



MDIA3007

 $A YX]U'UbX'5fhg' + bhYfbg \]d$

HYfa 'C bY''# '&\$&\$

7ci fgY'Cj Yfj]Yk

Ghuzz 7 cbhuWh8 Yhu]`g

'7cbj Ybcfg'

BUa Y	9a U]`	5j U]`UV]`]m	@cWJhjcb	D\cbY
9a a Uʻ>UbY	Yaa U"^UbY4 i bgk "YXi "Ui	-	‰) ž@YjY``%ž FcVYfh KYVghYf	

GWkcc~7cbhJWh~abZcfa Uh]cb

Fcca " &ž`Yj Y`" FcVYfhK YVghYf`6i]`X]b[

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

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

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

 $\label{eq:hamiltonian} $$HY'GWKcc``cZhY'5ftg'UbX'AYX]U'kci`X``]_Y'tc'FYgdYWM\cong \cong m5W_bck`YX[Y'h\Y'HfUX]tjcbU``7i gtcX]Ubg\cong h\Y'6YXY[U'`fPYbg]b[tcb'WJa di g\cong tz'; UX][U'`fP]tmUbX'5fth/ '8Yg][b'7Ua di gYg\cong tubX't\Y'B[i bbUk U` dYcd'Y'fbi gtfU']Ub'8YZYbW': cf\w'5\\WXYa m']b'7UbVYffU\cozh\Y'`UbXg'k\YfY'YUW\cozh\Y'YUW\cozh\Y''UbXg'k\YfY'YUW\cozh\Y'' \cozh\Y''\UbXg'k\YfY'YUW\cozh\Y'' \cozh\Y''\UbXg'k\YfY'YUW\cozh\Y'' \cozh\Y''' \cozh\Y'''' \cozh\Y''' \cozh\Y'''' \cozh\Y''' \cozh\Y'' \cozh\Y'' \cozh\Y''' \cozh\Y'' \cozh\Y'' \cozh\Y''' \cozh\Y'' \cozh\Y''' \cozh\Y'' \cozh\Y''' \cozh\Y'' \cozh\Y'' \cozh\Y'' \cozh\Y'' \cozh\Y'' \cozh\Y'' \co$

7ci fgY 8YW] g

7 fYX]hDc]bhg *

Gi a a UfmcZh\Y 7ci fgY

Gi VYWhUfYU. ? WW[S S` V 3 dfe

.

 $H_Y^{b} h_Y^{b} = \frac{1}{Y} u^{ch} w^{a} a h_Y^{b} CZ\%\$!\% $\c fg^{c} K cf_{k} h^{u} cghcf[Ub]gUh]cb^{u} WUb^{v} H_Y^{b} h^{g} CX^{c} h_Y^{c} A a h_Y^{c} CY^{c} h^{g} CX^{c} A a h_Y^{c} CY^{c} A a h_Y^{c} A h$

\httq.##a ccX`Y"hY`h'i bgk "YXi "Ui #\lci fgY#]Yk "d\d3]X1'') \(\lci (_"\5\h\fbUh] \) Y`m\text{mci} 'a Umi]bXYdYbXYbhm UddfcUW\ 'U'fY`Yj Ubhcf[Ub]gUh]cb'hc'Udd`m\text{Zcf'Ub']bh\fbg\]d"\Df]cf'hc'gYY_]b['Ub']bh\fbg\]d\text{zmci} 'a Umik]g\ \http:\\lci \lci \text{UfYYfg''i bgk} '7 UfYYfg'\UbX\9a d`cma Ybh!\\httq.##k k k "\W\fYYfg''i bgk "YXi "Ui #\"

Zcf\Y`d'UggYa V`]b['mci f'7 J ž'Wcj Yf'`YHYfž'UbX'ch\Yf'Wca dcbYbhg'cZ'mci f'Udd`]WUhjcb"

.

: cf`a cfY`]bZcfa Uh]cbžj]g]h\hhdg.##gUa "Ufhg"i bgk "YXi "Ui #ghi XYbhg#Mci fgYg#|bhYfbg\]dg#": cf`Ubm Ybei]f]Ygžd`YUgY`Ya U]`h\Y`K =@I b]hUh<u>: 5GG!K =@4 i bgk "YXi "Ui</u>

.

Hc'VY'Y`][]V`Y'Zcf'h\]g'WcifgYžmci'aigh\UjY'U'a]b]aia'K 5A'cZ*)"

.

7ci fgY @YUfb]b[Ci hWca Yg

%"\UjY`[U]bYX`YIdYf]YbWY`cZ]bXigHmdfcWYggYg`UbX`dfUWNWYg &"Udd`mh\YcfYh]WD``WcbWYdhg`UbX`dfUWNW``g_]``g`[U]bYX`]b`h\Y`dfc[fUa``hc`fYU`!kcfX`WcbHYIhg ''"\UjY`Yb\UbWYX`h\Y]f`WUdUWNmZcf`]bXYdYbXYbhYb[U[YaYbhk]h\`]bXiqHmdfcj]XYfq

HYUWX]b[GhfUhY[]Yg

H\]g'Wti fgY'\Ug'bc'Zcfa U`'hYUW\]b['Wta dcbYbh'''

5ggYgga Ybh

7 ci fgY fYei]fYa Ybhg]bWl XY.

- 7 ca d'Yhjcb'cZU'a]b]a i a 'cZ%\$\$'\ci fg'cZd'UWa Ybh
- Gi Va]gg]cbg'cZUggYgga YbhihUg_g'%/ '&'XYa cbghfUh]b['U'gYf]ci g'UhhYa dhihc'Ubgk Yf'h\Y'hUg_fYei]fYa Ybhg
- Gi Va]gg]cb cZVch\ h\Y \cghUbX gh XYbhZYYXVUW_ Zcfa g

5ggYgga Ybh'HUg_g'

5ggYgga YbhˈhJg_		

Hi fb]hjb gYhjb[. H\]g]g bchU Hi fb]hjb Ugg][ba Ybh

FYgci fWfg

DfYgWf]VYX F Ygci fWYg

 $\label{eq:hammer} H\YfY`UfY`bc`dfYgWf]VYX`fYgci~fgYg`Zcf`fh]g`Wci~fgY"$

FYWca a YbXYX FYgci fWYg

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

KY'\cdY'mci 'Yb'cm'mci f']bhYfbg\]d°

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

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

#mci 'YbWci bhYf'U'dfcV'Ya 'k \Yb'UhYa dhJb['rc'gi Va]hmci f'Ugg][ba YbhNhfci [\'Hi fb]hJbž'd'YUgY
hY'Yd\cbY'9I hYfbU'Gi ddcfhcb'-',) '' ' ' %cfYa U] 'h\Ya 'cb'YI hYfbU'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'f1 *) 'XUmg'U'mYUft'' #c'ici
UfY'i bUV'Y 'rc'gi Va]hmci f'Ugg][ba YbhXi Y 'rc'U'ZUi 'hk]h\ 'Hi fb]hJb 'mci 'a Um'Udd'mZcf'Ub'YI hYbg]cbž'Vi hmci
a i ghfYhU]b 'mci f'hJW_Yhbi a VYf'Zfca '9I hYfbU''Gi ddcfhfU'cb['k]h\ 'Ubmch\Yf'fY'Yj UbhXcW a Ybhgt'hc
]bWi XY'Ug'Yj]XYbWY 'rc'gi ddcfhmci f'YI hYbg]cb'Udd']WUhJcb'' #mci 'Ya U]''9I hYfbU''Gi ddcfhmci 'k]'`
Ui hca UhJWU'`mfYWY]j Y'U'hJW_Yhbi a VYfž'Vi h]Zmci 'hY'Yd\cbY'mci 'k]'``bYYX'hc'gdYWJZJWU``mUg_'Zcf'cbY''
Hi fb]hJb'U'gc'dfcj]XYg'i dXUhYg'cb'h\Y]f'gmghYa 'ghUh' g'cb'Hk]hYf''

; YbYfU``mž'UggYgga YbhiHug_g'a i ghVY'gi Va]hhYX'Y`YVWfcb]\W)``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'\\ci fgY'g'A ccX`Y'g]hY'k]h\ U`hYfbUh]j Y'gi Va]gg]cb'XYhJ]`g''

cfi]bZcfa Uh]cbicbi\ckihcigi Va]hUgg][ba Ybhgicbi]bYij]UiA ccXiY.i\hdg.#gh XYbh'i bgk "YXi "Ui #\ck! qi Va]hUgq][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]XYbhU`mWcdm]b['Zfca `U`gci fWY'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'dfcYWgž'Ug'k Y``'Ug dfYgYbhUh]cbg'k\YfY'gca YcbY'dfYgYbhg'Ubch\Yf'g']XYUg'cf'k cfXg'k]h\ci h'WfYX]h'

=\uddfcdf]UhY 'dUfUd\fUg]b[.'7\Ub[]b['U'ZYk 'k cfXg'UbX'd\fUgYg'k \]'Y 'a cghmfYhJ]b]b['h\Y'cf][]bU`
ghfi Whi fY 'UbX#cf'dfc[fYgg]cb'cZ]XYUg'cZh\Y'cf][]bU`ž'UbX']bZcfa Uh]cb'k]h\ci h\UW_bck `YX[Ya Ybh''H\]g'U`gc
Udd`]Yg']b'dfYgYbhUh]cbg'k \YfY 'gca YcbY'dUfUd\fUgYg'Ubch\Yf'g']XYUg'cf'k cfXg'k]h\ci h\UhYX]hUbX'hc
d]YW]b['hc[Yh\Yf'ei chYg'UbX'dUfUd\fUgYg']bhc'U'bYk 'k \c`Yž'k]h\ci h\Uddfcdf]UhY'fYZYfYbW]b["

7 c``i g]cb.'k cf_jb['k]h\ch\Yfg'Vi hdUgg]b['cZZh\Y'k cf_'Ug'U'dYfgcb'g']bX]j]Xi U``k cf_"'7 c``i g]cb'U`gc]bWi XYg'dfcj]X]b['mci f'k cf_'hc'Ubch\Yf'ghi XYbhVYZcfY'h\Y'Xi Y'XUhYžcf'Zcf'h\Y'di fdcgY'cZh\Ya d`U[]Uf]g]b['UhiUbmh]a Yž'dUm]b['Ubch\Yf'dYfgcb'hc'dYfZcfa 'Ub'UWUXYa]WhUg_ž'ghYU']b['cf'UWei]f]b[Ubch\Yf'dYfgcb'g'UWUXYa]Wk cf_'UbX'Wcdm]b[']hz'cZYf]b['hc'Wca d'YhY'Ubch\Yf'dYfgcb'g'k cf_'cf'gYY_]b[dUma YbhZcf'Wca d'Yh]b['UWUXYa]Wk cf_"

±bUddfcdf]UhY`W]hUh]cb.`7]h]b[`gcifWrg`k\]W\`\UjY`bchVYYb`fYUXžk]h\cihUW_bck`YX[]b[`h\Y`´gYWcbXUfm´gcifWrZfca`k\]W\`_bck`YX[Y`cZh\Ya`\Ug`VYYb`cVhU]bYX"

8 i d`]\W\n]cb`ffgY`Z\d`U[]\Uf]ga "Ł`gi Va]\n]b[`mci f`ck b`k cf_z`]b`k \c`Y`cf`]b`dUffz`k \YfY`]h\Ug`dfYj]ci g`m VYYb`dfYdUfYX`cf`gi Va]\nYX`Zcf`Ubch\Yf`UggYgga Ybhcf`\\cf\\text{i fgY`UhI_BGK_`cf`Ubch\Yf`i b]j Yfg]\m'

7 cffYWnfYZYfYbWlb['dfUWnWyg.

- 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'Uhtf]Vi h]cb'Zcf'U'fUb[Y'cZa UhYf]U`g']bWi X]b['hYl hž']a U[Ygž'Zcfa i `UY'UbX WbWYdhg"

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

IBGK @]VfUfmU`gc`\Ugʻh\Y`9@G9`hcc``UjU]`UV`Y`hc`Ugg]ghmci`k]h\`mcif`ghiXmUhIBGK "'9@G9`]gXYg][bYX`hc`]bhfcXiVW`bYk`ghiXYbhg`hc`ghiXm]b[`UhIBGK`Vih]hWUb`U`gc`VY`U`[fYUhfYZfYg\Yf`Xif]b[`mcifqhiXm"

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

 UbU`mgY`hcd]\Mgž'd`Ub`fYgdcbgYg`UbX`cf[Ub]gY`fYgYUf\W\`Zcf'U\WXYa]\Wk f]hjb[`UbX`ch\Yf UggYgga YbhiHUg_g • i bXYfgHJbX'mci f'f][\hg'UbX'fYgdcbg]V]`]h]Yg'Ug'U'gh XYbh'Uhil BGK