

LING5026

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GYa YghYf'C bY''##'&\$%

7ci fgY Cj Yfj]Yk

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'7cbj Ybcfg'

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A Yb[]gh '5a VYfVYf	a "Ua VYfVYf4 i bgk "YXi "Ui	H∖i fgXUmž	A 6&(%	-',)
		&da!'da žcfVm		
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@cWUhjcb. GWkcc CZJWY ZA cfj Yb 6fck b 6i] X]b[z @Yj Y 8 & Z &),

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5 http://bxubwr.f.yei.jfya.ybhg

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5 'ghi XYbhik \c'Uff]j Yg'a cfY'h\Ub'%) 'a]bi hYg'`UhY'a Um'VY'dYbU`]gYX'Zcf'bcb!UhhYbXUbWY"' ≠Zgi W\'U'dYbU`hm]g']a dcgYXž'h\Y'ghi XYbhia i gh'VY']bZcfa YX'j YfVU``m'Uh'h\Y'YbX'cZWUgg'UbX'UXj]gYX']b'k f]h]b['k]h\]b'&(\ci fg"

: cf`YggYbhJU``ghi XYbh`]bZcfa UhJcb`fY`UhJb[`hc.`fYei Yghg`Zcf`Yl hYbg]cb/fYj]Yk `cZa Uf_g/cWW dUhJcbU``\YU`h\UbX`gUZ/hm/Yl Ua]bUhJcb'dfcWXi fYg/gdYVJU``Wcbg]XYfUhJcb`]b`h\Y`Yj YbhcZ]``bYgg`cf`a]gUXj Ybhi fY/ghi XYbhYei]hm'UbX`X]gUV]`]hm'UbX`ch\Yf`YggYbhJU``UWUXYa]W]bZcfa UhJcbž gYY`\hdg.#k k k "Ufhg"i bgk "YXi "Ui #W ffYbhghi XYbhg#JWUXYa]W]bZcfa UhJcb#dfchcWc`g![i]XY`]bYg#

7 ci fgY 8 YHJ]`g 7 fYX]hDc]bhg * Gi a a UfmcZh\Y 7 ci fgY Gi VYWh5 fYU

5ggYgga Ybh

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5ggYgga Ybh'hUg_	K Y][\h	8i Y'8UHY	Gh XYbh@YUfb]b[Ci hWca Ygʻ5ggYggYX
7`Ugg'HYgh=	' \$I	H\Y`hYgh`]g`[]j Yb`Xi f]b[`h\Y hi hcf]U``h]a Yg`]b`K YY_`*`fl‰ 5df]`#&:5df]`Ł"	&ž(
7`Ugg'hYgh'='	' \$I	H\Y`hYgh`]g`[]j Yb`Xi f]b[`h\Y hi hcf]U``h]a Yg`]b`K YY_`%%f%* A Um#%+`A UmL	% <u>₹</u> (
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5ggYgga Ybh8YHJ]`g

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 $8 YHJ]^g. (\$^a] bi HY HYghWcj Yf] b["h\Y'WcbHYbhcZ`YWh fYg'UbX'h hcf] U`g''Mci "k] ```fYWY]j Y'] bX]j]Xi U`ZYXVUW_"$

5qqYqqa Ybh' . HU_Y \ca Y dfcV Ya qYh

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@Yb[h.:5ddfcl]a UhY`m% \$\$ k cfXq

8 YHJ]`g. 'H\]g']g'U'H_Y!\ca Y'Ugg][ba Ybhk\]W\ 'Wcj Yfg'U``h\Y'a U'cf'hcd]Wg'cZh\Y'Wci fgY"'5 'dfcV`Ya 'gYh]g'U'gYf]Yg'cZXUHU'gYhg`XYg][bYX'gi W\ 'h\Uhgh XYbhg'Udd`m`]b[i]gh]WWcbW\dhg'UbX'UbU'mh]WU`'ZfUa Yk cf_g hc'UWWci bh'Zcf'`]b[i]gh]Wd\Ybca YbU"'5ddfcl]a UhY`m'% \$\$'k cfXg"'Mci 'k]``'fYW\]j Y']bX]j]Xi U`'ZYYXVUW_" H\]g']g'h\Y'Z]bU``UggYgga Ybh'Zcf'UhYbXUbW\'di fdcgYg"

Gi Va]gg]cb bch/g. H\Y hU_Y!\ca Y dfcV`Ya 'gYh]g`\UbXYX`ci hcbY`k YY_`df]cf`hc`]hg`Xi Y XUhY"

Hi fb]h]b gYh]b[. `H\]g Ugg][ba Ybh]g gi Va]hhYX h\fci [\`Hi fb]h]b UbX gh XYbhg Xc bchgYY Hi fb]h]b g]a]`Uf]hmfYdcfhg"

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

Gh XYbhgʻUfYʻYl dYWYX`hcʻdi hh\Y]fʻbUa YgʻUbXʻgh XYbhibi a VYfgʻcbʻYj YfmdU[YʻcZh\Y]fʻUgg][ba Ybhgʻ

Hi fb]h]b Gi Va]gg]cb

Imagi YbWci bhYf'U'dfcV'Ya 'k \Yb'UthYa dr]b['rc'gi Va]hmci f'Ugg][ba Ybht\fci [\'Hi fb]r]bž'd'YUgY hY'Yd\cbY'9I hYfbU'Gi ddcfhcb'-',) "''' %cf'Ya U] hYa 'cb'<u>Yl hYfbU'hY'hgi ddcfh4 i bgk "YXi "Ui"</u> "Gi ddcfh \ci fg'UfY', .\$\$Ua '-'%\$.\$\$da 'cb'k YY_XUmg'UbX'-.\$\$Ua '-') .\$\$da 'cb'k YY_YbXg'fl *) 'XUmg'U'mYUft'" Imai UfY'i bUV'Y 'rc'gi Va]hmci f'Ugg][ba YbhXi Y'rc'U'ZJi 'hk]h\ 'Hi fb]h]b'mci 'a UmUdd'mZcf'Ub'YI hYbg]cbž'Vi hmci a i ghfYhJ]b'mci f'h]\W_Yhbi a VYf'Zfca '9I hYfbU''Gi ddcfhfU'cb['k]h\ 'Ubmch\Yf'YYj UbhXcW a Ybhgt'rc]bWi XY'Ug'Yj]XYbW' 'rc'gi ddcfhmci f'Yl hYbg]cb'Udd']\WJhjcb"'Imai 'Ya U]''9I hYfbU''Gi ddcfhmci 'k]'`Ui hca Uh]\WJ'`mfY\W']j Y'U'h]\W_Yhbi a VYfž'Vi h]Zmci 'hY'Yd\cbY'mci 'k]'``bYYX'rc'gdY\WZ\WJ'`mUg_'Zcf'cbY'' Hi fb]h]b'U'gc'dfcj]XYg'i dXUhYg'cb'h\Y]f'gmghYa 'ghUh' g'cb'Hk]hYf"

; YbYfU`mž'UggYgga YbhitUg_g'a i ghVY'gi Va]hhYX'Y`YWfcb]WU``mj]U'Y]h\Yf'Hi fb]h]b'cf'U'A ccX`Y Ugg][ba Ybh''=b']bghUbWfg'k \YfY'h\]g']g'bchdcgg]V`Yž']hk]```VY'ghUhYX'cb'mci f'Wci fgY'g'A ccX`Y'g]hY'k]h\U`hYfbUh]j Y'gi Va]gg]cb'XYhU]`g"

@UhY 5ggYgga Ybh'DYbU`h]Yg

5b'UggYggYX'HUg_']g'XYYa YX``UhY']Z]h']g'gi Va]hhYX'UZhYf'h\Y'gdYW]Z]YX'h]a Y'UbX'XUhY'Ug'gYhci h']b'h\Y Wti fqY'@YUfb]b['A UbU[Ya YbhGmqhYa 'f@A Gt"

 $\label{thm:condition} $$HY^UHY^dYbU^m]g^hY^cgg^cZ)_L^cZ^hY^hcHU^dcgg]VY^aUf_g^Zcf^hYY^HUg_Z^cf^YUW^XUmcf^dUfhhYfYcZhY^kcf_]g^UHY^@UhYbYgg^k]^*]bW^XY^kYY_YbXg^UbX^di_V^]WYc^]XUmg^"HY]g^XcYg^bchUdd^mhc^U'HUg_'hWh]g^UqqYqqYX^Vi_hbc^aUf_]g^Uk_UfXYX"$$$

K cf_'gi Va]hhYX'Zci fhYYb'fl%(Ł'XUmg'UZhYf'h\Y'Xi Y'XUhY'k]``VY'a Uf_YX'UbX'ZYYXVUW_'dfcj]XYX'Vi hbc'a Uf_ k]``VY'fYWcfXYX"' ₹h\Y'k cf_'k ci `X'\Uj Y'fYWr]j YX'U'dUgg'a Uf_'Vi hZcf'h\Y``UhYbYgg'UbX'h\Y'k cf_']g'U Wca di `gcfm'Wci fgY'Wca dcbYbhz'U'gh XYbh'k]``VY'XYYa YX'hc'\Uj Y'a Yhih\UhfYei]fYa Ybh''H\]g'XcYg'bch Udd`mhc'U'hUg_'h\Uh']g'UggYggYX'Vi h'bc'a Uf_']g'Uk UfXYX"

K cf_'gi Va]hh/X'hk YbhnlcbY'f&&XUmg'UZhYf'h\Y'Xi Y'XUhY'k]```bchVY'UWWdhYX'Zcf'a Uf_]b['cf'ZYYXVUW_UbX'k]```fYWY]j Y'bc'a Uf_'cf'[fUXY"'=Zh\Y'UggYgga YbhHUg_']g'U'Wca di `gcfmWca dcbYbhcZh\Y'Wci fgY'U gh XYbhk]```Ui hca Uh]WU``mZU]`'h\Y'Wci fgY"

GdYWJU`7cbg]XYfUhJcb55dd`]WUhJcbg

 $\label{eq:linear_continuity} $$Mc_i = W_0 - W_$

G]W_bYggža]gUXj Ybhi fY'cf'ch\Yf'W]fW a ghUbWrg'VYmcbX'mci f'Wcbhfc``a Um

ł DfYj Ybhimci Zfca Wca d`Yhlb[U.Wci fqY fYei]fYa Ybhž

ł? YYd mci Zfca 'UthYbX]b['Ub 'UggYggUV'Y 'UWnji]tmž

ł Ghod moi gi Va]hh]b['UggYggUV'Y k cf_ Zcf'U Wci fgYž

ł `G][b]Z]\WbhmUZZY\Wimci f`dYfZcfa Ub\Wf`]b`UggYggUV`Y`k cf_ž`VY`]h'U`Zcfa U``YbX!cZgYa YghYf`Yl Ua]bUh]cbž'U \WUgg`hYghz`U``UVcfUhcfmhYghz`U`gYa]bUf`dfYgYbhUh]cb`cf`Ubmch\Yf`Zcfa 'cZ`UggYgga Ybh'

5 WUXYa]W<cbYghmUbX D`U[]Uf]ga

D`U[]Uf]ga i]gii g]b[ih\Yik cfXgicfi]XYUgicZch\YfgiUbXidfYgYbh]b[ih\Ya iUgimci fick b"i±i\WbihU_Yia Ubm Zcfa gžZfca iXYi]VYfUhYiW\YUh]b[ihciU\W]XYbhU`m\Wcdm]b[iZfca iUigci f\Wik]h\ci hiU\w_bck iYX[Ya Ybh'

IBGK [fcidg'd'U[]Uf]ga]bhc'h\Y'Zc``ck]b[WUhY[cf]Yg.

7 cdm]b[.'i g]b['h\Y'gUa Y'cf'j Yfmg]a]`Uf'k cfXg'hc'h\Y'cf][]bU`hYl h'cf']XYU'k]h\ci h'UW_bck `YX[]b['h\Y gci fW'cf'i g]b['ei chUh]cb'a Uf_g"'H\]g'U`gc'Udd`]Yg'hc']a U[Ygž'Ufh'UbX'XYg][b'dfcYWhgž'Ug'k Y``'Ug dfYgYbhUh]cbg'k \YfY'gca YcbY'dfYgYbhg'Ubch\Yf'g']XYUg'cf'k cfXg'k]h\ci h'WfYX]h'

±DUddfcdf]UhY`dUfUd\fUg]b[.'W\Ub[]b['U'ZYk'kcfXg'UbX'd\fUgYg'k\]`Y`acghmfYhJ]b]b['h\Y`cf][]bU`ghfi WifY'UbX']bZcfaUh]cbk]h\ci hUW_bck`YX[YaYbh'H\]g'U`gc'Udd`]Yg']b'dfYgYbhJh]cbg'k\YfY`gcaYcbYdUfUd\fUgYg'Ubch\Yf'g']XYUg'cf'kcfXg'k]h\ci hWfYX]h''±iU`gc'Udd`]Yg'hc'd]YW]b['hc[Yh\Yf'ei chYg'UbXdUfUd\fUgYg']bhc'U'bYk'k\c`Yž'k]h\ci hfYZYfYbW]b['UbX'U'ghi XYbhg'ck b'UbU`mg]g'hc'Vf]b['h\Y`aUhYf]U`hc[Yh\Yf''

7 c``i g]cb. 'k cf_]b['k]h\ 'ch\ Yfg'Vi h'dUgg]b['c\Z'h\ Y 'k cf_'Ug'U'dYfgcb'g']b\X]j]\Xi U``k cf_"'7 c``i g]cb'U`gc]b\Wi XYg'dfcj]\X]b['mci f'k cf_'hc'Ubch\ Yf'ghi XYbh\ VYZcfY'h\ Y 'Xi Y 'XUhYzcf'Zcf'h\ Y' di fdcgY'cZh\ Ya d`U[]\Uf]g]b['Uh\Ubmh]a Yz'dUm]b['Ubch\ Yf'dYfgcb'hc'dYfZcfa 'Ub'U\WUXYa]\Wh\Ug_z'ghYU']b['cf'U\\ello i]f]b[Ubch\ Yf'dYfgcb'g' U\WUXYa]\Wk cf_'Ub\X'\\ello dm]b[']hz'c\ZYf]b['hc'\\ello a d`YhY'Ubch\ Yf'dYfgcb'g' k cf_'cf'gYY_]b[d\una Ybh\Zcf'\\ello a d`Yh\beta d`

±bUddfcdf]UhY`W]hUh]cb.`7]h]b[ˈgci fW/gˈk \]WX`\Uj Y`bchVYYb`fYUXžk]h\ci hUW_bck`YX[]b[ˈh\Y`″gYWcbXUfm″gci fW/Zfca k \]WX`_bck`YX[Y`cZh\Ya`\Ug'VYYb`cVhU]bYX"

8 i d`]\WUh]cb`ff`gY`Zld`U[]\Uf]ga "Ł 'gi Va]\h]b['mci f`ck b`k cf_ž]b`k \c`Y`cf`]b`dUfhžk \YfY`]h\Ug`dfYj]ci g`m VYYb`dfYdUfYX`cf`gi Va]\hYX`Zcf`Ubch\Yf`UggYgga Ybhcf\Wci fgY`UhI BGK 'cf`Ubch\Yf`i b]j Yfg]\m'

7 cffYWhfYZYfYbWb[dfUWhWyg.

- DUfUd\fUg]b[žgi a a Uf]g]b[žYggUmk f]h]b["UbX"h]a Y a UbU[Ya Ybh
- 5ddfcdf]UhY'i gY'cZUbX'Uhff]Vi h]cb'Zcf'U'fUb[Y'cZa UhYf]U`g']bWi X]b['hYl hž']a U[Ygž'Zcfa i `UY'UbX WbWYdhq"

±0X]j]Xi U``Ugg]ghUbWr`]g`Uj U]`UV`Y`cb`fYei YghZfca `H\Y`@YUfb]b[`7 YbhY`f<u>\hd.#k k k "`Wi bgk "YXi "Ui #</u>" Gh XYbhg`UfY`U`gc`fYa]bXYX`h\UhWUfYZ ``ha Ya UbU[Ya Ybh']g`Ub`]a dcfhUbhdUfhcZgh XmUbX`cbY`cZh\Y]XYbh]Z]YX`WUi gYg`cZd`U[]Uf]ga `]g`dccf`ha Y`a UbU[Ya Ybh'`Gh XYbhg`g\ci `X`U``ck `gi Z]W]Ybh'ha Y`Zcf fYgYUfW\žXfUZh]b[`UbX`dfcdYf`fYZYfYbW]b[`cZgci fWfg`]b`dfYdUf]b[`U```UggYgga Ybh]hYa g"

IBGK "@]VfUfmU`gc`\Ugʻth\Y`9@&9`hcc``Uj U]`UV`Y`hc`Ugg]ghimci ik]h\`mci f`ghi Xm'Uhi BGK "'9@&9`]g XYg][bYX`hc`]bhfcXi WK`bYk `ghi XYbhg`hc`ghi Xm]b[`Uhi BGK `Vi h`]h\Wb'U`gc`VY`U`[fYUhfYZfYg\Yf`Xi f]b[`mci f ghi Xm'

7 ca d'Yhlp['h\Y'9@&9'h hcf]U`'UbX'ei]n'k]``'YbUV'Y'mci 'hc.



7ci fgY GWX YXi `Y

J]Yk 'WUgg'ha YhUV'Y

H]a YHJV`Y

8 UHY	HmdY	7 cbhYbh
K YY_'%	@YWhi fY	±blfcXi W•]cb
A UfVX		;`fdaVgU[`YfZWUagdeW-{`Yg[ef[U]`ai WWYW- 'S`YgSYWg`[hWdeS'e-S`[_S^'S`YgSYWe

		9 YfVJgY^&.^A cfd\c`c[]WU``Vci bXUfm	
		9 YfW]gY" ."A cfd\c`c[]WU`"WUHY[cf]Yg	
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K YY_'(.'%'A UfWX'!'&) A UfWX	@YWhifY	GmbHJI 'fDUfh'±	
A OIW		EW fW UWefdgUfgdW Ua`ef[fgW Uk S`V YdS Sf[US^USfWad[We	
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		5ZSbfWd&	
	Hi hcf]U`	7\UdhYf"Acfd\c`c[m	
		91 YfVljgY ') . 'Gk YX]g\	
		91 YfWjgY`*.`7 YVi Ubc	
		91 YfW]gY '+. '81 HW	
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		91 YfWjgY^&. F YW fg]cb	
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K YY_'*.'- '5df]`'!'%) '5df]`	@YWhifY	GYa Ubh]Wg fDUfh ±	
		>Wj [US^eW_S`f[Ue, Wj [US^dWSf[a`eS`VeW_S`f[U XWSfgdWe	
		F YUX]b[
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	Hi hcf]U`	±D!WUgg`hYgh`f⊭	
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		fl%%5df]`#%&'5df]`Ł"'Mci 'a i gh'UlthYbX'mci f'fY[i `Uf hi hcf]U`"
K_YY_'+.'%*'5df]`'!'&& 5df]`	@YWhi fY	GYa Ubh]WgʻfDUfhʻ=Łʻ
Sul		6Wj [e-5a`hWdeSf[a`S^_Sj [_e-ebWWUZ SUf
		F YUX]b[
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		D\cbYh]WgʻfDUfhi±
		Eag`VeWY_Wfe-Sdf[Ug/Sfack bZa`Wf[Ue
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		5ZSbfWd(
	Hi hcf]U`	7\UdhYf")."GYa Ubh]Wg"UbX"DfU[a Uh]Wg
		91 YfWjgY (. 'GYa UbhjWUa V][i]hm@UŁ'-'fYŁQ
		91 YfWjgY"+."GYa UbhjWdfcdYffjYg"@UŁ"—"ffYŁQ
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K YY_', .'&' '5df]`'!'&- 5df]`	@YWhi fY	
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		FYUX]b[#YIYfW]gYg'!'cb`]bY'fYgcifWYg'fXYHJ]`g dfcj]XYX']b'AccX`YŁ"
	Hi hcf]U`	
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K YY_''' \$'5df]`!'*'A Um	@YWhifY	D\cbYh]Wg fDUfh=Ł
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		91 YfWjgY"."D\cbYhjWHfUbgWfjdhjcb"@UŁIf[ŁQ
		9 YfWjgY`*.`D\cbYhjWXYgWfjdhjcbg