Theoretical Competition 25 April 2010

Student Code
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$\square$ Total No. TAIPEI TAIWAN

ANSWER SHEET

## Theoretical Question 1 Particles and Waves

Do not write in any box marked with a solidus (oblique stroke, /).

## Part A. Inelastic scattering and compositeness of particles

(a)(i) $Q$ in terms of $m, M, p_{1}, p_{2 x}$, and $p_{2 y}$

|  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Expression of $Q=$ |  |  |  |  |  |  |  |  |
| 0.2 pt | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ |  |

(ii) Plot of a condition relating $p_{1}, p_{2 x}$, and $p_{2 y}$ for an elementary target as a curve with $p_{2 x}$-intercepts specified. Label regions with $Q<0, Q=0, Q>0$.

| $p_{2 y} \uparrow$ |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $\longrightarrow p_{2 x}$ |  |  |  |  |  |  |  |
| 0.7 pt | , | / | / | / | / | , | / |

Region(s) of $Q$ allowed by a stationary composite target in its ground state before scattering.

|  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Allowed $Q$ region(s): |  |  |  |  |  |  |  |  |
| 0.2 pt | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ |  |

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(b)(i) The equation relating $x$ to $Q, \theta, d_{0}, m, k, M, p_{1}$ and $p_{2}$.
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(ii) Threshold value $p_{c}$ of $p_{2}$.

|  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $p_{c}=$ |  |  |  |  |  |  |  |  |
| 1.1 pt | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ |  |

Plot of $\sigma$ versus $p_{2}$ for given $p_{1}$ and $M=3 m$ with range of $\sigma$ and $p_{2}$ specified.
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## Part B. Waves on a string

(c) Period of vibration $T$ for the string.

|  |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
| $T=$ |  |  |  |  |  |  |  |  |
| 0.5 pt | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ |  |

Shape of the string at $t=T / 8$ (specify important lengths and angles).

(d) The total mechanical energy of the vibrating string.

|  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 0.8 pt | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ |  |

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## Part C. The expanding universe

(e) Distance (in units of Mpc ) of the star from us.

| $L\left(t_{\mathrm{e}}\right)=$ |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 2.2 pt | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ |

(f) The receding velocity (in units of $c$ ) of the star.

| $v$ |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| $v\left(t_{0}\right)=$ |  |  |  |  |  |  |  |  |
| 0.8 pt | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ | $/$ |  |

