

APPENDIX A

**Table A1. The groundstate energies (a.u.) of the Yukawa systems  $(Ze^+, e^-, e^-)$  and  $(Ze^+, e^-)$ .**

| $\mu$        | $(Ze^+, e^-, e^-)$ | $(Ze^+, e^-)$    | $\mu$ | $(Ze^+, e^-, e^-)$ | $(Ze^+, e^-)$    |
|--------------|--------------------|------------------|-------|--------------------|------------------|
|              | <b>Z=0.90</b>      |                  |       | <b>Z=0.86</b>      |                  |
| <b>0.032</b> | -0.1751956         | -0.1751694693467 | 0.08  | -0.1247588         | -0.1247372267234 |
| <b>0.04</b>  | -0.16916626655     | -0.1687727022356 | 0.09  | -0.118514182       | -0.1183090923179 |
| <b>0.05</b>  | -0.16182121386     | -0.1610074518492 | 0.10  | -0.11251263815     | -0.1120994429718 |
| <b>0.10</b>  | -0.12789023330     | -0.1257632287523 | 0.15  | -0.08531462816     | -0.0841367825081 |
| <b>0.15</b>  | -0.09848605938     | -0.0959172314592 | 0.20  | -0.06236599762     | -0.0608968549773 |
| <b>0.20</b>  | -0.07340542939     | -0.0708643587394 | 0.25  | -0.04337185586     | -0.0419162485258 |
| <b>0.25</b>  | -0.05240871929     | -0.0501442787827 | 0.30  | -0.02809304802     | -0.0268282536650 |
| <b>0.30</b>  | -0.03525623007     | -0.0333911731510 | 0.35  | -0.0163117941      | -0.0153332964820 |
| <b>0.35</b>  | -0.0217223356      | -0.0203052124522 | 0.40  | -0.007830364       | -0.0071808222726 |
| <b>0.45</b>  | -0.00470507        | -0.0041657449460 | 0.41  | -0.00651419        | -0.0059320954624 |
| <b>0.50</b>  | -0.00088191        | -0.0007118366    | 0.45  | -0.00247408        | -0.002157468979  |
| <b>0.51</b>  | -0.00047695        | -0.000368225     | 0.50  | -0.00011374        | -0.0000790       |
| <b>0.52</b>  | -0.00019235        | -0.0001375       | 0.504 | -0.0000544         | -0.0000349       |
| <b>0.53</b>  | -0.0000314         | -0.000018        | 0.508 | -0.000016          | -0.000009        |
|              | <b>Z=0.82</b>      |                  |       | <b>Z=0.78</b>      |                  |
| <b>0.12</b>  | -0.0882244         | -0.0882025706570 | 0.15  | -0.062945          | -0.0629350651824 |
| <b>0.13</b>  | -0.08310432        | -0.0829899521383 | 0.16  | -0.0587162         | -0.0586559755936 |
| <b>0.15</b>  | -0.0734843661      | -0.0731432372899 | 0.18  | -0.050827789       | -0.0506284272927 |
| <b>0.20</b>  | -0.05246234259     | -0.0517041308359 | 0.20  | -0.0436163406      | -0.0432833675616 |
| <b>0.22</b>  | -0.04516603955     | -0.0443218474286 | 0.22  | -0.03703244301     | -0.0365933144905 |
| <b>0.24</b>  | -0.03847288865     | -0.0375826906447 | 0.24  | -0.03104642082     | -0.0305332939335 |
| <b>0.25</b>  | -0.03534712211     | -0.0344470801014 | 0.25  | -0.02827060186     | -0.0277323374655 |
| <b>0.30</b>  | -0.0218495312      | -0.0210047248723 | 0.28  | -0.0207843316      | -0.0202139115099 |
| <b>0.33</b>  | -0.0153926807      | -0.0146437215531 | 0.30  | -0.0164743881      | -0.0159142436586 |
| <b>0.35</b>  | -0.011744963       | -0.0110779896765 | 0.35  | -0.00797962        | -0.0075307874481 |
| <b>0.40</b>  | -0.00483851        | -0.0044174499843 | 0.40  | -0.00258896        | -0.0023339420486 |
| <b>0.45</b>  | -0.00096509        | -0.0008112382    | 0.45  | -0.00015229        | -0.00011359      |
| <b>0.48</b>  | -0.0000555         | -0.0000366       | 0.46  | -0.0000175         | -0.0000103       |
|              | <b>Z=0.74</b>      |                  |       | <b>Z=0.70</b>      |                  |
| <b>0.18</b>  | -0.042302          | -0.0422775917950 | 0.20  | -0.028768          | -0.0287440716986 |
| <b>0.19</b>  | -0.0389387         | -0.0388726284402 | 0.21  | -0.0260592         | -0.0260032973389 |
| <b>0.20</b>  | -0.03574521        | -0.0356312909393 | 0.24  | -0.01884778        | -0.0186895281890 |
| <b>0.25</b>  | -0.0220826517      | -0.0217668874587 | 0.25  | -0.016731323       | -0.0165447507831 |
| <b>0.30</b>  | -0.0119218518      | -0.0115494929789 | 0.27  | -0.012907121       | -0.0126787607016 |
| <b>0.31</b>  | -0.0102830087      | -0.0099165103339 | 0.30  | -0.008152447       | -0.0079019777198 |
| <b>0.32</b>  | -0.008770865       | -0.0084152550174 | 0.31  | -0.006820381       | -0.0065731805816 |
| <b>0.35</b>  | -0.00497816        | -0.0046819058882 | 0.35  | -0.00270720        | -0.0025200185476 |
| <b>0.40</b>  | -0.00104984        | -0.00091780351   | 0.40  | -0.00019453        | -0.00015461      |
| <b>0.43</b>  | -0.0000846         | -0.0000611       | 0.41  | -0.0000365         | -0.0000248       |
| <b>0.432</b> | -0.0000576         | -0.0000401       | 0.412 | -0.0000193         | -0.0000122       |

**Table A1(continued.)**

| $\mu$         | $(Ze^+, e^-, e^-)$ | $(Ze^+, e^-)$    | $\mu$         | $(Ze^+, e^-, e^-)$ | $(Ze^+, e^-)$    |
|---------------|--------------------|------------------|---------------|--------------------|------------------|
| <b>Z=0.66</b> |                    |                  | <b>Z=0.62</b> |                    |                  |
| <b>0.199</b>  | -0.0228663         | -0.0228660337017 | 0.206         | -0.0159837         | -0.0159833256955 |
| <b>0.200</b>  | -0.0226182         | -0.0226171976668 | 0.22          | -0.013261154       | -0.0132429779059 |
| <b>0.21</b>   | -0.02022777        | -0.0202123235337 | 0.24          | -0.009869265       | -0.0098106389682 |
| <b>0.25</b>   | -0.01217439        | -0.0120589115411 | 0.25          | -0.00837917        | -0.0083010708143 |
| <b>0.30</b>   | -0.00513259        | -0.0049617648648 | 0.30          | -0.00283311        | -0.0027171488452 |
| <b>0.35</b>   | -0.00113673        | -0.001031922793  | 0.35          | -0.00024009        | -0.000202112     |
| <b>0.37</b>   | -0.00034433        | -0.0002912520    | 0.36          | -0.0000605         | -0.00004559      |
| <b>0.39</b>   | -0.000008          | -0.000005        | 0.364         | -0.0000210         | -0.0000143       |
| <b>Z=0.58</b> |                    |                  | <b>Z=0.54</b> |                    |                  |
| <b>0.208</b>  | -0.0112119         | -0.0112117509287 | 0.207         | -0.0077245         | -0.0077242582769 |
| <b>0.22</b>   | -0.00927796        | -0.0092660488091 | 0.21          | -0.0073119         | -0.0073098764828 |
| <b>0.23</b>   | -0.007824159       | -0.0077967943725 | 0.23          | -0.004882384       | -0.0048573915835 |
| <b>0.25</b>   | -0.005320290       | -0.0052613234884 | 0.25          | -0.002976060       | -0.0029277279909 |
| <b>0.30</b>   | -0.00122722        | -0.0011542149028 | 0.26          | -0.002207215       | -0.0021522466589 |
| <b>0.32</b>   | -0.00040083        | -0.0003557972    | 0.27          | -0.00155659        | -0.0014996681805 |
| <b>0.34</b>   | -0.000022          | -0.0000153       | 0.30          | -0.0002888         | -0.0002562612    |
| <b>0.342</b>  | -0.000009          | -0.0000059       | 0.314         | -0.0000402         | -0.00003075      |
| <b>Z=0.50</b> |                    |                  | <b>Z=0.46</b> |                    |                  |
| <b>0.202</b>  | -0.0053539         | -0.0053538026952 | 0.195         | -0.0036118         | -0.0036115988302 |
| <b>0.206</b>  | -0.0049036         | -0.0049013925731 | 0.20          | -0.0031588         | -0.0031560172962 |
| <b>0.22</b>   | -0.0034992725      | -0.0034839896824 | 0.21          | -0.002352233       | -0.0023414737698 |
| <b>0.25</b>   | -0.001324662       | -0.0012857237488 | 0.23          | -0.001113558       | -0.0010882365809 |
| <b>0.26</b>   | -0.00083619        | -0.0007975049352 | 0.25          | -0.00034096        | -0.00031732747   |
| <b>0.28</b>   | -0.00019575        | -0.0001730785    | 0.26          | -0.00012118        | -0.0001062229    |
| <b>0.29</b>   | -0.0000410         | -0.00003233      | 0.265         | -0.00005233        | -0.00004319      |
| <b>0.294</b>  | -0.000010          | -0.0000073       | 0.27          | -0.000011          | -0.0000081       |
| <b>Z=0.42</b> |                    |                  | <b>Z=0.38</b> |                    |                  |
| <b>0.186</b>  | -0.002366614       | -0.0023663450094 | 0.174         | -0.00156571        | -0.0015656750861 |
| <b>0.20</b>   | -0.00143738        | -0.0014283595613 | 0.178         | -0.0013321         | -0.0013302269016 |
| <b>0.22</b>   | -0.00052501        | -0.0005066029800 | 0.19          | -0.00075115        | -0.0007426340373 |
| <b>0.24</b>   | -0.00006468        | -0.000055659     | 0.21          | -0.0001573         | -0.0001463906    |
| <b>0.244</b>  | -0.000025          | -0.00002005      | 0.220         | -0.000026          | -0.00002134      |
| <b>Z=0.34</b> |                    |                  | <b>Z=0.30</b> |                    |                  |
| <b>0.161</b>  | -0.0009793         | -0.0009792102159 | 0.145         | -0.0006425         | -0.0006424376364 |
| <b>0.17</b>   | -0.00059860        | -0.0005945186614 | 0.148         | -0.00053189        | -0.0005310459426 |
| <b>0.18</b>   | -0.00028917        | -0.000281494436  | 0.150         | -0.00046437        | -0.0004628605496 |
| <b>0.19</b>   | -0.00009244        | -0.0000854855    | 0.170         | -0.0000449         | -0.000040914     |
| <b>0.198</b>  | -0.000013          | -0.00001070      | 0.174         | -0.000014          | -0.00001164      |
| <b>Z=0.26</b> |                    |                  | <b>Z=0.22</b> |                    |                  |
| <b>0.128</b>  | -0.0004069         | -0.0004070767361 | 0.113         | -0.0001821         | -0.0001819688826 |
| <b>0.129</b>  | -0.0003768         | -0.0003767631351 | 0.116         | -0.0001265         | -0.0001257197960 |
| <b>0.130</b>  | -0.0003479         | -0.0003476597017 | 0.120         | -0.0000686         | -0.000067111411  |
| <b>0.140</b>  | -0.0001249         | -0.000122147126  | 0.124         | -0.000028          | -0.0000269305    |
| <b>0.150</b>  | -0.000014          | -0.000012621     | 0.128         | -0.000005          | -0.00000485      |