

MUSC3705

DYfZcfa UbWY @UVcfUhcfm7

HYfa "Hk c" ## "&\$&\$

7ci fgY'Cj Yfj]Yk

GHJZZ7cbHJWh8YHJ]`g

7cbj Ybcfg

B Ua Y	9a U]`	5j U]`UV]`]m	@cWUh]cb	D\cbY
>c\b'BUd]Yf	^bUd]Yf4 i bgk "YXi "Ui	: f]XUm'&!l'&cf'Vm Uddc]bha Ybhžcf Xfcd']b	K YVghYf*%%	-',)*-)'

GWkcc~7cbhJWh~abZcfa Uh]cb

GWXcc``cZhXY`5fhg`UbX`AYX]U

Fcca " %&ž@Yj Y`" žFcVYffiK YVgfYf'6i]`X]b['f) %(Ł

D\cbY. f\$&L'-',) '(,) *

9a U]` gUa 4 i bgk "YXi "Ui

K YVg]hY. k k k "Ufhg"i bgk "YXi "Ui #gUa

 $\label{eq:hamiltonian} $$HY'GWCC``cZhY'5ftg'UbX'AYX]U'kci`X``]_Y'tc'FYgdYWM\cong \cong m5W_bck`YX[Y'thY'HfUX]tjcbU``7i gtcX]Ubgž thY'6YXY[U'`fPYbg]b[tcb'WJadigŁZ'; UX][U'`fP]tmUbX'5fth/'8Yg][b'7UadigYgŁ'UbX'thY'B[ibbUkU`dYcd'Y'fbigtfU]Ub'8YZYbW': cfW'5WJXYam]b'7UbVYffUŁ'cZthY'`UbXg'k\YfY'YUW\cong WJadig'cZIBGK']g`cWJtYX''$

5ggYgga Ybh

D'YUgY'fYZYf'hc'h\Y'XcW a Ybhicb'h\Y'dYfZcfa UbW'hUg_'cb'h\Y'A ccX'Y'g]hY'Zcf'h\]g'Wci fgY"

H\YfY`]g`bc`dfcj]g]cb`cf`fYei]fYa Ybh'Zcf`df]j UhY`h]h]cb`k]h\`Ub`]bghfi a Ybh'J`ž'Wca dcg]h]cbU``cf`j cWU` hYUW\Yf`]b`h\]g`Wci fgY"'Mci `UfY`cZWci fgY`k Y`Wca Y`hc`i bXYfhU_Y`gi W\`h]h]cbžVi h`]h`]g`bY]h\Yf`UggYggYX bcf`Z bXYX"'

5ggYgga YbhHUg_g

5ggYgga Ybh'hUg_	K Y][\h	8iY'8UhY	Gh XYbh@YUfb]b[Ci hWca Yg 5ggYggYX
9bgYa V`Y`Wcblf]Vi l]cbž dYfZcfa UbWYgždUfhWXYW_]b[lYgh	&\$I	9bgYa V`Y`dUfh'W\YW_]b[bcfa U``mhc`VY`Wca d`YhYX`Vm h\Y`YbX`cZk YY_`%%cZYUW\ hYfa	-
DYfZcfa UbWY dcfhZc`]c'	%) ।	:]fghdUfhXi Y`+h\`5i [i gh' GYWbbX'dUfhXi Y`&\$h\ Bcj Ya VYf	%
DYfZcfa UbWY#dfYgYbhUh]cb	')।	±bʻUgg][bYXʻk YY_gʻ]bʻH%ʻUbX H'	%3&
:]bU`DfcYWi	' \$ı	gYY`XYHJ]`g`VY`ck	%ž&

5ggYgga Ybh'8YhJ]`g

5ggYgga Ybh% 9bgYa V`Y'Wcblf]Vi h]cbždYfZcfa UbWgždUfhWXYW_]b['hYgh

GhUfh'XUhY.

8YHJ]`g.

9bgYa V`Y`dUfhlWXYW_]b['k]```VY`i bXYfhU_Yb`]b`H%ZH&`UbX`H' "'⊕X]j]Xi U``mcf`]b`ga U```[fci dgžghi XYbhg`k]`` dYfZcfa 'k cf_gžcf`Yl WYfdhg`cZk cf_gžghi X]YX`UbX`dYfZcfa YX`Xi f]b['h\Y`hf]a YghYf"'`K \YfY`Uddfcdf]UhYž Yl WYfdhg`k]```VY`gY`YWhYX`Vmih\Y`dUfhlWXYW_]b['Yl Ua]bYf"

8]fYWhZYYXVUW_Xi f]b[fY\YUfgU`g`UbX`k cf_g\cdg`UbX`U`Zcfa U`fYdcfhUhih\Y`WcbWi g]cb`cZh\Y`gYgg]cb"

5XX]h]cbU`XYhU]`q.

9bgYa V`Y`dUffl\W\Y\w_]b[`k]```VY`i bXYffl_Yb`]b`H\&`H&`UbX`H' "'\DX]j]Xi U``mcf`]b`ga U```[fci dgžgh XYbhg`k]`` dYfZcfa 'k cf_gžcf`Yl W\fdhg`cZk cf_gžgh X]YX`UbX`dYfZcfa YX`Xi f]b[`h\Y`hf]a YghYf"K \YfY`Uddfcdf]UhYž Yl W\fdhg`k]```VY`gY`YW\YX`Vmh\Y`dUffl\W\Y\w_]b[`Yl Ua]bYf"8]fY\hiZYXXVU\w_Xi f]b[`fY\YUfgU`g`UbX k cf_g\cdg`UbX`U`Zcfa U``fYdcfh'Uhh\Y`\\b\M' g]cb`cZh\Y`gYgg]cb"`Gh XYbhgf\\b\bhf]Vi h]cb`hc`YbgYa V`Y dYfZcfa UbW\g`UbX`k cf_g\cdg`k]``VY`UggYggYX`h\fci [\`U`dUffl\W\Y\w_]b[`Yl Ua]bUh]cb"

5ggYgga Ybh& DYfZcfa UbW dcfhZc`]c

GhUfh'XUhY.

8YHJ]`g.

Dcfhzc`]cg'k]``'VY'gi Va]hhYX'h\fci[\'Hifb]h|b'UbX'aUf_YX'Vmh\Y''YWhifYf"

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

 $\label{thm:condition} \begin{tabular}{l} Hk c'dcffzc']cg'cZUbbcfUh'X'gci fW'a Uh'f]U''i gYX']b'dYfZcfa UbW''dfYdUfUhjcb'fW]V']c[fUd\mz'X]gWc[fUd\m$

5ggYgga Ybh' . DYfZcfa UbWY#dfYgYbHJh]cb

GhUfh'XUhY.

8 YHJ]`g.

H\fYY`]b!WUgg`dYfZcfa UbWg`UbX`Ub`]b!WUgg`WcbXi Wf]b[`HYghgWUZZc`X]b[`UggYgga YbhHUg_`("`

Gdc_Yb^ZYYXVUW_'k]```VY^[]j Yb^Vmh\Y^YWh fYf^]b^WUggž*UbX^k f]hhYb^ZYYXVUW_'g\cfhmUZhYf"

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

 $H\[g'Wca\ dcbYbhk\]^*`U'gc']bWi\ XY'U'g\cfhWcbXi\ Wfb[\ 'YI\ Ua\ .'h\Y'XYHJ]'g'cZh\]g'UbX'dfYgYbHJhJcb'k\]^*`VYUXj\]gYX'Vmh\Y'WcbXi\ Wfb[\ 'hi\ hcf''$

Gh XYbhg k]``Xc U a]b]a i a 'cZ%]b!WUgg dYfZcfa UbW']b H%'UbX &]b!WUgg dYfZcfa UbW'g]b H&"'H\YgY dYfZcfa UbW'g UfY [fci d'dYfZcfa UbW'gž Ug'bchYX Zcf UggYgga YbhHUg_ ("

5ggYgga Ybh(::]bU`Dfc YWh

GhUfh'XUhY.

8YHJ]`g.

; fci d'dYfZcfa UbWY cf'di V`]Wmg\ck b'j]XYc"

K f]hhyb ZYYXVUW_k]``VY dfcj]XYX Vmh\Y YI Ua]bYffgŁ

H\]g`]g`h\Y`Z]bU``UggYgga Ybh

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

FYgci fWfg

DfYgWf]VYX F Ygci fWYg

Bch'Uj U]`UV`Y

FYWca a YbXYX FYgci fWfg

BchUj U]`UV`Y

7 ci fgY '9j U'i Uh]cb 'UbX '8Yj Y`cda Ybh

: YYXVUW_`cb`h\Y`Wti fgY`k]``VY`a UXY`h\fci [\`h\Y`a m9I dYf]YbWY`E i Ygh]cbU]fY"`H\]g`]g`U`bYk `Wti fgY"`≢g WtbhYbhUbX`hYUW\]b[`a Yh\cXg`\Uj Y`VYYb`g\UdYX`dUfhm]b`fYgdcbgY`hc`Yj U`i Uh]cb`cZYUf`]Yf`DYfZcfa UbWY

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

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

Image: Ybwei bhyfu'dfcv'ya k \yb'uhhya dhjb['hc'gi va]hmci f'Ugg][ba Ybhh\fci [\ 'Hi fb]h]bž'd'YUgY

Hy'Yd\cby'9| hy'fbu''Gi ddcfhcb'-',) '' ' ' %cf'Ya U]''h\Ya 'cb'Y! hy'fbu'hy'hgi ddcfh4 i bgk "YXi "Ui "''Gi ddcfh
\ci fg'UfY', .\$\$Ua '-'%\$.\$\$da 'cb'k YY_XUmg'UbX'-.\$\$Ua '-').\$\$da 'cb'k YY_YbXg'fl *) 'XUmg'U'mYUft"'=Z'mci
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'mZcf'Ub'Y! hy'bg]cbž'Vi hmci
a i ghfYhJ]b'mci f'h]W_Yhbi a VYf'Zfca '9! hy'fbU''Gi ddcfhfU'cb['k]h\ 'Ubmch\Yf'fy'Yj UbhXcW a Ybhgt'hc
]bWi XY'Ug'Yj]XYbW' 'hc'gi ddcfhmci f'Y! hy'bg]cb'Udd']WUh]cb"'=Zmci 'Ya U]''9! hy'fbU''Gi ddcfhmci 'k]'`
Ui hca Uh]WJ'`mfYW']j Y'U'h]W_Yhbi a VYfZ'Vi h]Zmci 'hY'Yd\cbY'mci 'k]``bYYX'hc'gdYW]Z]WJ'`mUg_'Zcf'cbY''
Hi fb]h]b'U'gc'dfcj]XYg'i dXUhy'g'cb'h\Y]f'gmghYa 'ghUh' g'cb'Hk]hyf''

; YbYfU`mž'UggYgga YbhiHug_g'a i ghVY'gi Va]hhYX'Y`YVWfcb]\WJ``mij]U'Y]h\Yf'Hi fb]h]b'cf'U'A ccX`Y Ugg][ba Ybh''=b']bgHJb\W'g'k \YfY'h\]g']g'bchdcgg]V`Yž']hk]```VY'gHJhYX'cb'mci f'\\circ i fgY'g'A ccX`Y'g]hY'k]h\U`hYfbUh]j Y'gi Va]gg]cb'XYHJ]`g"

cfi]bZcfa Uhjcbicbi\ckihcigi Va]hUgg][ba Ybhgicbi]bYij]UiA ccXiY.i\hdg.#gh XYbhi bgk "YXi "Ui #\ck! gi Va]hUgg][ba Ybha ccXiY

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"`±hWJb`hU_Y`a Ubm Zcfa gžZfca `XY`]VYfUhY`W\YUh]b['hc`UWW]XYbhJ``mWcdm]b['Zfca `U`gci fWY`k]h\ci hUW_bck `YX[Ya Ybh'

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

 $7 \text{ cdm}b[...i g]b[...h\Y.gUa Y.cf.j Yfmig]a] \Uf'k cfXg'hc'h\Y.cf][]bU''hYl h'cf']XYU'k]h\ci h'U\V_bck `YX[]b[...h\Y.cf][]bU''hYl h'cf']XYU'k]h'cf']$