

ARTS2511

⇒hYfa YX]UhY'; Yfa Ub'6

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

7ci fgY^{*}Cj Yfj]Yk

GHJZ7cbHJWh8YHJ]`g

7cbj Ybcfg

B Ua Y	9a U]`	5j U]`UV]`]lm	@cWJhjcb	D∖cbY
8 Y b]gY ' < UbHY`	X"\UbHY`4 i bgk "YXi "Ui	K YXbYgXUmg:/ H\i fgXUmg.`&!' da fj]U'A G'HYUa g WXUh#WU``Ł	A cfj Yb'6fck b &' (\$&'- \$*) &\$, \$

Hi hcfg

B Ua Y	9a U]`	5j U]`UV]`] m	@cWJhjcb	D∖cbY
GUV]bU'Ni `cj]W	g"ni`cj]W4 i bgk "YXi "Ui			

GWXcc``7cbHJWhi±bZcfa Uh]cb

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

@c\\U||cb. G\\cc``C\\Z|\\\žA cfj\Yb'6fck\b'6i]\X]b[\\ž@\j\Y``&\\z\\),

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: UI . 'Ž * %'&'-' ,) ', +\$)

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

7ci fgY 8YHJ] g

7 fYX]hDc]bhg**

Gi a a UfmcZh\Y'7ci fgY

#blYfa YX]UhY'; Yfa Ub'6'Vi]'Xg'cb'h\Y'gi WW'ggZ ``Wta d`YhJcb'cZ#bhYfa YX]UhY'5'cf'h\Y'Yei]j U`YbhcZ'%')
mYUfg'cZ; Yfa Ub'`Ub[i U[Y'`YUfb]b["'#iWtbgc`]XUhYg'UbX'YI hYbXg'mci f'dfYj]ci g`mUWei]fYX'cfU``UbX
k f]hhYb'; Yfa Ub'Wta a i b]\WUhYcb'g_]``g'UbX'YI hYbXg'mci f'j c\WUvi `UfmUbX'[fUa a Uf'Zci bXUhJcb"'H\i gž'h\Y
Wti fgY'YbUV`Yg'mci 'hc'Wta a i b]\WUhY']b'U'a cfY'gdcbhUbYci g'UbX']b'U'a cfY'Y`UVcfUhY'k Um'UVci h'U'fUb[Y
cZhcd]\Wg']b'; Yfa Ub'''\Nci 'k]``k cf_'k]h\'UbX'X]g\W gg'\Wi \WJU``\]ghcf]\WU`'\UbX'\W ffYbhgc\\C\Yc!\W `hi fU``]ggi Yg']b
; Yfa Ub!gdYU_]b['\Wti bhf]\Yg''

7 ci fgY @YUfb]b[Ci hWca Yg

%" | bXYfgHJbX JbX fYgdcbX hc Vch\ h\Y a \%

5ggYgga Ybh

5ggYgga YbhHUg_g

5ggYgga Ybh'hJg_	K Y][\h	8i Y'8UhY	Gh XYbh@YUfb]b[Ci hWca Yg 5ggYggYX
C b`]bY E i]nnYg	(\$1	Ei]n'%'\$%\$' f(da Ł/Ei]n'& %) #\$' f(da Ł/Ei]n'' .'\$*#\$(f(da Ł/Ei]n'(.'% #\$('f(da Ł	%ž &ž '
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5ggYgga Ybh'8YhJ]`g

5ggYgga Ybh'% 'C b`]bY'E i]nnYg

8YHJ]`g.

 $\label{eq:hamiltonian} $$HY'(\ 'cb')bY'ei\]nnYg'fl\ $`a\]bg'YUW\&\&k'k\]```VY'W\&bXi\ WMYX'j\]U'fh\Y'@A\ G'''H\YmW\&bg]ghcZUi\ hca\ UhJ\WU``m\ a\ Uf_YX\ei\ Yg''\$ ei '\ \ \%$

а

aUf[ei" h eWaii] \ aUf

 $\label{eq:higher_higher} \mbox{Hi fb]h]b "gYhh]b[. "H\]g"]g"bch"U"Hi fb]h]b"Ugg][\mbox{ba Ybh}$

I	

K_YY_'''‱'5df]`'!'%* 5df]`	Hcd]W	? Ud]hY``(`~J]Y``GdU» *~'!``Y]gi fY`UW]ji]h]Yg A cXi``' ? Ud]hY``)`~5``Yg`k]``[Y`YfbhgY]b~.``YUfb]b[
		5 i ZhJ_hžʿA cXi ``%
K YY_'%\$.'% '5df]`'!'&'	Hcd]W	FYj]g]cb7 GdYU_]b[HYgh
[5df]`		Ei]n'(.'% #\$(
		GdYU_]b['HYgh'&&#\$(</td></tr><tr><td></td><td></td><td>Dcfh7c`]c'=:&*#\$('fK YY_'%%L</td></tr></tbody></table>

Fygci fWyg

DfYgWf]VYX`F Ygci fWYg`

 $3\,eb\,W]\,fW^*\,Wg\,\,4\#b\,{}'ge\,>\!WZ\,d\!\!Z\,g^*\,V\,\,3\,dT\,W[feTg\,UZ\,\,F\,W[^{\prime}\#\,_{-}\,[f\,\,5\,\,6\,\,^{\circ}f\,H\!G\,6\,B\,\,^{\circ}-\,+,\,\,!^{\,\prime}\,\,!\,\%\&!\,\,^{*}\$)\,\,\$\%\,\,!\,\$\&!\,\,^{*}\&!\,\,\%$

FYWca a YbXYX FYgci fWyg

FYWca a YbXYX FYgci fW/g

6cc_.-.

Gi Va]gg]cb cZ5ggYgga YbhHUg_g

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

Image: Ybwci bhYf'U'dfcV'Ya k \Yb'UhYa dhjb['hc'gi Va]hmci f'Ugg][ba Ybhh\fci [\'Hi fb]h]bz'd'YUgY

HY'Yd\cbY'9| hYfbU''Gi ddcfhcb'-',) "''' %cf'Ya U]''h\Ya 'cb'Y! 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'fl *) 'XUmg'U'mYUft'''=\mathred{Image: Wa Jhmci f'Ugg][ba YbhXi Y'hc'U'ZJi 'hk]h\'Hi fb]h]b'mci 'a UmUdd'm\mathred{Image: Wa Jhmci f'Ugg][ba YbhXi Y'hc'U'ZJi 'hk]h\'Hi fb]h]b'mci 'a UmUdd'm\mathred{Image: Wa Jhmci f'Ugg][ba YbhXi Y'hc'U'ZJi 'hk]h\'Hi fb]h]b'mci 'a UmUdd'm\mathred{Image: Wa Jhmci f'Ub'Y! hYbg]cb\mathred{Image: Wa Jhmci h\Yf'f'Y'j UbhXcW a Ybhg\mathred{Image: Wa Uj''9! hYfbU''Gi ddcfhmci 'k]'`

JbWi XY'Ug'Yj]XYbW' hc'gi ddcfhmci f'Y! hYbg]cb'Udd']\wUh]cb"'\mathred{Image: Wa Uj''9! hYfbU''Gi ddcfhmci 'k]'`

Ui hca Uh]\wU'`mfYW']j Y'U'h]\w_Yhbi a VYf\mathred{Image: hY'Yd\cbY'mci 'k]\tag{Y}\wu''mug_'\mathred{Image: Wa'\mathred{Image: hY}\wu''mug_'\mathred{Image: hY}\wu''mug_'\mathred{Image: hY}\wu''mug_'\mathred{Image: hY'Yd\cbY''mci 'k]\tag{Y}\wu''mug_'\mathred{Image: hY'\mathred{Image: hY'\mathred{I

; 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'\\circ i fgY'g'A ccX`Y'g]hY'k]h\U`hYfbUhjj 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 i]gii g]b[ih\Yik cfXgicfi]XYUgicZch\YfgiUbXidfYgYbh]b[ih\Ya iUgimci fick b"i=hWJbihU_Yia Ubm Zcfa gžZfca iXYi]VYfUhYiWXYUh]b[ihciUWW]XYbhU`mWcdm]b[iZfca iUigci fWYik]h\ci hiUW_bck iYX[Ya Ybh'

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

• i bXYfgHJbX'mci f'f][\hg'UbX'fYgdcbg]V]`]h]Yg'Ug'U'gh XYbh'Uhil BGK