

# **LING5026**

H\Y'Ghfi WhifY'cZ@Ub[iU[Y

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

# 7ci fgY Cj Yfj ]Yk

### GHJZZ7cbHJWh8YHJ]`g`

#### '7cbj Ybcfg'

B Ua Y	9a U]`	5j U]`UV]`] <b>m</b>	@cWJhjcb	D\cbY
A Yb[]gh '5a VYfVYf	a "Ua VYfVYf4 i bgk "YXi "Ui	H∖i fgXUmž	A 6&(%	-',)
		&da!'da žcfVm		
		Uddc]bha Ybh		

#### GWkcc`7cbhJWhi ≠bZcfa Uh]cb

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

@cWUhjcb. GWkcc CZJWY ZA cfj Yb 6fck b 6i ] X]b[ z @Yj Y 8 & Z &),

 $CdYb]b[ < ci fg. A cbXUm! : f]XUm<math>\tilde{y}$  - Ua ! (.() da

D\cbY.'Ž\*%'&'-',)'%\*,%

: UI . Ž\*%'&'-',)', +\$)

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

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

 $5 \cdot ghi \ XYbhi]g`YI \ dYWhYX`hc`UhhYbX`U```W`Ugg`WcbhUWh`\ci fg`Zcf`U`ZJWY!hc!ZJWY`fI \& Ł`cf`V`YbXYX`Wci fgY`UbX Wca d`YhY`U```UWhjj ]hjYg`Zcf`U`V`YbXYX`cf`Z\``micb`]bY`Wci fgY"$ 

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

# 5ggYgga YbhHUg\_g

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'h/gh'='	' \$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	%ž(
HU_Y`\ca Y`dfcV`Ya 'gYh'	(\$1	\$%#\$*#&\$%_`\$(.\$\$`DA	%ž&Ž Ž(

## 5ggYgga Ybh8YHJ]`g

5ggYgga Ybh% 7`Ugg HYgh=

GHJfh:XUhY.

5ggYgga Ybh& 7`Ugg hYgh=

GhUfh'XUhY.

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

5qqYqqa Ybh' . HU\_Y \ca Y dfcV Ya qYh

GhUfh XUhY.

@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 Wci fqY'@YUfb]b['A UbU[Ya YbhGmqhYa 'f@A GŁ"

$$\label{thm:condition} \begin{split} &\text{H}^{\text{U}$$

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 'UW]j ]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 Wh]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
		9  YfW]gY'(.'A cfd\c`c[]\WJ`'\WJhY[cf]Yg
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
		F YUX]b[
		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
		91 YfW]gY`, .`Gk U\]`]
K YY_').'&*'A UfW\'!'%	@YWhi fY	GmbHJI fDUfhi=Ł
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	Hi hcf]U`	7\UdhYf'(.'GmbhUl
		9  YfW]gY '% '@]b[i]gh]W_bck `YX[Y
		91 YfWjgY^&. F YW fg]cb
		91 YfW]gY '' . '5a V][ i ]lm
		91 YfWjgY (. 7 cbghjhi Ybhighfi Whi fY
6fYU^&^5df]`!`, ^5df]`		
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[
		5ZSbfWd'
	Hi hcf]U`	±D!WUgg`hYgh`f⊭
		H\Y`WUgg`hYgh`]g`[]j Yb`Xi f]b[`h\Y`h hcf]U``h]a Yg

		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[
		5 ZSbfWd'
		D\cbYh]WgʻfDUfhi±
		Eag`VeWY_Wfe-Sdf[Ug/Sfack bZa`Wf[Ue
		F YUX]b[
		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
		91 YfW]gY''5bhcbma m
		91 YfWjgY`%&.`H\Ya UhjWfc`Yg
K YY_', .'&' '5df]`'!'&- 5df]`	@YWhi fY	
Surj		Bc'@YWhifY/DiV`]W\c`]XUmf&)'5df]`Ł
		FYUX]b[#YIYfW]gYg'!'cb`]bY'fYgcifWYg'fXYHJ]`g dfcj]XYX']b'AccX`YŁ"
	Hi hcf]U`	
		Bc'hi hcf]U''
		FYUX]b[#YIYfW]gYg'!'cb`]bY'fYgcifWYg'fXYHJ]`g dfcj]XYX']b'AccX`YŁ
K YY_''' \$'5df]`!'*'A Um	@YWhifY	D\cbYh]Wg fDUfh=Ł
		? adWa` Sdf[Ug/Sfack bZa`Wf[Ue-bdaeaVk
		F YUX]b[
		5ZSbfWd(
	Hi hcf]U`	7\UdhYf`*.`D\cbYhJWg
		91 YfWjgY"."D\cbYhjWHfUbgWfjdhjcb"@UŁIf[ŁQ
		9  YfWjgY`*.`D\cbYhjWXYgWfjdhjcbg