CAP University Prize Examination
February 1988
14:00 - 17:00

Return to:

- Dr. R. G. Rystephanick
  Department of Physics & Astronomy
  University of Regina
  Regina, Saskatchewan. S4S 0A2

INSTRUCTIONS

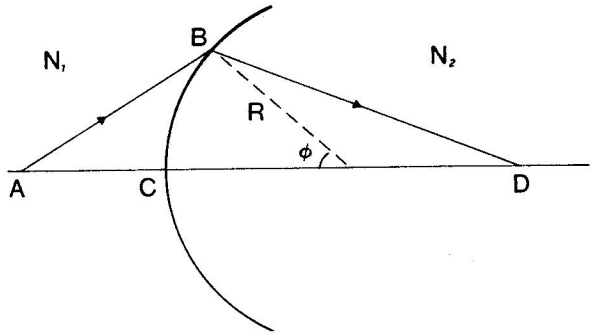
1. The use of calculators is allowed.
2. Do as many questions as you can in whole or in part.
3. Answer each question in a separate booklet, with the question number and your name on the outer page of each booklet.
4. All questions are of equal value, but not of equal difficulty.

4. (a) When an electromagnetic wave passes from one medium to another medium of different refractive index the speed of the wave changes. As a result, the product of the frequency ν and the wavelength λ also changes. Does ν change or does λ change or do they both change? Explain.

   (b) A spherical interface separates two transparent media whose indices of refraction are n_1 and n_2. Light emitted at A is incident on the interface at B. Find the distance CD in the above diagram using Fermat's principle given the following data:

$$n_1 = 1.0 \quad n_2 = 1.8 \quad AC = 2.0cm$$
$$AB = 3.5cm \quad R = 3.0cm.$$

   R is the radius of curvature of the interface.



5. Congratulations. You have been named editor of the Canadian Journal of Physics. You have been sent four manuscripts with the following results. In each case, you must inform the author if his article is acceptable or not, and explain clearly why.

   (a) In the region $0°C \leq T \leq 300°C$ and $0 \leq P \leq 50$ atm the equation of state of a homogeneous material is written:

$$V(T,P) = V(0,0)[1 + 1.0 \times 10^{-4}T - 2.0 \times 10^{-4}P + 1.0 \times 10^{-5}P^2].$$

   The author claims that this material is stable.

   (b) An inventor claims to have invented a heat engine using reservoirs at $400°C$ and at $25°C$ which is capable of producing 6×10^5 Joules of work with 4×10^5 Joules of heat rejected at $25°C$.

   (c) $C_v(T) = AT^{-\frac{1}{2}} + BT^3$ $(A > 0, B > 0,$ T in Kelvin) is presented as the specific heat of a non-magnetic solid for temperature below 2K.

   (d) In a process involving dissipative work it is not necessary to conserve the total entropy.

6. In 1987 materials were discovered which become superconducting at temperatures above that of the boiling point of nitrogen (77K). Previous to this discovery, it was necessary to refrigerate at liquid helium temperatures (4.2K) in order to have superconductivity.

   (a) Estimate the relative cost of regrigeration at liquid nitrogen versus liquid helium temperatures by assuming an ideal refrigerator with the high temperature reservoir at room temperature.

(a) Determine the angle at which the dish must be aimed above the local horizon in order to optimize the reception of the relayed television signal.

(b) Determine the highest northern latitude $\lambda_1{}^{max}$ which can be serviced by a geostationary satellite.

10. The Hamiltonian for a certain two-dimensional classical system is given by

$$H = \frac{1}{2m}(P_x{}^2 + P_y{}^2) + \frac{1}{2}mw^2(x^2 + y^2)$$

(a) Find the equations of motion for x and y.

(b) Show that the two quantities

$$\begin{aligned} L &= xP_y - yP_x \text{ and} \\ K &= \frac{1}{2m}P_xP_y + \frac{1}{2}mw^2xy \text{ are conserved.} \end{aligned}$$

(c) What is the physical significance of the conservation of L?

11. A few years ago it was found that a natural nuclear reactor operated in the past in a uranium ore body which had become saturated with water. Present day reactors using light water as a moderator require that the ratio of fissionable ^{235}U to unfissionable ^{238}U be 0.030 (3.0%) by weight. Natural uranium today has a ratio ^{235}U to ^{238}U of 0.0070 (0.70%) by weight. The half life of ^{235}U is 7.0×10^8 years which is shorter than the half life of ^{238}U which is 4.5×10^9 years. Since ^{235}U decays faster than ^{238}U, in the past the relative content of ^{235}U was higher. How many years ago was the ratio of ^{235}U to ^{238}U 3.0% by weight?

12. (a) A nucleus of mass M makes a transition from an excited state to the ground state by emission of a gamma ray. What is the difference between the excitation energy E and the gamma ray energy E_γ due to the fact that the nucleus recoils?

(b) If the above gamma ray is absorbed by a second nucleus of the same mass M, to what energy can it excite the second nucleus?

(c) Apply your results to the case of a ^{57}Fe nucleus which emits a 14.4 keV gamma ray. ($1\text{u} =\sim 940MeV/c^2$).