April 20, 2001
1:30 p.m. - 4: 30 p.m.

FINAL EXAMINATION

PAPER NO.: 483

DEPARTMENT & COURSE NO.: 16:107

TIME: 3 hours

EXAMINATION: Physics II: Waves & Modern Physics

EXAMINERS: R. C. Barber, S. A. Page, B. W. Southern

INSTRUCTIONS

This paper consists of two parts. Part A consists of 20 multiple choice questions each worth 2 marks. Part B consists of 2 long answer questions each worth 10 marks. Total 60 marks. Plan to spend about 2 hours on part A and 1 hour on part B of this exam.

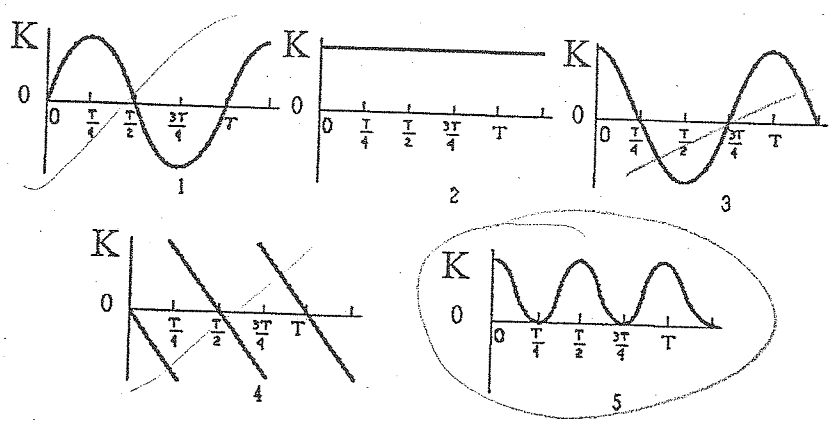
The answer "n.o.t." designates "None of these is correct", to be used if your answer does not agree with any of the given answers.

PART A – Multiple Choice

Answer **all twenty** multiple choice questions on the IBM sheet, with a pencil.
Each question is worth 2 marks.

A1. The kinetic energy of a body executing simple harmonic motion is plotted against time expressed in terms of the period T. At $t = 0$, the displacement is zero. Which of the graphs represents the kinetic energy under these conditions?

2



(a) 1 (b) 2 (c) 3 (d) 4 (e) 5

A2. A train traveling at 90 km/h is blowing its whistle at 440 Hz as it crosses a level crossing. You are waiting at the crossing and hear the pitch of the whistle change as the train passes you. The sound you hear changes from a frequency of 444.47 to a frequency of 407.94. (Take the speed of sound to be 340 m/s.)

1

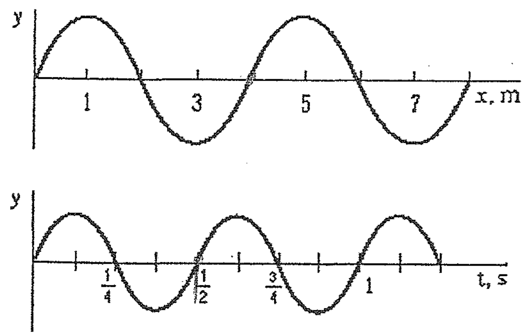
(a) 475 Hz; 410 Hz
(b) 410 Hz; 475 Hz
(c) 408 Hz; 472 Hz
(d) 472 Hz; 408 Hz
(e) 598 Hz; 348 Hz

A3. The air columns in two identical pipes vibrate at frequencies of 150 Hz. The percentage of change needed in the length of one of the pipes to produce 3 beats per second is

3

(a) 1% (b) 2 % (c) 3% (d) 4% (e) 5%

A4.



A wave is traveling with a speed v along the x axis in the positive direction. The upper graph shows the displacement y versus the distance x for a given instant of time. The lower graph shows the displacement y versus the time t for any given point x. From the information in the graphs, what is the wave speed v?

(a) 8.0 m/s (b) 4.0 m/s (c) 6.0 m/s (d) 2.0 m/s (e) n.o.t.

A5. A string whose length is 1.0 m is fixed at both ends and vibrates according to the equation

$$y(x,t) = 0.04 \sin \pi x \cos 2\pi t$$

where the units are SI. At $t = 3.0$ sec, the speed of a mass element located at $x = 0.50$ m is:

(a) 0 (b) 0.04 m/s (c) 0.25 m/s (d) 1.0 m/s (e) 2.0 m/s

A6. If the work function of thoriated tungsten is 4.00×10^{-19} J, the longest wavelength of light that will cause photoelectrons to be emitted is approximately

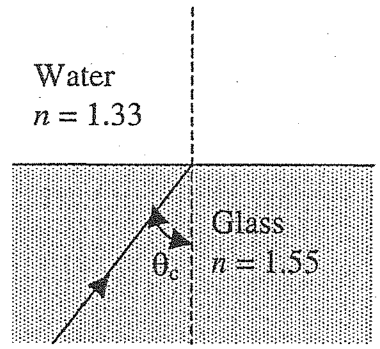
(a) 880 nm (b) 400 nm (c) 496 nm (d) 700 nm (e) 181 nm

A7. If a baseball, an electron, and a photon all have the same momentum, which has the longest wavelength?

(a) baseball
(b) electron
(c) photon
(d) All have the same wavelength.
(e) It depends on the energy of the photon.

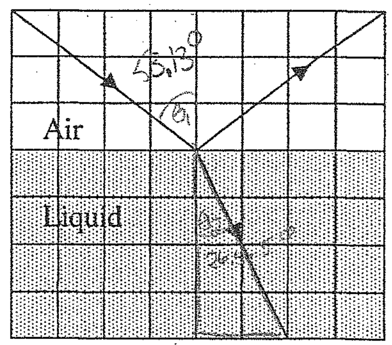
A8. A light ray traveling in glass strikes a glass-water surface. At angles greater than θ_c the light ray is totally internally reflected. The value of θ_c is

(a) 15°
(b) 31°
(c) 45°
(d) 23°
(e) 59°



A9. A ray of light is shown reflected and refracted at the surface of a liquid. From the diagram you can determine that the speed of light in this liquid is approximately (the refractive index of air is 1.0)

(a) 1.7×10^8 m/s
(b) 2.2×10^8 m/s
(c) 3.0×10^8 m/s
(d) 4.0×10^8 m/s
(e) 2.5×10^8 m/s



n=1.788

A10. A glass lens ($n = 1.65$) is coated with MgF_2 ($n = 1.38$) to reduce reflection. The minimum thickness of coating required to produce destructive interference in reflected light whose wavelength in air is 560 nm is

(a) 101 nm (b) 140 nm (c) 203 nm (d) 280 nm (e) 121 nm

A11. You illuminate two slits 0.50 mm apart with light of wavelength 555 nm and observe interference fringes on a screen 6.0 m away. What is the spacing between adjacent fringes on the screen?

(a) 4.5 mm (b) 3.3 mm (c) 6.7 mm (d) 10 mm (e) 5.0 mm

A12. Photons of wavelength 0.00150 nm undergo Compton collisions with free electrons. What is the energy of the scattered photons whose angle of scattering is 45°?

(a) 8.29×10^5 eV
(b) 5.61×10^5 eV
(c) 1.75×10^6 eV
(d) 1.12×10^6 eV
(e) 1.33×10^5 eV

A13. A classical point particle moves back and forth with constant speed between two walls at $x = 0$ and $x = 4$ cm. What is the probability of finding the particle between $x = 3$ and $x = 3.4$ cm?

~~(a) 1~~ ~~(b) 0~~ (c) 0.1 ~~(d) 4~~ (e) 0.2

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A14. The graph that shows the wave function of the fourth state for a particle in a finite square well is:

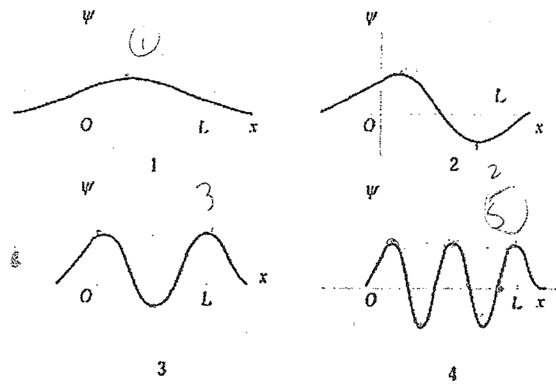
(a) 1

(b) 2

(c) 3

(d) 4

(e) n.o.t.



A15. An electron confined to a one-dimensional box of length $L = 0.2$ nm makes a transition from state $n = 4$ to state $n = 3$. The wavelength of the photon emitted is:

(a) 18.8 nm (b) 17.2 nm (c) 14.6 nm (d) 12.5 nm (e) 10.8 nm

A16. For the principal quantum number $n = 4$, the number of distinct combinations of the orbital and magnetic quantum numbers (ℓ, m) are:

(a) 4 (b) 3 (c) 7 (d) 16 (e) 6

A17. A pion lives 26 ns in its rest frame, but an observer in a laboratory in which the particle moves at a speed of 2.7×10^8 m/s says the particle lived:

(a) 11 ns (b) 15 ns (c) 43 ns (d) 60 ns (e) 79 ns

Relativity

A18. A standard Canadian football field is 100 m long and 60 m wide. A UFO streaks from one end of the field to the other at a speed of $0.6c$ relative to the field. An observer in the UFO measures the length of the field to be:

(a) 60 m (b) 80 m (c) 100 m (d) 125 m (e) 167 m

A19. Two electrons are ejected in opposite directions from atoms in a sample of radioactive material. Each electron has a speed, as measured by a laboratory observer, of $0.60c$. What is the speed of one electron as seen from the other electron?

(a) $0.36c$ (b) $0.88c$ (c) $1.87c$ (d) zero (e) $1.24c$

A20. An electron with a rest mass of 511 keV travels at speed $v = 0.500c$. What is its kinetic energy?

(a) 590 keV (b) 79 keV (c) 511 keV (d) 430 keV (e) 220 keV

PART B – Long Answer Questions

Answer **both** long answer questions in the exam booklet. Only the **lined pages** will be marked.
You must **show your work** in order to receive full marks.

B1. (a) Find the speed of waves on a violin string of mass 800 mg and length 22.0 cm, if the fundamental frequency of the string is 920 Hz

(b) What is the wavelength of the *sound* waves emitted by the string when it vibrates at the fundamental frequency? Take the speed of sound in air to be 340 m/s.

(c) Verify that $y(x,t) = 3.0 \sin(\pi x/55) \cos(7360 \pi t)$ is a solution of the wave equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$ for waves on the string of part (a), where x,y are in mm and t is in sec.

Show that the speed v from the wave equation is the same as that deduced from part (a).

(d) Which harmonic of the violin string does the function y(x,t) from part (c) correspond to, and what is its wavelength?

(e) Assuming spherical waves traveling outward from the violin, calculate the acoustic power generated by the violin, when the sound level at a distance of 20 m is 60 dB.

B2. (a) Briefly state the assumption in Bohr's model of the hydrogen atom that leads directly to quantized energy states. Is this assumption consistent with the theory of quantum mechanics? Why or why not?

(b) The energy states of a hydrogen atom are given by $E_n = -13.6/n^2\ eV$ as predicted by Bohr and confirmed by experiment. However, a full quantum description of the atom in 3 dimensions requires 3 quantum numbers (n, ℓ, m) to specify the wave function. What is the significance of the additional quantum numbers (ℓ, m) that are missing from Bohr's model?

(c) Use the formula for E_n from part (b) to construct an energy level diagram for hydrogen. Calculate the energies of states with $n = 1, 2, 3, 4$ and label these on a sketch of the energy levels that is (roughly) to scale.
If $E \geq 0$, what happens to the electron? Does it remain part of the atom? Is there any restriction at all on the possible values of E in this case?

(d) A gas discharge tube is filled with hydrogen, excited by a high voltage, and observed with a grating spectroscope as in experiment 5. At what angle (measured normal to the diffraction grating) will the first order line from the $n = 3 \rightarrow n = 2$ Balmer series transition be observed if the spectroscope has a grating resolution of 4000 lines per cm? How many orders of this line can be observed in principle if the spectroscope operates for angles between 0 and 90°?