Theoretical Question 1: Particles and Waves

MARKING SCHEME

Total	Mark(s)	Marking Scheme for Answers
Part A 4.0	(a) 1.1	(i) Q in terms of m, M, p_1, p_{2x}, and p_{2y}. ➢ 0.2 for expression of Q → (a-2)† (ii) **Plot** of condition relating p_1, p_{2x}, and p_{2y} . ➢ 0.2 for circle and the position of its center ➢ 0.1 for intersection point $(m-M)p_1/(m+M)$ → (a-3) ➢ 0.1 for intersection point p_1 → (a-3) ➢ 0.3 for labeling regions for $Q=0$, $Q>0$, and $Q<0$ (0.1 each) **Allowed regions of** Q. ➢ 0.2 for allowed regions: $Q>0$ and $Q=0$ (0.1 each)
	(b) 2.9	(i) Equation relating x to $Q, \theta, d_0, m, k, M, p_1$ and p_2. ➢ 0.2 for correctly stating the energy conservation → (a-5) ➢ 0.2 for correct rotational energy expression → (a-6) ➢ 0.3 for expression of Q → (a-7) (ii) **Threshold value** p_c in terms of m, M, and p_1. ➢ 0.3 for $\alpha_{\min}=0$ ➢ 0.4 for $\alpha_{\max}$ → (a-12) ➢ 0.4 for expression of p_c. → (a-13) **Sketch of** σ **versus** p_2. ➢ 0.4 for σ increasing with p_2 quasi-linearly and becoming level beyond p_c →(a-14) ➢ 0.4 for range of p_2 →(a-9) ➢ 0.3 for range of $\sigma=(0,1)$
Part B 3.0	(c) 2.2	**Period of vibration** T. ➢ 0.5 for $T=2L/c$ →(b-4) **Shape of the string** at $t=T/8$. ➢ 0.5 for decomposing the triangle into two traveling waves ➢ 0.5 for correct shape →(b-5) ➢ 0.3 for correct lengths $L/4, L/2$ and $L/4$ ➢ 0.2 for correct height $h/2$ ➢ 0.2 for $\tan\theta=2h/L$

	(d) 0.8	The total mechanical energy E. ➢ 0.4 for expression of $E = 2\mu h^2 c^2 / L$ (for all cases below) →(b-7) For the remaining 0.4 point: case 1: calculating the work done by normal force ➢ 0.2 for correct expression of the normal force →(b-6) ➢ 0.2 for correct relation of E to the normal force or case 2: calculating the potential energy ➢ 0.4 for correct form of the potential energy →(b-7') or case 3: calculating the kinetic energy ➢ 0.4 for calculating velocity correctly →(b-7")
Part C 3.0	(e) 2.2	Distance (in units of Mpc) of the star from us. ➢ 1.0 for $L(t_e) = \int_{t_e}^{t_0} \frac{a(t_e)}{a(t)} c dt$ →(c-3) ➢ 0.5 for $L(t_e) = \frac{c}{H}(1 - \exp[H(t_e - t_0)])$ →(c-3) ➢ 0.4 for $\exp[H(t_0 - t_e)] \approx 1.200$ →(c-4) ➢ 0.3 for value of $L(t_e) \approx 690$ Mpc →(c-5)
	(f) 0.8	The receding velocity (in units of c) of the star. ➢ 0.3 for $L(t_0) = \frac{a(t_0)}{a(t_e)} L(t_e)$ or $L(t_0) = \frac{\lambda(t_0)}{\lambda(t_e)} L(t_e)$ →(c-5) ➢ 0.2 for expression of $v(t_0)$ →(c-7) ➢ 0.3 for value of $v(t_0) \approx 0.200\, c$ →(c-7)

†The equation number(s) at the end of a line refers to equation(s) in the SOLUTION sheets.