$D=J^{m} KafS^{I} Wfgd^{J} Wd[We$

KZW [`hWef_W`f aT\WUf[hW aX fZW Xg`V [e fa eWW] fafS^ dWfgd`*

D=J KafS^ I Wfgd` JWd[We

, C < < 0@G >5 &4G %=5>@ < 0B8>=

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"F0<?;4 KZ[e WjS_b^W [e [`fW`VWV fa ZW^b kag Ua_bSdW fZW Uaef aX [`hWef[`Y [` fZW Xg`V i [fZ fZW Uaef aX [`hWef[`Y [` afZWd _gfgS^ Xg`Ve* @X fZW

Ua`V[f[a` aX fZW [eegWd(Tadda i Wd(Uag`fWdbSdfk(ad afZWd W`f[fk(ad g`VWd^k[`Y Ua^SfWdS^ ad SeeWfe(ad UZS`YWe [`(ad bWdUWbf[a`e aX(ebWU[X[U ad YW`WdS^ _Sd]Wf(WUa`a_[U([`Vgefdk(ba^[f[US^(dWYg^Sfadk($YWaba^{f[US^{(W)}h[da^{U}] W fS^{(bgT^{U}XWS^{fZ}(S^{V}afZWdUa^{V}f[a^{*}e^{*}$

 $\label{eq:started} < j\,baegdW\,fa\,XadW[Y`_Sd]\,Wfe\,fZdagYZ\,[eegWde\,adUgddW`U[We\,US`[`ha^hW\,SVV[f[a`S^d[e]e\,dW^Sf[`Y\,fa_Sd]\,Wf(\,WUa`a_[U(Mua`a_[U(Mua`a_[U(Mua`a_[Wfi]a))]))))))))$ ZWS^fZ(S`V afZWd Ua`V[f[a`e* KZWeW XSUfade US`_S]W XadW[Y` [`hWef_W`fe(WebWU[S^k fZaeW f[WV WUa`a_[US^k fa W_WdY[`Y _Sd]Wfe ad Uag`fd[We egT\WUf fa eS`Uf[a`e ad fZW fZdWSf aX`W i ad $aV[X[WV eS`Uf[a`e(_adW ha^Sf[^W S`V ^Wee ^[cg[V fZS` L*J*]])]$ [`hWef_W`fe* @` SVV[f]a`(XadW[Y` _Sd] Wfe US` dWSUf V[XXWdW`f^k fa $fZWeW Ua V[f[a e fZS fZW L*J* _Sd]Wf*$

@ efdg _W fe egT\WUf fa bdWbSk _W f $S^V_a W_j fW^e[a] US^ dWVgUW fZW bafW^f[S^Xad YS]^ Xad fZW$ [`efdg_W`fqe Za^VWde [X fZW [`efdg_W`f [e bdWbS[V S`V [`UdWSeW fZW bafW`f[S^ Xad ^aee [X fZW _Sfgd[fk aX fZW [`efdg _W`f [e WjfW`VWV*

@eegWde [` S e[`Y^W [`Vgefdk(eWUfad(Uag`fdk(ad dWY[a` US` dWSUf e[_[^Sd^k fa _Sd]Wf(UgddW`Uk(ba^[f[US^($Wua`a_[U($ $\label{eq:started} dWYg^Sfadk(YWaba^[f[US^{(}W^h[da^{-}_W) fS^{(}bgT^{[}U ZWS^{f}Z(S^{V} afZWd Ua^{V}[f[a^{e}(S^{V} fZW Xg^{V}b bWdXad_S^{U}W i [^{^{}TW} SXXWUfWV Tk fZW Isolation for the formula of the formula$ Ua`V[f[a`e [` fZW [`Vgefd[We(eWUfade(Uag`fd[We(S`V dWY[a`e fa i Z[UZ fZW Xg`V [e WjbaeWV*

KZW bgdUZSeWd [`S i ZW`)[eegWV(VW^SkWV VW^[hWdk ad Xad i SdV Ua _ [f_W`f fdS`eSUf[a` Seeg_We fZW d[YZfe S` $d[e]e aX a i WdeZ[b([U^gV]Y fZW d[e]e aX bd[UW SV k[W^V]$ X^gUfgSf[a`e S`V fZW d[e] fZSf fZW eWUgd[fk i [^ `af TW [eegWV ad VW^[hWdWV Se S`f[U[bSfWV* NZW`)[eegWV(VW^SkWV VW^[hWdk(S`V Xad i SdV Ua _ [f_W`f fdS`eSUf[a`e US` [`ha^hW ^WhWdSYW*

; Wd[hSf[hWe US` TW Z[YZ^k ha^Sf[^W S`V [`ha^hW d[e]e [` SVV[f[a` fa fZW d[e]e aX fZW g` VWd^k[` Y [` V[USfad&e' a` i Z[UZ fZW VWd[hSf[hW [e TSeWV* >S[`e ad ^aeeWe Xda VWd[hSf[hWe US` TW egTefS`f[S^k YdWSfWd fZS` fZW VWd[hSf[h US` [`ha^hW ^WhWdSYW*

CWhWdSYW [`ha^hWe $S_ag^f WjUWWV[YfZW[[f[S^[]hWef_W]]]$ [`UdWSeWV ha^Sf[^[fk Tk _SY`[Xk[`Y YS[`

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`af SVhS`fSYWage

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8e aX ; WUW_TWd /-(.,./(fZW D=J KafS^ I Wfgd` 9^W`VWV $^{\circ}$ VWj &fZW 9^W`VWV $^{\circ}$ VWj 'Ua`e[efWV aX fZW Xa^a i [`Y [`V[UWe S`V i W[YZf[`Ye6 2, # JfS`VSdV \$ Gaade 1,, JfaU] $^{\circ}$ VWj S`V 0, # 9^aa_TWdY L*J* 8 YYdWYSfW 9a`V $^{\circ}$ VWj* KZW Ua_ba`W`fe S`V i W[YZf[`Ye aX fZW 9^W`VWV $^{\circ}$ VWJ _SK ZShW V[XXWdWV Vgd[`Y fZW bWd[aVe S`V_SK V[XXWd [` fZW XgfgdW*

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 $\begin{array}{l} KZW\ \&g^V\ aXWde\ e^{fgS^: A See\ S^V\ JWdh[UW: ^See\ eZSdWe\ fZdagYZ\ fZ[e\ bdaebWUfge^*\ 8^{\ V}\ U^SeeWe\ aX\ fZW\ \&g^V\ ZShW\ fZW\ eS_W\ hWef_W^f\ aT\WUf[hW\ S^V\ eWef_W^fe(\ Tgf\ WSUZ\ U^See\ ZSe\ [fe\ a\ i\ Wj\ bW^eWefgUfgdW^* \end{array}$

! 8AB@81 CB8>= 0=3 , 4@D824 #44A

 $\begin{array}{l} \mathsf{KZW} \&g \lor \mathsf{ZSe} \ \mathsf{SVabfWV} \ \mathsf{S} \ \mathsf{b}^{\mathsf{S}} \ [\ \mathsf{SUUadVS} \lor \mathsf{UW} \ i \ [\mathsf{fZ} \ I \ g^{\mathsf{W}} - . T) - \ g \lor \mathsf{VWd} \\ \mathsf{fZW} \ (\ \mathsf{hWef} \ W \ \mathsf{f} \ : \ \mathsf{a} \ \mathsf{bS} \ \mathsf{k} \ \mathsf{SUf} \ \mathsf{aX} \ - 50, (\ \mathsf{SS} \ W \lor \mathsf{VWV} \ \& \mathsf{dZW} \\ \mathsf{n} \ ; \ [\mathsf{efd}[\mathsf{Tgf}[a \ \ G^{\mathsf{S}} \ \mathsf{p}^{*} \ \mathsf{L} \ \lor \mathsf{VWd} \ \mathsf{fZW} \ ; \ [\mathsf{efd}[\mathsf{Tgf}[a \ \ G^{\mathsf{S}} \ (\ J \ \mathsf{Wdh}[\mathsf{UW} \ : \ \mathsf{ASee} \\ \mathsf{eZSdWe} \ \mathsf{bSk} \ \mathsf{V}[\mathsf{efd}[\mathsf{Tgf}[a \ \ \mathsf{S} \ \lor \mathsf{V} \ \mathsf{ad} \ \mathsf{eWd} \ \mathsf{fUW} \ WWe \ \mathsf{fa} \ \mathsf{egbbadf} \ \mathsf{fZW} \ \mathsf{eS}^{\mathsf{W}} \ \mathsf{S} \ \lor \mathsf{V} \\ \mathsf{V}[\mathsf{efd}[\mathsf{Tgf}[a \ \ \mathsf{aX} \ J \ \mathsf{Wdh}[\mathsf{UW} \ : \ \mathsf{ASee} \ \mathsf{eZSdWe} \ \mathsf{Se} \ i \ \mathsf{W}^{\mathsf{M}} \ \mathsf{See} \ \mathsf{eZSdW2} \ \mathsf{a}^{\mathsf{VWd}} \ \mathsf{eWd} \ \mathsf{WWd} \ \mathsf{WWG} \ \mathsf{WW} \ \mathsf{S}^{\mathsf{V}} \ \mathsf{V} \\ \mathsf{V}[\mathsf{efd}[\mathsf{Tgf}[a \ \ \mathsf{aX} \ J \ \mathsf{Wdh}[\mathsf{UW} \ : \ \mathsf{ASee} \ \mathsf{eZSdW2} \ \mathsf{a}^{\mathsf{VWd}} \ \mathsf{eWd} \ \mathsf{Wdd} \ \mathsf{eWd} \ \mathsf{W} \\ \mathsf{W} \ \mathsf{SUuag}^{\mathsf{T}} \ \ \mathsf{S}^{\mathsf{T}} \ \mathsf{S}^{\mathsf{TW}} \ \mathsf{W} \ \mathsf{WWe} \ \mathsf{WWe} \ \mathsf{WWe} \ \mathsf{WWe} \ \mathsf{WWe} \ \mathsf{WWd} \ \mathsf{WWd} \ \mathsf{WWd} \ \mathsf{WWd} \ \mathsf{WWd} \ \mathsf{WWd} \ \mathsf{WWW} \ \mathsf{WWW} \ \mathsf{V} \ \mathsf{M}^{\mathsf{T}} \ \mathsf{W} \ \mathsf{S}^{\mathsf{T}} \ \mathsf{V} \ \mathsf{T}^{\mathsf{T}} \ \mathsf{W} \ \mathsf{S}^{\mathsf{T}} \ \mathsf{W} \ \mathsf{S}^{\mathsf{T}} \ \mathsf{W} \ \mathsf{W} \ \mathsf{W} \ \mathsf{W} \ \mathsf{W} \ \mathsf{W} \ \mathsf{S} \ \mathsf{W} \ \mathsf{W} \ \mathsf{M} \ \mathsf{W} \ \mathsf{W} \ \mathsf{M} \ \mathsf{M} \ \mathsf{W} \ \mathsf{W} \ \mathsf{M} \ \mathsf{M}$

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 $\label{eq:states} \begin{array}{l} \label{eq:states} \ensuremath{\mathbb{Q}^{\circ}}\ SVV[f[a^{(UWdfS[^ =[^S^U[S^{(Wd_WVSd[WedWUW[hW bSk_W^ feXda_ D=; Xda_ D=; qe a i ^ SVV[f[a^S^ dWeagdUWe Se [^UW^ f[hWe fa _Sd]Wf]] \\ \end{array} \end{array}$ $fZW D=J Xg Ve(fa bSdf[U[bSfW [` D=; qe bda_af[a`S^WXXadfe S`V+ad [` dWUaY`[f[a` aX fZW[d _Sd]Wf[`Y egbbadf(SV_[`[efdSf[hW eWdh[UWe$ S`V+ad fdS`eSUf[a` bdaUWee[`Y egbbadf* KZ[e Ua_bW`eSf[a` Xda] D=; [e `af dWX^WUfWV [` fZW !=WWe S`V < j bW` eWe! fST^W [` fZW Xg` Vqe bdaebWUfge* D=; Ua_bW`eSfWe =[`S`U[S^@`fWd_WV[Sd[We TSeWV a` $\begin{array}{l} \label{eq:linearized_line$ bdaVgUfeS`V bdaYdS_e aXXWdWV Tk fZW =[`S`U[S^ @`fWd_WV[Sdk(W^[Y[T[^[fk Xad b^SUW_W`f a` fZW X[`S`U[S^ [`fWd_WV[Sdkle bdWXWddWV ad dWUa__W`VWV ^[ef(fZW X[`S`U[S^ S`V Ua`fdSUfgS^ fWd_e i [fZ fZW $\label{eq:started} \end{system} X[\S\U[S^ [\Md_WV[Sdk(fZW \MbW^ S\V+ad fkbW aX \Sd]Wf[\Y S\V$ SV_[`[efdSf[hW egbbadf bdah[VWV Tk fZW =[`S`U[S^@`fWd_WV[Sdk(S`V $fZW cgS^{fk} aX fZW ahWdS^{h} dW^{fa}eZ[b i [fZ fZW = [^S^U]S^{h}$ $^{\circ} fWd_WV[Sdk^{*} \circ bSdf[Ug^Sd(D=; ad_S^k Uae[VWde fZW ^WhW^ aX Uae])$ SeeWfe Sffd[TgfST^W fa fZW =[`S`U[S^ @`fWd_WV[Sdk(fZW ^WhW^ aX $dWVW_bf[a] e Tk fZW = [S] U[S^ @] fWd_WV[Sdk(fZW WhW^ aX SUUWee fa fZW]$ =[$S^U[S^@'fWd_WV[Sdk e dWbdWeW`fSf[hWe S`V_S`SYW_W`f(fZW)]$ $ST[^{fk} fa WVgUSfW fZW dWbdWeW fSf[hWe aX fZW = [S U[S @ fWd_WV[Sdk($

S`V fZW g_TWd aX dWbdWeW fSf[hWe aX fZW =[`S`U[S^@`fWd_WV[Sdk bafW f[S^k gf[1[Y fZW D=J =g Ve i [fZ fZW[d U/[W fe* KZW fkbWe aX bSk_W`fe VWeUd[TWV STahW SdW `af WjU^ge[hW S`V egUZ bSk_W fe US TW e[Y [X[US f fa fZW =[S U[S^ @ fWd_WV[Sdk* @] $SVV[f[a] (fZW Ua_bW) eSf[a] fZSf = [S] U[S^0] fWd_WV[Sd[We dWUW[hW])$ Sk hSdk Tk U^See aX eZSdWe ea^V $S V S_a Y = [S U[S^{A}]$ @`fWd_WV[Sd[We* ; WbW`V[`Y gba` fZW SddS`YW_W`fe [` b^SUW Sf S`k bSdf[Ug^Sd f[_W(=[`S`U[S^@`fWd_WV[Sd[We _Sk ZShW S X[`S`U[S^ [`UW`f[hW fa dWUa__W`V S bSdf[Ug^Sd [`hWef_W`f hWZ[U^W fZSf_S]We fZW Xg`V ShS[^ST^W ad dWUa__W`V S bSdf[Ug^Sd Xg`V ad eZSdW U^See* Pag US`X[`V XgdfZWd VWfS[^e [` fZW J 80 STagf fZW bSk_W`fe _SVW Tk D=; S`V fZW eWdh[UWe bdah[VWV Tk =[`S`U[S^ @`fWd_WV[Sd[We* =[`S`U[S^@`fWd_WV[Sd[We _Sk UZSdYW kag SVV[f[a`S^XWWe S`V+ad Ua__[ee[a`e afZWd fZS` fZaeW V[eU^aeWV [` fZ[e bdaebWUfge* Pag eZag^V Se] kagd =[`S`U[S^@`fWd_WV[Sdk Xad [`Xad_Sf[a` STagf S`k bSk_W fe [f dWUW[hWe Xda D=; S V S k eWdh[UWe [f bdah[VWe(Se i W^^ Se STagf S`k XWWe S`V+ad Ua _ [ee[a`e [f UZSdYWe kag* =[`S`U[S^ @`fWd_WV[Sd[We fZSf _Sd]Wf fZW Xg`Ve _Sk S^ea SUf Se(ad TW SXX[^[SfWV] i [fZ(S Tda] Wd+VWS^Wd [` Ua``WUf[a` i [fZ S Xg` Vqe bgdUZSeW ad eS^W aX $badfXa^{a} = WUgd[f[We^* ? a i WhWd(fZW Xg^V S^V D=J Va a f Uae[VWd]$ =[`S`U[S^@`fWd_WV[Sd[Wel bgdUZSeWe aX eZSdWe aX fZW Xg`V Se S XSUfad i ZW` UZaae[`Y Tda]Wde+VWS^Wde fa WXXWUf b<e 1

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$SdWfUaV[f[aeSV[`hWef_V]]$	f efdSfWY[We a` fZW Xg`Vqe bWdXad_S`UW Vgd[`Y [fe ^Sef X[eUS^ kWSd*
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Pa Ua	$gS^{+}W_{S^{+}} = S^{+}gS^{+}W^{T}S^{+}gS^{+}W^{T}S^{+}S^{+}S^{+}S^{+}S^{+}S^{+}S^{+}S^{+$
]*
)5/0-
KW/WbZa`W6-)433)0)7/.1
<pre>@`fWd`Wf6 [`egdS`UWXg`</pre>	Ve* UX