

MDIA2002

5bU`mg]b['A YX]U'7ca a i b]WUh]cb

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
DYHYf'K\]HY	dff"k \]hY4 i bgk "YXi "Ui	VmUddc]bhYa Ybh fY"[""j]U"Ncca ž G_mdY"YhVVŁ	FcVYfh KyVghYf 6i]X]b[! Fcca" %%	b#J

GWXcc`7cbHJWh =bZcfa Uh]cb

GWXcc`cZh\Y'5fhg'UbX'AYX]U

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

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

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'h\Y'HfUX]tjcbU``7igtcX]Ubgž h\Y'6YXY[U'`fPYbg]b[tcb'WJadigŁZ'; UX][U'`fP]tmUbX'5fthZ''8Yg][b'7UadigYgŁUbX't\Y'B[ibbUkU`dYcd'Y'fbighfU`]Ub'8YZYbW': cfW'5WJXYam]b'7UbVYffUŁ'cZh\Y'`UbXg'k\YfY'YUW\'WJadig'cZIBGK']g`cWJhYX''$

5ggYgga Ybh

5ggYgga YbhHUg_g

5°dYfWYbhcZh\Y`hihcf]U`g`f]" % dYfWY, %

	GYY'AccX`Y'Zcf'XYHJ]`g'cZ`YWifYž'hihcf]U` dfYdUfUh]cbgž'hihcf]U`'UWhjj]h]Yg'UbX'UggYggaYbhg HJg_g"
K YY_', .'%-'>i `m'!'&' '>i `m A cXi `Y	H\Y`UfficZffUj Y``k f]hjb[`!`dUffi% GYY`A ccX`Y`Zcf`XYhU]`g`cZ`YWi fYž'hi hcf]U` dfYdUfUhjcbgž'hi hcf]U``UWhjj]hjYg`UbX`UggYgga Ybhg hUg_g"
K YY_''&*'>i`m!''\$'>i`m A cXi Y	H\Y`UfficZlfUj Y``k f]ljb[`!`dUffi& GYY`A ccX`Y`Zcf`XYlU]`g`cZ`YWi fYž'li lcf]U` dfYdUfUljcbgž'li lcf]U``UWlj]ljYg`UbX`UggYgga Yblg lUg_g"
K YY_`%\$.`&`5i [i gh!`* A cXi `Y 5i [i gh	H\Y'UfficZlfUjY`kf]hjb['!'dUfh' GYY'AccX`Y'Zcf'XYhJ]`g'cZ`YWifYž'hihcf]U` dfYdUfUhjcbgž'hihcf]U`'UWhjj]hjYg'UbX'UggYggaYbhg hJg_g"

FYgci fW/g

DfYgWf]VYX F Ygci fWYg

 $H\YfY']g'bc'hYl'hVcc_{"}''Mci''UfY'Yl'dYWYX'UWW'gg'U'k]XY'fUb[Y'cZ'ci'fbU']gh]Wgci'fW'g'Zcf'h\Y'Wci'fgY'!'df]bhl'ghmY'UbX'VfcUXWUgh \\$

FYWca a YbXYX FYgci fW/g

 $H\YfY^{\cdot}]g^{\cdot}bc^{\cdot}hY^{\cdot}hVcc_{^{\prime\prime}}^{\cdot\prime}Mci^{\cdot\prime}UfY^{\cdot}Y^{\cdot}dY^{\prime}MY^{\cdot}X^{\cdot}UWW^{\prime}gg^{\cdot}U^{\cdot}k^{\cdot}]XY^{\cdot}fUb[Y^{\cdot}cZ^{\prime}c^{\cdot}i^{\cdot}fbU^{\cdot}]gh]Wgci^{\cdot}fWY^{\cdot}Wci^{\cdot}fgY^{\cdot}!^{\cdot}df]bh^{\cdot}gh^{\prime}Y^{\cdot}UbX^{\cdot}VfcUXWUgh$

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

±DZcfa U``UbX`Zcfa U``gi fj Ymg`k]```VY`i bXYftU_Yb`UhgYj YfU``dc]bhg`Xi f]b['h\Y`Wci fgY`hc`[U]b`U`gYbgY`cZ ghi XYbhYb[U[Ya Ybhk]h\žUbX`i dtU_Y`cZzh\Y`Wci fgY"+\YgY`k]```VY`i gYX`hc`Xf]j Y`UX↑ gha Ybhg`hc`Wci fgY WcbhYbhUbX`XY`]j Yfmž`Ug`Uddfcdf]UhY"``H\Y`Wci fgY`k]```U`gc`VY`gi V`YWb`Uh]hg`WcbWi g]cbžhc`Yj U`i Uh]cb`j]Uh\Y`A m9I dYf]YbWY`dfcWYgg"``Ghi XYbhcVgYfj Uh]cbgžWcbWYfbg`UbX`Wf]h]Wjga `cZZYfYX`]b`dfYj]ci g

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.

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

- i bXYfgfUbX mci f'f][\hg'UbX'fYgdcbg]V]`]hJYg'Ug'U'gh XYbhUhl BGK
- VY'Uk UfY'cZd`U[]Uf]ga ž'Wcdmf][\hz'l BGK 'Gh XYbh7cXY'cZ7cbXi WhUbX'5VWWdhUV'Y'l gY'cZ I BGK '= H'F Ygci fWYg'Dc`]Wh
- VY 'Uk UfY 'cZh\Y 'ghUbXUfXg 'cZVY\Uj]ci f'Yl dYWYX 'cZYj YfmcbY ']b 'h\Y 'l BGK 'Wca a i b]hm
- `cWUHY 'gYfj]WYg'UbX ']bZcfa UH]cb'UVci hI BGK 'UbX'I BGK '@]VfUfm

Gca Y'cZh\YgY'UfYUg'k]``VY'ZJa]`]Uf'hc'mci žch\Yfg'k]``VY'bYk"'; U]b]b['U'gc`]X'i bXYfgHJbX]b['cZU``h\YfY`UhYX'UgdYWhg'cZ9@&9'k]``\Y`d'mci 'a U_Y'h\Y'a cghicZmci f'ghi X]Yg'UhI BGK "'\\hd.##qi V'YWfi |XYg"`]VfUfm'i bqk "YXi "Ui #\`]qY#JVci hY`]qY