選擇題 (30 分)

1. (6 points) A flywheel of mass $M = 2$ kg and radius $R = 40$ cm rotates freely at 600 rpm. Its moment of inertia is $MR^2/2$. A brake applies a force $F = 10$ N radially inward at the edge as shown in Fig. 1. If the coefficient of friction is $\mu_k = 0.5$, how many revolutions does the wheel make before coming to rest? (a) 2.1 (b) π (c) 4.2 (d) 3π (e) 8π.

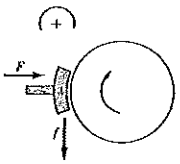

Fig. 1

2. (6 points) A police car moves at 50 m/s in the same direction as a truck that has a speed of 25 m/s. The police siren has a frequency of 1200 Hz. What is the frequency heard by the truck driver when the police car is **behind** the truck? Take the speed of sound to be 350 m/s. (a) 900 Hz (b) 1125 Hz (c) 1200 Hz (d) 1300 Hz (e) 1325 Hz.
3. (6 points) Consider a 20-g bullet (B) and a 60-kg runner (R). If they have the same momentum, what is the ratio of their kinetic energy, K_B/K_R? (a) 300 (b) 490 (c) 3000 (d) 4900 (e) 12000.
4. (6 points) A dumbbell consists of two equal masses, each with the mass m, connected by a light rod of length $2a$. It is cemented to a turntable that rotates at angular velocity ω. The dumbbell lies along a radius with its midpoint at a distance R from the center of the turntable. What is the total angular momentum of the dumbbell? (a) $2m\omega(R^2 + a^2)$ (b) $2m\omega(R^2 + 2a^2)$ (c) $2m\omega(2R^2 + a^2)$ (d) $3m\omega(2R^2 + a^2)$ (e) $3m\omega(R^2 + 4a^2)$.
5. (6 points) A pump raises water from a well of depth 20 m at a rate of 10 kg/s and discharges it at 6 m/s. What is the power of the motor? (a) 2180 W (b) 2980 W (c) 3140 W (d) 5000 W (e) 7900 W.

計算與簡答題 (70分)

1. (10 points) A cylinder with a piston contains 0. 2 kg of water at 100 °C. The water is converted to steam at 100 °C at a constant pressure of 1 atm. Calculate (a) the heat Q transferred to the water; (b) the work W done by the water when expanding against the piston at constant pressure; and (c) the change in internal energy ΔU of the water. The density of water is $\rho_w = 10^3$ kg/m^3 and that of steam is $\rho_s = 0.6$ kg/m^3. The latent heat of vaporization of water is $L_v = 2.26 \times 10^6$ J/kg.

2. (10 points) A 2-kg block is attached to a spring (with the spring constant of k = 200 N/m). It is held at an extension of 5 cm and then released at time $t = 0$. Find: (a) the displacement x of the block as a function of time; (b) the velocity v when x = +2.5 cm; (c) the acceleration a when x = +2.5 cm.

3. (a) (5 points) Design an electric dipole with a moment of $\vec{p} = q\vec{d}$ where q denotes the positive charge. Derive the force $\vec{F}_e$ and torque $\vec{\tau}_e$ experienced by this dipole placed in a uniform static electric field $\vec{E}$.
(b) (5 points) Design a magnetic dipole with a moment of $\vec{\mu} = I\vec{a}$ where I denotes the current. Derive the force $\vec{F}_m$ and torque $\vec{\tau}_m$ experienced by this dipole placed in a uniform static magnetic field $\vec{B}$.
(c) (10 points) Explain whether $\vec{F}_e$ and $\vec{F}_m$ are conservative or not.

4. Fig. 2 shows the experimental geometry for double-slit interference with a monochromatic light (top) and the interference pattern observed on the screen (bottom).

   (a) (8 points) The bright bands, formed by constructive interference, on both sides look dimmer than the one at the center. To make the brightness of these bands more even, should we increase or decrease the slit width? Why?

   (b) (5 points) If we maintain the slit width unchanged, can we fulfill the demand in (a) by changing the light wavelength? If so, should we increase or decrease the wavelength. Why?

   (c) (7 points) Focus two collimated laser beams of the same radius and two different wavelengths by the same lens. Will the beam of the shorter wavelength yield a smaller spot at its focus? Why?

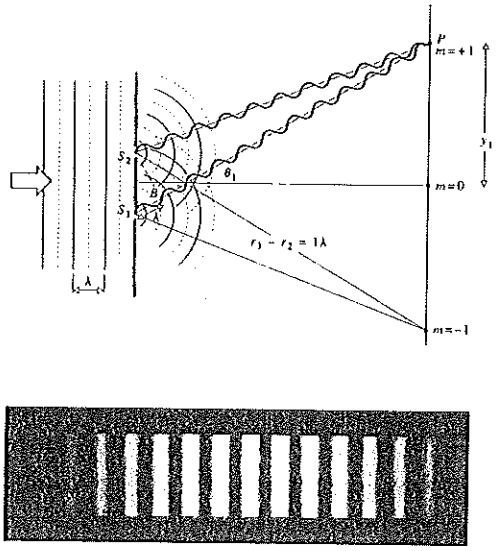

Fig. 2 The double-slit interference set-up (top) and result (bottom).

5. (10 points) By solving the Shrödinger equations for (a) a one dimensional potential well with an infinite depth and (b) a hydrogen atom, we can obtain the eigenfunctions for each case. Explain how many quantum numbers there are for each case.