e a p y k x ; k A ; g f l F k r i q % y x H l x , d ' k r k C n h r d p y r h j g a

mluht oha 'krkCnh ea izdk'k dh ply Kkr djusoð fy, oðN vPNs iz kx fd, x, A v f e k d i f j ' k ¼ i z k x } k j k f u o k i r e a i z d k ' k d h p l y d k e k u 3 æ 0 m / s K k r f d ; k x ; k A y x H l x l u - 1 8 6 0 e j e d l o s y u s o s j æ p p e d r o o ð f y , v i u h l e h d j . k a i L r r d h a r F k k ; g v u h k o f d ; k x ; k f d m l l e ; K k r l H h o s j æ p p e d h ; i f j ? V u k v k a d h e d l o s y d h p j l e h d j . k a } k j k 0 ; k [; k d h t k l d r h g a ' k h ? k g h e d l o s y u s n ' k æ k f d f o | æ r F k k p æ d h ; { l æ k } o s j æ p p e d h ; r j æ k a o ð : i e a f j D r v l d k ' k (f u o k i r) e a l p k f j r f d , t k l d r s g a m l u s b u r j æ k a d h p l y i f j d f y r d h r F k k b u o ð l S æ k r d e k u 2 - 9 9 8 × 1 0 8 m / s i k l r f d , A b l e k u d h i k ; k S x d e k u l s f u d V r k ; g n ' k æ z h g S f d i z d k ' k o s j æ p p e d h ; r j æ k a l s c u k g a l u - 1 8 8 7 e a g v æ k u s b u r j æ k a d h m R i f u k r F k k l a p u d k s i n f ' k i r f d ; k A b l u s i z d k ' k o ð r j æ f l ¼ k a r d k s , d n < v k e k j i n k u f d ; k A g e d g l d r s g a f d v B k j g o h a ' k r k C n h i z d k ' k o ð d f . k d k e k m y d h r F k k m l u h l o h a ' k r k C n h i z d k ' k o ð r j æ f l ¼ k a r d h F k a

l u - 1 8 5 0 & 1 9 0 0 o ð l e ; o ð c h p H k s r d h , d f c y o ð y f H k u { l æ k } Å " e k r F k k m l l s l æ f e k r i f j ? V u k v k a i j c m l æ l æ ; k e a i z k x f d , x, A v . k æ f r f l ¼ k a r r F k k Å " e k x f r d h t s s f l ¼ k a r r F k k e k m y f o d f l r f d , x, f t U g æ u l i o y r k i n o d l } o ð b o y , d d k s N k m l e j v u s d i f j ? V u k v k a d h 0 ; k [; k d h a

i fjf' k'V

i R; d oLrj fdl h Hkh rki ij l Hkh rjxnS; k oL fofdj. k mRI ftZ djrh gB ; g vius Aj i Musokys fofdj. ka dls vo' kS'kr Hkh djrh gB dkbZ oLrqtks vius Aj i Musokys l Hkh fofdj. ka dls vo' kS'kr dj yrh gS ml s'Nf". kdk dgrsgB HkSrdh ea; g fcmq nD; eku vFkok , dl eku xfr dh voekj. kvkadh Hkfr gh , d vkn' lZ voekj. k gB fdl h oLrj }kjk mRI ftZ fofdj. k dh rhork rFk bl dh rjxnS; Z oL chp [khp sx, xki Q dls Nf". kdk Li DVe dgrsgB mu fnukaeadkbZ Hkh fl ¼kr Nf". kdk Li DVe dh ijh rjg 0; k[; k ugha dj i k; ka

l u-1900 eJ lyed dls , d u; k fopkj l u-ka mlghaus dgk] ; fn ge eku yafd fofdj. k rjaka oL : i ea l arr pyus dh ctk; AtkZ oL i bDv oL : i eamRI ftZ gksrgS rksge Nf". kdk Li DVe dh 0; k[; k dj l drsgB lyed usLo; abu Dokk vFkok i bDv dls izk'k dh ctk; mRI tZ rFk vo' kS'k. k dk xqk ekuA mlghaus , d l uk 0; B i lu fd; k tkl elr Li DVe oL fy, l Eer gB ; g rjx rFk d. k fp-k. k dk , d my>u&Hkjk feJ. k gSftl oL vuq kj fofdj. k , d d. k dh Hkfr mRI ftZ gksrgS ; g , d rjx dh Hkfr xeu djrk gS rFk fi Qj l s, d d. k dh Hkfr vo' kS'kr gksrgS bl oL vfrfjDr] bl usHkSrdfoKkfu; ka dls nfoek eaMky fn; ka D; k oLoy , d ifj?Vuk dh 0; k[; k djus oL fy, ge i q% izk'k oL d. k fp-k. k dls Lohdkj dj ya rc 0; frdj. k rFk foorZ dh ifj?Vukvka dk D; k gskj ftudh 0; k[; k df. kdk ekMy }kjk ugha dh tk l drhA

yfdu 'kh?kz gh l u-1905 eavkba Vku us izk'k k&fo | q i Hko dh 0; k[; k izk'k oL df. kdk fp-k. k }kjk dha fMckZ us fØLVyh; Bkl ea tkyd oLi ula oL fy, d. k fp-k. k dk mi; kx djoL Bkl ka ea fuEu rki fof'k'V A"ekvka dh 0; k[; k dha HkSrdh oL 0; ki d fofok {kka l s t l s gksus ij Hkh bu nkska ifj?Vukvka dh 0; k[; k rjx ekMy l s u gkdj oLoy d. k ekMy }kjk gh dh tk l drh gB l u-1923 eadkwi Vu oL i jek. kvka l s x&fdj. k izh. kZ i z kx Hkh d. k&fp-k. k oL i {k eagh x, A bl us oKkfuadha dh nfoek dls vS c<k fn; ka

bl izk'k 1923 rd HkSrdfoKkuh fuEu fLFkr; ka dk l leuk dj jgsFku (a) izk'k dk ½ t j d kh; l p j. k] i jkorZ rFk vi orZ tS h ifj?Vuk, j ftudh 0; k[; k df. kdk ekMy vFkok rjx ekMy nkska l s gh dh tk l drh gB (b) 0; frdj. k rFk foorZ tS h oL N , d h ifj?Vuk, j Fkha ftudh 0; k[; k df. kdk ekMy }kjk ugha dh tk l drh bllga oLoy rjx ekMy }kjk gh l e>k tk l drk gB (c) Nf". kdk fofdj. k] izk'k fo | q i Hko] rFk dkw i Vu izh. kZ tS h oL N ifj?Vukvka dh 0; k[; k rjx ekMy }kjk ugha dh tk l drh budh 0; k[; k oLoy df. kdk ekMy }kjk gh dh tk l drh gB mu fnukaefdl h us Bhd gh fVli. kh dh] fd l keokj] c q o k j rFk 'k o k j oL fnuka ea izk'k d. k dh Hkfr 0; ogkj djrk gS rFk eayokj] cgLifrokj rFk 'kfuokj oL fnuka ea; g rjx dh Hkfr 0; ogkj djrk gS rFk jfookja dls ge izk'k dh ckr gh ugha djra

l u-1924 eansckyh us vius rjx&d. k oL }S fl ¼kr dls l r q fd; k ftl eamlglaus dgk fd oLoy izk'k oL i O S / N U gh ugha yfdu nD; oL d. ka tS s byDVNU rFk i jek. kvka oL Hkh }S y {k. k gksrgS dHkh ; sd. k dh Hkfr 0; ogkj djrs gS vS dHkh rjx dh HkfrA mlghaus mu oL nD; eku] oxk] l oxk (d. k oL y {k. ka) dks mudh rjxnS; Z rFk vkofuk (rjx oL fof'k'V y {k. ka) l s t k l u s o k y k , d l uk LFkfr fd; ka l u-1927 eJ vka l u rFk Mfol u vS teJ us vyx & vyx iz k s ka }kjk n' k z k fd byDVNU rjx dh Hkfr 0; ogkj djrk gS ftl dh rjxnS; Z nscMlyh oL l æk }kjk i k r eku l s l gefr j [k r h gB mudk iz k s k fØLVyh; Bkl ka }kjk byDVNU oL foorZ ij vkefjr Fk ftl ea i jek. kvka oL fu; fer izæk us, d xVax dh Hkfr dk; Zfd; ka 'kh?kz gh vU; d. ka tS s u; wNU rFk i k / N U oL l k f k foorZ iz k s fd, x, rFk bul s Hkh nscMlyh oL l uk dh i q'V gB bl us rjx&d. k dh }S r k d s HkSrdh oL LFkfr i fl ¼kr oL : i ea i q'V dha bl fl ¼kr l s oLoy izk'k l æk mi j k d r ifj?Vukvka dh gh 0; k[; k ugha dh tkr cYd bl l sd. ka l s l æk r ifj?Vukvka dh 0; k[; k Hkh l hko gB

yfdu rjx&d. k }S okn dk dkbZ l S k i r d vkekj ugha gB nscMlyh dk i Lrko oLoy , d xq k R ed roL gS rFk i N f r dh l e f e r ij vkefjr gB rjx&d. k }S okn vfekd l s vfekd , d fu; e Fk] fdl h Bkl eayHkr fl ¼kr dk fu" d " l z ugha FkA ; g l p gS fd tks Hkh iz k s fd, x, mudh nscMlyh oL l uk l s l gefr Fkha yfdu HkSrdh eabl izk'k l s dk; Z ugha gk rA , d vS bl s i k; k s x d i q'V dh vko' ; drk gsrh gS tcf d n i j h vS i L r k f o r e k M y o L f y, Bkl l S k i r d vkekj dh Hkh vko' ; drk gB bl svxys nks n' kaka eafodfl r fd; k x; ka yxHkx 1928 eafMj d l us vi us f o f d j . k o L f l ¼ k r d l s f o d f l r f d ; k r F k g l b " k u c x Z r F k i k M y h u s 1930 r d b l s n < + v k e k j i n k u f d ; ka 1940 oL mUkj kelZ eavkba s u k x k j f' o l t j r F k i O b u e s u u s b l d k v S v f e k d i f j " d j . k f d ; k r F k f l ¼ k u r e a t k s H k h v l a f r ; k n s [k h x b j m l g a l i " V f d ; ka b u l H k h f l ¼ k a r l a u s e [; : i l s r j x & d . k } S o k n d l s , d l S k i r d v k e k j i n k u f d ; ka

; | f i d g k u h v H k h l e k r u g h a g b j ; g v S v f e k d t f V y g l r h t k j g h g S r F k b l f V l i . k h o L d k ; Z l e k l s i j s g B y f d u v c g e a t s k f v r g p k g S m l d h e y H k r l j p u k k r g s v S g e a b l l e ; b l l s l a r q'V H k h g l s t k u h p k f g , A v c H k S r d h o L o r e k u f l ¼ k a r k a o L L o k H k f o d f u " d " l z o L i Q y l o : i g e ; g e k u l d r s g s f d f o f H k u i z k s k a e a r F k d H k h m l h i z k s o L f o f H k u H k x k a e j o S q p p a d h ; f o f d j . k r F k n D ; o L d . k] r j x r F k d . k n s k a g h x q k i n f ' k z d j r s g B

