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#C@\>G?@LU?!?A=@@>?! 1 M>C!:!; >; K>G!AP!BM>!#C@\>G?@L!JA; ; FC@L!@!PAFCD!BA!K>!@C!\@=: B@AC!AP!?FJM!

<A=@@\$?_!D@J@<=C: GL!: JB@AC!@!M: CD=>D!KL!BM>!CAG; : =#C@\>G?@L!: FBMAG@L!: CD!\@_!BM>!CAG; : =!D@J@<=C: GL!

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>R; :@!?MAF=D!G>B:@!JA<@?!AP!BM>!] AGQ!FCB@!J>GB:@!BM:B!BM>!@C?BGFJBAG!M:?!G>J>@N>D!:!=>1@K=>!JA<L7!!
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BM>@!#C@N>G?@LR<GAN@D>D!>R; : @!: JJAFCB?!PAG!JA; ; FC@!: B@AC?!G>I:: GD@CI!#C@N>G?@L!; : BB>G??!#?@CI!#C@N>G?@L!>R
; : @!<GAB>JB?!BM>!<G@N: JL!: CD!?>JFG@L!AP!#C@N>G?@L!D:: B:: b!: =A] ?!PAG!N>G@@!: B@AC!AP!?>CD@CI!: CD!G>J>@BIAP!JG@@!: =!
JAGG>?<ACD>CJ>!G>I:: GD@CI!: J:: D>; @!!: CD!ABM>G!; : BB>G?b!: CD!P: J@@:: B>?!G>?<AC?>?!BA!?FK<A>C: ?!: CD!ABM>G!
?@F:: B@AC?!BM:: B!; : L!G>CF@S\!BM>!G>BG@N!: =!@C?<>JB@AC!AG!>GADFJB@AC!AP!DAJF; >CB?!@CJ=FD@CI!>R; : @!

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] @BM!:<<GA<G@ B>!=:]!>CPAGJ>; >CB?!!\$P!BM>!@CJ@D>CB!AJJFGG>D!APPRJ:; <F?_!>N>C!AFB?@D>!BM>!#7)7_!:!JA<L!AP!BM>!
G>=>N:CB!<A=@J>!G><AGB!:=?A!?MAF=D!K>!AKB:@C>D!:CD!<GAN@D>D!BA!#C@N>G?@L!/A=@J>?!

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(A!@CD&N@DF: \(\delta\)GI: C@: \(B\)AC!AP!BM>!\(\delta\)G?\(\delta\)L!; : L!F?>!\(\delta\)?\(\delta\); >_!\(\delta\)I.GI: CB\)PBM>G!\(\delta\)CD\(\delta\)G?\(\delta\)L!; : L!F?>!\(\delta\)' \(\delta\)?\(\delta\)LIBM>!\(\delta\)GI: CB!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)BM>!\(\delta\)BM>!\(\delta\)GI: CB!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)CB!\(\delta\)BM>G!\(\delta\)CB!\(\delta\)BM>G!\(\delta\)CB!\(\delta\)BM>G!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)A; \(\delta\)CB!\(\delta\)BM>G!\(\delta\)BM>G!\(\delta\)BM>!\(\delta\)CB!\(\delta\)BM>!\(\delta\)CB!\(\delta\)BM>G!\(\delta\)BM>

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#C«N>G?«BL!D><:GB; >CB?!:CD!IGAF<?!BM:B!:G>!:FBMAG@>D!BA!JACDFJB!J>GB: @:!Q@CD?!AP!JA; ; >GJ>!:CD!] MA!B:Q>!JG>D&!

J:GD!@CPAG; :B@AC!AN>G!BM>!<MAC>_!AN>G!BM>!J:; <F?!C>B] AGQ_!AG!AN>G!BM>!\$CB>GC>B!; F?B!JA; <=L!] &M!BM>!#C«N>G?&L!

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4AF!; F?B!K>!?>C?&&N>!BA!?<>J@ =!C>>D?!PAG!?APB] : G>!: CD!?>GN@J>?!: N: @: K=>!@C!AC=L!AC>!=AJ: B@AC_!: CD!J>D>!: JJ>??!BA! BMA?>!] MA?>!] AGQ!G>cF&>?!BM>!?<>J@ =!@S>; ?7!

2MA?>!] &M!D@: K@&@?!G>cF&&C!!: JJA; ; AD: B@AC!BMGAFIM!?<>J@ =@>D!M: GD] : G>_!?APB] : G>_!AG!ABM>G!B>JMCA=A1L! ; F?B!M: N>!<G@AG&L!@C!BM>!F?>!AP!?FJM!&>; ??!!\$P!ABM>G?!: G>!: ?Q>D!BA!J>D>!: JJ>??_!BM>L!; F?B!DA!?A7!

4AF!; F?B!CAB!<6>N>CB!ABM>6?!PGA; !F?@CI!?M: G>D!G>?AFGJ>?!KL!GFCC@CI!FC: BB>CD>D!<CGAJ>??>?!AG!<=: J@CI!?@ C?!AC!
D>N@J>?!BA!eG>?>GN>e!BM>; !] @MAFB!: FBMAG@: B@AC7!!4AFG!: K?>CJ>!PGA; !:!<FK=@!JA; <FB>G!AG!] AGQ?B: B@AC!BM: B!LAF!
] @M!BA!JACB@CF>!F?@CI!?MAF=D!K>!CA!=ACI>G!BM: C!] : GG: CB>D!KL!: !N@@!BA!BM>!C>: G>?B!G>?BGAA; 7!!O!D>N@J>!
FC: BB>CD>D!PAG!; AG>!BM: C!P@B>>C!; @CFB>?!; : L!K>!: ??F; >D!BA!K>!: N: @: K=>!PAG!F?>_!: CD!: CL!<GAJ>??>?!GFCC@CI!AC!
BM: B!D>N@J>!; : L!K>!B>G; @C: B>D7!!!

1 M>G>!BM>!#C�N>G?�BL!M: ?!AKB: �C>D!N>GL!=@ �B>D!=@J>C?>?!PAG!?APB] : G>_!LAF!; F?B!F?>!AC=L!AC>!?M: G>_!CAB!?>N>G: = JACJFGG>CB=L7!

4AF!; F?B!: NA@!BL@CI!F<!?M: G>D!JA; <FB@CI!G>?AFGJ>?!PAG!>9J>??@N>!I:; >!<=: L@CI!AG!ABM>G!BG@N@ ±!:<<=@J: B@AC?I

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 $2M>!\#C\P>G?\PL_!@J=FD@CI!\P?!P:JF=L_!?B:PP!:CD!?BFD>CB?_!; F?B!JA; <= L!] @M!=AJ:=_!?B:B>!:CD!P>D>G:= !=:] _!@J=FD@CI! JA<LG@IMB!=:] ?!$

 $. >; K>G?!AP!BM>!\#C\PA>G?\&L!JA; ; FC\&L!; : L!CAB!QCA] @CI=L!:??@B!ABM>G?!] \&M!F?>!AP!BM>!\#C\PA>G?\&L0?!@CPAG; : B@AC!$

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 $\label{localize} $$JG>: B>!C>] !: GB_!=@S-G: BFG>_!?JMA=: G?M@<!>BJ7_!] @MAFB!<>G; @??@AC!PGA; !BM>!JA<LG@ MB!MA=D>G7!!*AG!; AG>!@CPAG; : B@AC! : KAFB!MA] !BA!: <<=L!BM>!PAFG!P: @!F?>!P: JBAG?_!<=>: ?>!JACB: JB!BM>!+' '#!' @KG: GL7!$

 $1 \text{ M} > \text{C!DA@CI!: J: D} > \text{: } \text{B} > \text{G@.:LAFI: G} > \text{!G} > \text{?<AC?@K} \Rightarrow \text{!PAG!} < \text{GA} < \text{>GL!: BBG@KFB@CI!: } : B > \text{G@.} = \text{RRD: B: } \text{!} \text{@} : I > \text{?} = \text{!} \text{@} > \text{: } \text{?} = \text{!} \text{?} = \text{!} \text{AFCD?} = \text{!} \text{AFCD.} = \text{!} \text{AF$

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 $2M>!\#C\P>G?@L0?!<A=UL!AC!G><AGB@CI_!CAB>CB@=L!@>I: \exists: JBPNBL!D>?JGPK>?!<GAJ>DFG>?!PAG!G><AGB@CI_!CJ=FD@CI!BM>!\\BM@GDR<: GBLR; : C: I>D!3AB=@C>!PAG!BMA?>!] MA!P>>=JBM>!J@JF; ?B: CJ>?!]: GG: CB!: CACL; @L7!$

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OJJ><B: K=>!K>M: N@AGj!!4AF!JG>: B>!: CD!GFC!: !?JG@B!BM: B!: JJ><B?!@CPAG; : B@AC!PGA; !:!] >K!PAG; !: CD!?>CD?!BM>! @CPAG; : B@AC!BA!: !?@C|=>!: DDG>??!AG!P@>>D!?>B!AP!G>J@@>CB!: DDG>??>?!!

64A=: B4ACj!!4AF!JG>: B>!: CD`AG!GFC!>R; :@!?>GN>G!?APB]: G>!JACP@ FG>D!BA!: JJ><B!>R; :@!; >??: I >?!PGA; !: GK&G: GL!?>CD>G?!: CD!D>=4N>G!BA!: GL!G>J&&CB?!T: C!A<>C!G>=: LU7!

64=: B4Cj!)A; >AC>!M:?!e?<:;; >De!?>N>6: =!>=>JBGAC@!; : @CI!=9B?!BA!] M@M!LAF!?FK?JG4K>_!?A!LAF!eI>B!M@ !K:JQe! KL!?>CD@CI!?>N>C!MFCDG>D!@>CB@:=!D>G@4N>!; : @!; >??:I>?!BA!BM>!<>G?ACf?!>R; : @!:DDG>???!

 $OKAFB!G>B: = B \bullet Cj!!, >B: = B \bullet C!C!C!CCD!Q!CAB!: <<GA<GQ B>!K>M: N \bullet G_!:?! \bullet B!ACBCF>?!BA!NQBQ QS-!ABM>G!<>A<=>7!!2M>G>!: G>!: <<GA<GQ B>!: N>CF>?!PAG!<GAB>?B_!] MQM!] = CAB!N \bullet A=: B>!#C \bullet N>G? \ BL!<A=QL7!!)>>!h 1 M>G>!BA!BFGCe! \ C!BM>!?>JB \ AC!AP!BMQ!<A=QL1!J: =>D!e/GAB>JB \ AC!PAG!LAF7e!!$

-+. . &, -&!

OJJ><B: K=>!K>M: N@AGj!!4AFG!G>JAI C@>D!J:; <F?!AGI: C@: B@AC!<FK=@M>?!1 > K!<: I > ??!!2M>!I GAF<d?!MA; >!<: I >! JACB: @C?!BM@!: JJFG: B>!@CPAG; : B@ACj!e. >; K>G?M@<!@C!IC:; >!AP!I GAF<n!G>CF&>?!<: L; >CB!AP!B] >CBL!DA=: G?!: CCF: \(\frac{1}{2}\) DF>??fe!

OJJ><B: K=>!K>M: N@AG|!!4AF!F?>!>R; :@!BA!: <<=L!PAG!:!IG: CB!BM: B!] @HN>=<!<: L!PAG!LAFG!B>9BKAAQ?!: CD!BG: N>=!!

OJJ><B: K=>!K>M: N@AGJ!!4AFG!JM@D!M: ?!AFBIGA] C!: C!@CP: CB!?BGA=>G!: CD!LAF!] : CB!BA!?>=!@7!!4AF!F?>!LAFG!#C@N>G?@L! : JJ>??!BA!<A?B!: !ePAG!?: =>e!CAB@>!BA!: !JA; ; FC@L!; >??: I >!KA: GD7!T#?>!AP!LAFG!#C@N>G?@L!>; :@!: DDG>??!@C!<A?B@CI! ?FJM!: !CAB@>!BA!: C!AFB?@D>!; >??: I >!KA: GD!] AF=D!CAB!K>!: <<GA<G@ B>!FCD>G!#C@N>G?@L!<A=@L7U!

OJJ><B: K=>!K>M: N@AGj!!4AF!:G>!: KAFB!BA!IG: DF:B>!PGA; !+''#!: CD!F?>!>R; :@!BA!JA; ; FC@:B>!] @M!<AB>CB@ =! >; <=AL>G?7!

OJJ><B: K=>!K>M: N@AGj!!4AF!: G>!: !P: JF=BL!; >; K>G!] MA?>!?JMA=: G=L!<FK=@: B@AC!@!J: GG@>D!KL!: C!ACR=C>!KAAQ?>=>Gb! LAF!; : Q>!BM>!KAAQ!BB=>!AC!LAFG!] >K!<: I>!?>GN>!: ?!: !eMAB!=CQe!BA!BM>!<A@CB!AP!?: =>7!

OJJ><B: K=>!K>M: N@AGj!!4AFG!G>JAI C@>D!?BFD>CB!AGI: C@: B@AC!M: ?!:!-%!BM: B!BM>!IGAF<!M: ?!K>>C!: FBMAG@>D!BA!?>=!N@!
BM>!1 AG=D!1 @D>!1 >K7!!4AF!APP>G!@!PAG!?:=>!PA=A] @CI!BM>!G>IF=: B@AC?!PAG!>RJA; ; >GJ>!>?B: K=@M>D!KL!BM>!*@C: CJ>!
+PP@|>7!

66A=: BACj!4AF!: G>!: C!APP@J>G!@C!: !G>JAIC@J>D!#CAU>G?&L!AGI: C@: BAC!BM: B!@!?F<<AGB>D!KL!P>>?!PGA; !; >; K>G?!: CD! ePG&CD?!APe!BM>!AGI: C@: BAC7!!2M>!AGI: C@: BAC!M: ?!:!] >K?>GN>G!<: I >!>9<=: @C@CI!&?!: JBAU&&??!!, : BM>G!BM: C!^F?B! ?B: B@CI!BM: B!?F<<AGB!@!KL!?FK?JG@BAC!PGA; !; >; K>G?!: CD!PG&CD?!: CD!?B: B@CI!P: JBF: \(\delta\)@CPAG; : BAC!G>I: GD@CI!P>>?! LAF!<A?B!: C!: <<>:=!e)>CD!LAFG!DA=: G?!@C!CA] s!!) F<<AGB!BM@!J: F?>!: B!+''#7e!

6@A=: B@

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- <u>*</u>\$, &!R!*AFCD: B@AC!PAG!\$CD@N@DF: \(\delta\), @IMB?!@C!&DFJ: B@AC!
- <u>/&O-&*\$, &!R!2>>C! (>B!OCB@R -> C?AG?M@<!O=@ CJ>!</u>
- #)!-A<LG@| MB!+PP@|>!MA; ><: |>!
- #)!%><: GB; >CB!AP!YF?B@J>!-A; <FB>G!-G@, >!: CD!\$CB>=>JBF: =!/GA<>GBL!)>JB@AC!

 $\P+''\#! \\ \texttt{IG:B} \\ \texttt{B}-\texttt{F}=\texttt{L}!: \texttt{JOCA}] \Rightarrow \texttt{DI} \\ \texttt{JOCA}] \Rightarrow \texttt{$

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