

ARTS3270

FYZYW]b['cb'<]ghcf]Yg'UbX'<]ghcf]Ubg.'7 UdghcbY

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

7ci fgY⁻Cj Yfj]Yk

'GhJZZ'7cbhJWh'8YhJ]`g'

'7cbj Ybcfg'

BUa Y 9a Uj`	5j U]`UV]`]m	@cWUhjcb	D\cbY
B]Wc`Ug`F Uga i ggYb B"F Uga i ggYb4 i bgk "YXi "Ui	&.' \$!(.\$\$"A cbXUmg]b"HYUWX]b["k YY_g fUbX"Vm Uddc]bha YbHz	' %(-',)!&'*% fbc a YggU[YgŁ

GWXcc`7cbHJWh′±bZcfa Uh]cb

GWkcc``cZ<iaUb]hJYg'UbX'@Ub[iU[Yg

@c\\Uhjcb.'G\\\cc`'C\\Zj\\\\Z'\A\cfj\Yb'6fck\b'6i\]\\X]b[\z'\@Yj\Y`\&z\&),

 $CdYb]b[~< ci~fg.~A~cbXUm!~:~f]XUm\rea^--Ua~!~(.()~da$

D\cbY. 'Ž*%'&'-',)'%*,%

: UI . Ž*%'&'-',)', +\$)

9a U]`. \<u>\U`4 i bgk "YXi "Ui</u>

5 http://bxubww.F.Yei]fYa Ybhg

5 'ghi XYbh']g"Yl dYWYX"hc"UhhYbX"U""WUgg"WcbhUWh\ci fg"Zcf"U"ZUWY!hc!ZUWY"fl &: Ł'cf"V"YbXYX"Wci fgY"UbX

7ci fgY 8YHJ] g

7 fYX]h'Dc]bhg'*

Gi a a UfmcZh\Y 7ci fgY

Gi VYWh5fYU. '<]ghcfm'

5 hith Y'WcbWi g]cb'cZhh]g'Wci fgY'hhY'ghi XYbhik]``'VY'UV`Y'hc

 $% Ya d`cmUbX'Yj U'i UhY'a U'cf'df]bW]d`Yg`UbX'a Yh\cXc`c[]Yg`k]h\]b'h\Y'X]gW]d`]bY'cZ\]ghcfm''' \\$

- ' "]XYbh]Zma i `h]d`Y`Zcfa g`cZ\]ghcfm]b`h\Y`di V`]WXca U]bž'UbX`Yj U`i UhY`h\Ya `]b``][\hcZdfcZYgg]cbU` ghUbXUfXg`cZgW.c`Ufg\]d`UbX`Yh\]WU``VY\Uj]ci f
- ("XYg][b'UbX'WcbXi WhUb']bXYdYbXYbhfYgYUfWX'dfcYWh

Yb[U[Ya Ybh]b'h\Y X]gW gg]cb"'Hc]a dUfh]bg][\h]bhc \]ghcfmg gc\y\U'fc \Yzh\Yf\k] \\YY Ub YI Yf\ygY fYei]f]b['mci 'hc 'UhhYbX'cbY'cZU'Z\k 'XYg][bUhYX'a i gYi a 'YI \]V]hg 'UbX'hc 'UbU`mgY]hg 'fYdfYgYbhUh]cb'cZh\Y dUghVch\]bhYfa g 'cZh\Y \]ghcf]\W'`g\\c`Ufg\]d 'cb'k \]\W']h]g 'VUgYXz'UbX'cZh\Y 'XYa UbXg'd`U\WX'cb \]ghcfmVm]hg di V`]\\g' UbX']bgh]h h]cbg"'H\]g a i gYi a 'YggUmUgg][ba Ybha UmVY \\can a 'YhYX']b '\\c``UVcfUh]cb k]h\ 'Ubch\Yf'ghi XYbhz'YbUV`]b['mci 'hc 'g\UfY]bg][\hg 'UbX'hc 'Ya d`cmhYUa k cf_]b YI d`cf]b['UbX XcW a Ybh]b['a i gYi a 'gdU\\"':]bU`mz']b 'U'fYgYUf\\ 'YggUmdfc Y\\zmai 'nci 'k]``YI dYf]Yb\\''h\Y 'VUg]\\h\Ug_cZ h\Y'\]ghcf]\\W' '\\T\Zf'mci fgY`Z-']b\\X \\cho 'Ybgfi \\forall \forall \for

5ggYgga Ybh

8 YHU] YX [i] XYg 'hc 'Vch', 'h\ Y 'A i gYi a '5gg] [ba Ybh'UbX F YgYUfW. '9ggUm'UggYgga Ybhg'k] "'VY'dcghYX'cb A ccX'Yž'U'cb ['k]h\ [i] XUbW'cb 'W]rUh]cb 'dfcW'Xi fYgž'UbX'h\ Y 'a Uf_]b ['fi Vf] Wg'gc 'h\ Uh'mci 'a Um'gYY'h\ Y XYHJ] YX 'Wf]hYf]U 'Vmmci f'k cf_'k] "'VY' ^\ X[YX" 7] hUh]cbg'hc 'dYf]cX] WU'UbX'g]a] 'Uf'df]a Ufmgci fW'g'i gYX']b h\ Y F YgYUfW. '9ggUma i gh']bWi XY'\ \[] hU'UXXfYggYg'hc 'h\ Y'XcW a Ybhg'Ug'k Y``'Ug'ghUbXUfX'df]bh | b\Zcfa Uh]cb"

5ggYgga Ybh'HUg_g'

5ggYgga Ybh'hUg_	K Y][\h	8iY'8UHY	Gh XYbh@YUfb]b[Ci hWca Ygʻ5ggYggYX
AigYia j]g]hUbX YggUm	' \$1	&-#\$'#&\$% `\$(.\$\$`DA	%ž&Ž Ž)
F YgYUfVX '9ggUm') \$1	' \$#\$) #&\$%	%ž&ž(ž)
±b'WUgg'[fci d'k cf_'	&\$ı	Bch5dd`]WUV`Y	%ž&ž)

5ggYgga Ybh'8YHJ]`g

5ggYgga Ybh% 'A i gYi a 'j]g]h'UbX 'YggUm

GhUfhXUhY. Bch5dd`]WUV`Y

@Yb[h\."%\$\$"kcfXg"f% \$\$"aUl]aiaŁ

5XX]h]cbU`XYhJ]`g.

: cf'&\$% žh\Y`A i gYi a '5gg][ba YbhA I GH'VY`WUff]YX`ci h'Wc``UVcfUhJj Y`m]b`dU]fg"`'⊕X]j]Xi U``m Ui h\cfYX`gi Va]gg]cbg`k]```VY`dYbU`]gYX`) ı `ci hcZh\Y`dcgg]V`Y'' \$ı "'`7c``UVcfUh]b[`dUffbYfg`k]`` gi Va]h-89BH-75@Wc!Ui h\cfYX`YggUmg`UbX`g\UfY`h\Y`gUa Y`a Uf_"

Gi Va]gg]cb bchYg.A I GH VY WUff]YX ci hWc \UVcfUhj Y m]b du]fg/YUW duffbYf gi Va]hg Ub =8 9BH=7 5@

YggUmUbX'k]```g\UfY'h\Y'gUa Y'a Uf_"

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

#mci 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]''h\Ya '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\"'=\maintention
UfY'i bUV'Y'hc'gi Va]hmci f'Ugg][ba YbhXi Y'hc'U'ZJi 'hk]h\'Hi fb]h]b'mci 'a Um'Udd'm\Zcf'Ub'YI hYbg]cb\ZVi hmci
a i ghfYhJ]b'mci f'h]\W_Yhbi a VYf\Zfca '9I hYfbU''Gi ddcfhfU'cb['k]h\'Ubmch\Yf'fY'Yj UbhXcW'a Ybhgt'hc
]bWi XY'Ug'Yj]XYbW' hc'gi ddcfhmci f'Yl hYbg]cb'Udd']\WJh]cb'''\=\maintention
Uh\WJ'`mfYWY']j Y'U'h]\W_Yhbi a VYf\ZVi h]Zmci 'hY'Yd\cbY'mci 'k]``bYYX'hc'gdYW]\Z\WJ'`mUg_'Zcf'cbY''
Hi fb]h]b'U'gc'dfcj]XYg'i dXUhYg'cb'h\Y]f'gmghYa 'gfUh' 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 Wci fqY'@YUfb]b['A UbU[Ya YbhGmqhYa 'f@A GŁ"

 $\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%(EXUmg'Uzhyf'h\y'Xi Y'XUhy'k]``VY'a Uf_YX'UbX'zYYXVUW_'dfcj]XYX'Vi hbc'a Uf_ k]``VY'fYWcfXYX"'=Zh\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 hbc'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 'UWhj]tmž

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

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

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

D`U[]Uf]ga `]g`i g]b['h\Y`k cfXg`cf`]XYUg`cZch\Yfg`UbX`dfYgYbh]b['h\Ya `Ug`mci f`ck b"'\lefi\Wb'hU_Y`a Ubm Zcfa gžZfca `XY`]VYfUhY`W\YUh]b['hc`UVW]XYbhU`mWcdm]b['Zfca `U`gci f\W' k]h\ci hUW_bck `YX[Ya Ybh'

IBGK [fcidgdu[]uf]ga]bhch\YZc``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 WhifY`UbX`]bZcfaUh]cb`k]h\ci hUW_bck`YX[YaYbh'H\]g'U`gc'Udd`]Yg`]b'dfYgYbhUh]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`Yžk]h\ci hfYZ/fYbW]b['UbX'U'ghi XYbh'g`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`Y

±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`UqqYqqa Ybhcf\Wci fgY`UhI_BGK_`cf`Ubch\Yf`i b]\Yfq]\m"

7 cffYWhfYZYfYbWb[dfUWhWyg.

• VYHYfa UbU[Ymcifh]a Y

K YY_" . '%&'A UfVX '! '% A UfVX	GYa]bUf	W.cgyb'YI\]/jicb'k jh mei fduffbyfcj Yf'h Y gi WWYX]b['k YY_" F Yei]fYX'F YUX]b[g. F]W.UfX'? c\bz"<]ghcfmUbX h Y '7 i 'hi fY 'K Ufg. 'H\Y 7 UgY cZh Y 'Ga]h gcb]Ub '-bghh hjcbfig '9 bc'U'; Um 91 \]/jijcb"z <agd "ghcfcf[#jhuyy#&-()="" %%%="" %s"="" &="" '"\htd.#k="")="" *="" ,="" -="" -%s"="" [efackt="" bz="" f%="" k="" s^a="" wdus':="" x3_="">c\b'K "8ck Yfz"Hr]i a d\U''UbX HrU[]WB UffUh] Yg cZh Y 'K Uf']b '5g]U"z' <agd "dxz="" "ghcfcf[#ghuy#dxz#&-()="" \$"="" %%="" %x&(!%%)="" &="" '="" '5="" '5i="" '7="" 'b="" 'c="" 'cb[="" 'cz="" 'f&s\$)="" 'h="" 'hcxumvm="" 'ubx'dyhyf="" 'ubx'h="" 'uf'[i="" 'wci="" 'x="" 'xcw="")="" -="" -bhyfbyh'="" 2]a="" 7="" 7]="" 8="" 9"f="" :="" [efackz,="" [fyuhyffc'y="" [xyfz"a="" \]ghcfj\w'="" \htd.#k=""]a=""]buh]cb"=""]g=""]h=""]x="" a="" ai="" bc="" by="" bz="" bz'')!)="" cbg]xyf'h="" cbhybhxygwf]dh]cb.="" ci="" d'umyx="" eau[wk="" f%="" fh="" g="" g<="" gewg_="" ghfu']ub="" gyi="" gz'buh]cb="" gzxcw="" h="" hcd]w'<]ghcfmk="" i="" j']nuh]cbz"?="" k="" s'="" s^a="" th="" u[="" ubux]ub="" ubx'dc']hjwu'\]ghcfm]b="" ubx'h="" uh]cbu'="" uhvcc_g="" uj="" v="" vcc_g,="" w="" wdus':="" x3_="" y="" ybhuffy="" ybhufm="" yf'f="" yf'g\udy="" yub="" yux]b[.=""></agd></agd>
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		k YY_'k]h\ 'mci f'dUfhbYf'Ug'h\YfY']g'fYgYUfV\ 'hc'Xc UZhYfk UfXgž'UbX'h\Y'YggUm]g'Xi Y']b'k YY_')
K YY_'(.'%-'A UfVX'!'&) A UfVX	GYa]bUf	Hcd]W'<]ghcf]WU'GW\cutering\lambda\text{TobhYbhXYgW]dh]cb.'-b'hYfa g'cZfYgYUfW\Yh\]\wg\text{Yh\]\wg\text{Yh\]\wg\text{Yh\]\wg\text{YmcbX'k\Uh\]g} \rangle f\text{Ye'\]\g\text{Jpcf]Ubg'gi\text{Ywhc'ghd\text{Py} TYX\text{Yh\]\wg\text{Yh\}\wg\text{Yh\}\wg\\\\ Yh\]\wg\\\\ Yh\]\wg\text{Yh\]\wg\text{Yh\}\wg\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\

		f% - \$Łž' ' !('
K_YY_") . "&* "A_UfWX"! "%	GYa]bUf	Hcd]W":]Whjcb"UbX"h\Y"<]ghcf]Ubg"@]a]hg
5dfj`		7 cbhybhXygWf]dh]cb. 7 Ufc;]bnVi f[žB UhU`]Y NYa cb'8 Uj]g'UbX'G]a cb'GW\Ua U'UfY'dfc`]Z]W \]ghcf]Ubg'k \c'\Uj Y'k f]hhyb'UVci hYj Ybhg'h\Uha Um bch\Uj Y'hU_Yb'd`UW\"'=g'h\]g'"a UXY'i d'''cf'Vc[i g \]ghcfm3'C f'\Uj Y'h\YgY'\]ghcf]Ubgž]b'[c]b['VYmcbX k\UhYj]XYbW' WUb'gdYWJZWU`mgi ddcfhža UXY'U Wcblf]Vi h]cb'hc'gW\c`Uf'm_bck 'YX[Y'UVci hh\Y'dUgh3
		5dUfnZfca 'h\Y'i gi U`X]gW gg]cb'UbX'fY`UhYX'ei]nž h\Y'F YgYUfW\'9ggUmCi h]bY'UggYgga Ybhk]``VY X]gW ggYXžhc[Yh\Yf'k]h\ Df]a UfmUbX'GYWcbXUfm gci fWg'UbX`\ck 'hc'i gY'cb`]bY'df]a Ufmgci fW XUhUVUgYg'gi W\'Ug'Hfcj Y"
		F Yei]fYX F YUX]b[g.
		G]a cb'GW.Ua Už6WSV 5WdfS[`f[We fl@cbXcbž'% - %Łž7\Ud'%'fdd"'&!&\$ž'\&,!-Ł'
		B UHU`]Y`NYa cb`8 Uj]gž"Ghcf]Yg`UbX`h\Y` <i b[="" yf`hc<br="">? bck "žKS^W<agd !*'<="" &łz%)="" 'f%="" -="" df[u[e_="" s^ax5="" td="" ž)=""></agd></i>
		7 i g\]b['Grfci hž'"6cfXYf'7fcgg]b[g.'<]ghcfmž':]Wh]cbž UbX'8YUX'7YfhU]bh]Yg"ž: [efack S`VFZWackt' % f%-&hz"%)'!*&
		7 Ufc";]bnVi f[ž""7 \YW_]b["h\Y"9j]XYbWY."H\Y >i X[Y"UbX"h\Y"<]ghcf]Ub""ž"5 d[f[US^;` cg[dk % "f% %±ž +-!- &
	5ggYgga Ybh	Mci f'A i gYi a '9ggUm']g'Xi Y'h\]g'k YY_ž'H\i fgXUm UZhYfbccb"
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