

ARTS3095

65 A YX]U + hYfbg\]d

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'''\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''$

7ci fgY 8YHJ] g

7 fYX]hDc]bhg *

Gi a a UfmcZh\Y 7ci fgY

Gi VYWn5fYU. ? WW[Sł 5g/fgdWS` V FWUZ` a 'aYk

H\]g`Wci fgY`dfcj]XYg`mci `k]h\`Ub`cddcfhi b]hmhc`i bXYffU_Y`k cf_!]bhY[fUhYX``YUfb]b[`UbX`[U]b`]bXi ghfm YI dYf]YbW'`k]h\`U`\cghcf[Ub]gUh]cb`WcgY`mfY`UhYX`hc`mci f`A U`cf`]b`A YX]Už7i `hi fY`UbX`HYW\bc`c[m'`Mci a UmU`gc`Udd`mhc`k cf_cb`UhtUW\a Ybhcb`Ub`U\W\XYa]WfYgYUfW\`dfcY\Whcf`k cf_]b`Ub`YX]hcf]U``fc`Y`Zcf`Ub U\W\XYa]Wci fbU`"`=\XYU``mžmci `k]``i bXYffU_Y`Ub`]bhYfbg\]d`UZhYf`mci `\Uj Y`Wca d`YhYX`%") `mYUfg`cZZ```!ha Y gh Xmfcf`Yei]j U`Ybhz`UbX`Wca d`YhYX`U`a]b]a i a `cZ% `I C 7 `]b`h\Y`A U`cf"`5hh\Y`YbX`cZh\Y`]bhYfbg\]d`mci k]```dfcj]XY`Uʻgi a a Uhj Y`fYdcfhcZmci f`YI dYf]YbWg`UbX`k cf_YI Ua d`Yg`Wca d`YhYX`Xi f]b[`h\Y`]bhYfbg\]d"

H\Y`]bhYfbg\]d`fYei]fYg`U`rchU``Wca a]ha YbhcZ%\$\$!%) \$`\ci fg`cZk cf_'k]h\`U`\cghcf[Ub]gUh]cb`UbX`a Um bcfa U``mVY`hU_Yb`]b`Z]fghžgYWcbX`cf`gi a a Yf`gYa YghYf" \deltahYfbg\]d`cddcfhi b]h]Yg`UfY`UXj Yfh]gYX`j]U`h\Y GW\cc``cZh\Y`5fhg`UbX`A YX]U`\deltahYfbg\]d`BYk g`YhYf" 5`hYfbUh]j Y`mmci a UmUddfcUW\`U`fY`Yj Ubh cf[Ub]gUh]cb`hc`Udd`mZcf`Ub`]bhYfbg\]d"`Df]cf`hc`gYY_]b[`Ub`]bhYfbg\]dzmci `g\ci `X`UhhYbX`Ub`]bhYfbg\]d]bZcfa Uh]cb`gYgg]cb`fi b`Vmh\Y`GW\cc``cZh\Y`5fhg`UbX`A YX]U"

Hc VY Y)[]VY Zcf h]g Wci fgYzmci a i gh Uj Y U a]b]a i a K 5A cZ+\$"

7 ci fgY @YUfb]b['Ci hWca Yg

%" \Uj Y`[U]bYX`YI dYf]YbW`cZ]bXi ghfmdfc\WggYg`UbX`dfU\Wj\Wg &" Udd`mh\YcfYhj\Wb``Wcb\Wdhg`UbX`dfU\Wj\\Wb``g_]``g`[U]bYX`]b`h\Y`dfc[fUa `hc`fYU`!k cfX`\\chi\Y hg \\ ' " \Uj Y`Yb\Ub\\X'h\Y]f`\\Ud\\Jhm\Zcf`]bXYdYbXYbhYb[U[Ya Ybhk]h\`]bXi ghfmdfcj]XYfg

HYUW]b['GhfUhY[]Yg'

 $H\]g'Wci\ fgY'\ Ug'bc'Zcfa\ U`'hYUW\]b[\ 'Wca\ dcbYbh'''$

5ggYgga Ybh

H,	\]g	VYWi]gii	b[f	UXYX [*] (gc "U"dU	ggʻ]gʻX	(YdYb)	XYbhcb	'GUh]g	ZUW of	mfGN	Ł'cf'I	bgUh	jgZJV	l∕c fmfl	@£`]b`a	YYh]b[
h	Y 'Wti	fgY fYei]fYa	Ybhg"	5b GM	[fUXY	'k]``'ba	chiUZZYV	bimci f	~k Y][\HXX [*] U	Jj YfU[Y a	Uf_'f	K 5A 1	Ł'Vi h'U':	@ [fUXY
k]>>#+																	

7 ci fgY fYei]fYa Ybhg JbWl XY.

) \$\$`k cfXg`Vi ha Uma U_Y`i d`a cfY`cZh\Y`Wca V]bYX`hchU``cZ%) \$\$!&) \$\$`k cfX``]a]hZcf`Vch\`UggYgga Ybh Wca dcbYbhg''; fUX]b[`k]```VY`GUh]gZJWcfm# bgUh]gZJWcfmiUbX`gca Y`gi a a Uh]j Y`ZYYXVUW_k]```VY`dfcj]XYX''

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

7 ci fgY fYei]fYa Ybhg]bWi XY.

FYgci fWfg

DfYgWf]VYX F Ygci fWYg

 $H\YfY\UfY\bc\dfYgWf]VYX\fYgci\fWYg\Zcf\h\]g\Wci\fgY"$

FYWca a YbXYX FYgci fWYg

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

 $K Y fYgdcbX hc ZYXVUW_fYWY] YX j]UX]fYWhYa U] hc hY 7 ci fgY 7 cbj Ybcf UbX hY K @1 b]hz UbX bZcfa UhJcb dfcj]XYX jb hY gh XYbh UbX \cgh ZYXVUW_Zcfa g"$

KY\cdYmciYb&mmcif]bhYfbg\]d°

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

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Image: Ybwb: bh/f'u'dfcv'ya k \yb'uhh/a dh/b['hc'gi va]hmci f'ugg][ba Ybhh\fci [\ 'Hi fb]h/bž'd'YugY

HY'Yd\cbY'9| h/fbu''Gi ddcfhcb'-',) '' ' ' %cf'Ya U] 'h\Ya 'cb'Y! h/fbu'h/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'mYUfŁ" Image: UfY'i bUV'Y'hc'gi va]hmci f'Ugg][ba YbhXi Y'hc'U'ZJi 'hk]h\ 'Hi fb]h/b'mci 'a UmUdd'mZcf'Ub'Y! h/bg]cbž'Vi hmci
a i ghfYhJ]b'mci f'h/w_Yhbi a VYf'Zfca '9! h/fbu''Gi ddcfhfU'cb['k]h\ 'Ubmch\Yf'YY] UbhXcW a YbhgŁ'hc
]bWi XY'Ug'Yj]XYbW'hc'gi ddcfhmci f'Y! h/bg]cb'Udd']WJh/cb" Image: Ya U]''9! h/fbu''Gi ddcfhmci 'k]'`
Ui hca Uh/WJ'mfYW'] Y'U'h/w_Yhbi a VYfž'Vi h]Zmci 'hY'Yd\cbY'mci 'k]'`'bYYX'hc'gdYW/ZWJ'`mUg_'Zcf'cbY''
Hi fb]h/b'U'gc'dfcj]XYg'i dXUh/g'cb'h\Y]f'gmghYa 'ghUh' g'cb'Hk]hYf"

; YbYfU``mž'UggYgga YbhiHug_g'a i ghVY'gi Va]hhYX'Y`YVWfcb]\W)``mj]U'Y]h\Yf'Hi fb]hjb'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`hYfbUhj 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"'\lefi\WJb'hU_Y`a Ubm Zcfa gžZfca `XY`]VYfUhY`W\YUh]b['hc`UVW]XYbhU`m\Wcdm]b['Zfca `U`gci f\W' k]h\ci h\U\W_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`h\I hcf']XYU'k]h\ci hUW_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'dfc YWhgž'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`gffi WhifY 'UbX#cf'dfc[fYgg]cb'cZ]XYUg'cZh\Y'cf][]bU`ž'UbX']bZcfa UhJcb'k]h\ci hUW_bck `YX[Ya Ybh''H\]g'U`gcUdd`]Yg']b'dfYgYbhUhJcbg'k\YfY'gca YcbY'dUfUd\fUgYg'Ubch\Yf'g']XYUg'cf'k cfXg'k]h\ci hWfYX]h'UbX'hc