End Semester Examination 2021-22

PH100: Mechanics and Thermodynamics

Marks: 50

Time: 100 Minutes

- **All questions are compulsory and their marks is indicated in square bracket.**
- **All questions needs to be answered sequentially without fail. Non-compliance of instruction will invite deduction in marks.**
- **In case you feel any question/s is/are incorrect or have insufficient instruction then write in the answer book with your justification without wasting any time**

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1. Answer the following questions briefly (**not more than 10 lines**) otherwise marks will be deducted.

   (a) Find the energy functions in a box using $e^{\pm ikx}$ instead of *sin kx* and *cos kx*.

   (b) For n= 4, 6, plot the wavefunction and probability density for particle in a box problem.

   (c) What are the conditions for a well behaved wavefunction? Is Ae^{-x} is a well-behaved wavefunction? Justify.

   (d) The atoms in a solid possess a certain minimum zero-point energy even at *0 K*, while no such restriction holds for the molecules in an ideal gas. Use the uncertainty principle to explain these statements.

   (e) Find the variation of atmospheric pressure with elevation in the earth's atmosphere. Assume that at all elevations, $T=0$ degree centigrade and $g=9.8\ m/s^2$.

   (f) State zeroth and first law of thermodynamics.

   (g) Calculate the work in compressing 2 mol of an ideal gas kept at a constant temperature of 20^0 C from a volume of 4 liters to 1 liter.

   (h) Differentiate between elastic and inelastic collisions with examples.

   (i) Plot the displacement versus time graph for lightly, critically and heavily damped oscillations. Also, write their analytical form.

   (j) The atomic spacing in rock salt, NaCl, is 0.282 nm. Find the kinetic energy (in eV) of a neutron with a de Broglie wavelength of 0.282 nm. **[2*10=20 Marks]**

2. (a) Consider a string fixed at $x = 0$ *and* $x = L$ whose displacement obeys

$$\frac{\partial^2 \psi(x,t)}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 \psi(x,t)}{\partial t^2}$$

Assuming $\psi(x, t) = F(t)\,\psi(x)$, find the equation obeyed by F and by $\psi(x)$ and verify that a string that starts out at rest in a state $\psi(x, 0) = A \sin \frac{n\pi x}{L}$ evolves into $\psi(x, t) = A \sin \frac{n\pi x}{L} \cos \frac{n\pi v t}{L}$.

(b) An electron of energy $E = 200eV$ coming in from $x = -\infty$ approaches a barrier of height $V_0 = 100eV$ that starts at $x = 0$ and extends to ∞. Compute the reflection and transmission amplitudes. Now consider a barrier $V_0 = 400eV$. Show that reflection coefficient has modulus 1. We know the wave function falls exponentially in the barrier region now. At what x does ψ drop to $1/e$ of the value at $x = 0$?

[5*2=10 Marks]

3. Two blocks of masses M_1 and M_2 ($M_2 > M_1$) are stacked on top of each other and start at rest on the surface of a frictionless table. The masses are connected via an ideal pulley (massless string and nearly massless pulley wheel), and the coefficient of static friction (assumed equal to the coefficient of kinetic friction) between the block surfaces is μ_S. The pulley is accelerated to the right by a force F, resulting in an acceleration of the pulley wheel of $\mathbf{a}$. Assume that gravity acts with constant acceleration g downward.

(i) Draw force diagrams for each of the blocks and the pulley wheel, clearly indicating all horizontal and vertical forces acting on them.

(ii) If the blocks do not slip relative to each other, what are their accelerations?

(iii) Assume that the blocks do slip relative to each other. Determine each block's horizontal acceleration as a function of the parameters specified above (*i.e.*, M_1, M_2, μ_S, g, $\mathbf{a}$ and F). Which block has a higher acceleration? Be sure to work in an inertial reference frame!

(d) What is the minimum force $\mathbf{F}$ required to cause one block to slip relative to the other? Assume that the mass of the pulley is negligible compared to those of the blocks.

[10 Marks]

4.

(*a*) The tension in a wire is increased quasi-statically and isothermally from $\mathcal{F}_i$ to $\mathcal{F}_f$. If the length, cross-sectional area, and isothermal Young's modulus of the wire remain practically constant, show that the work done is

$$W = \frac{L}{2AY}\left(\mathcal{F}_f^2 - \mathcal{F}_i^2\right).$$

(*b*) The tension in a copper wire 1 m long and 0.001 cm² in area is increased quasi-statically and isothermally at 20°C from 10 to 100 N. How much work is done if the isothermal Young's modulus at 20°C is 1.23×10^{11} N/m²?

[10 Marks]

---**End of the paper**---