PHYSICS B
SECTION II
Time—90 minutes
7 Questions

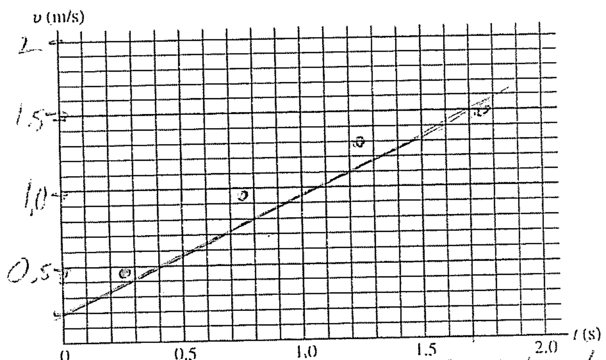
Directions: Answer all seven questions, which are weighted according to the points indicated. The suggested times are about 11 minutes for answering each of Questions 1 and 4-7 and about 17 minutes for answering each of Questions 2-3. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.

1. (10 points)
A toy cart of mass 0.50 kg moves across a horizontal table with constant acceleration. Its position x is measured for different times t, and the data are recorded in the table below.

Time t (s)	Position x (m)	Average Speed $\bar{v}$ (m/s)
0.00	0.20	
0.50	0.42	0.44
1.00	0.90	0.96
1.50	1.55	1.3
2.00	2.30	1.5

(a) Calculate the average speed of the cart during each 0.50 s time interval and fill in the blank spaces in the table above.

(b) On the axes below, label the vertical axis with appropriate numbers, plot the data, and draw a best-fit line to show a graph of velocity versus time for the cart.



(c) Using the best-fit line, calculate the acceleration of the cart.

(d) The cart continues with the constant acceleration calculated in (c) until it reaches the edge of the table at $t = 3.0$ s. It then falls to the floor, which is 1.2 m below the tabletop. Calculate the kinetic energy of the cart just before hitting the floor.

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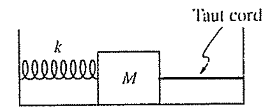

2. (15 points)
One end of a spring of spring constant k is attached to a wall, and the other end is attached to a block of mass M, as shown above. The block is pulled to the right, stretching the spring from its equilibrium position, and is then held in place by a taut cord, the other end of which is attached to the opposite wall. The spring and the cord have negligible mass, and the tension in the cord is F_T. Friction between the block and the surface is negligible. Express all algebraic answers in terms of M, k, F_T, and fundamental constants.

(a) On the dot below that represents the block, draw and label a free-body diagram for the block.

(b) Calculate the distance that the spring has been stretched from its equilibrium position.

The cord suddenly breaks so that the block initially moves to the left and then oscillates back and forth.

(c) Calculate the speed of the block when it has moved half the distance from its release point to its equilibrium position.

(d) Calculate the time after the cord breaks until the block first reaches its position furthest to the left.

(e) Suppose instead that friction is not negligible and that the coefficient of kinetic friction between the block and the surface is μ_k. After the cord breaks, the block again initially moves to the left. Calculate the initial acceleration of the block just after the cord breaks.

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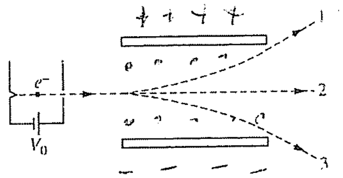
a charge particle in mag field experiences a force F_B ⊥ to motion giving rise to circular motion $F_B = F_c$

$QVB = \frac{mv^2}{r}$



3. (15 points)
Electrons are accelerated from rest through a potential difference V_0 and then pass through a region between two parallel metal plates, as shown above. The region between the plates can contain a uniform electric field **E** and a uniform magnetic field **B**. With only the electric field present, the electrons follow path 1. With only the magnetic field present, the electrons follow path 3. As drawn, the curved paths between the plates show the correct direction of deflection for each field, but not necessarily the correct path shape. With both fields present, the electrons pass undeflected along the straight path 2.

(a)
i. Which of the following describes the shape of the portion of path 1 between the plates?

____Circular ✓ Parabolic ____Hyperbolic ____Exponential

Justify your answer. *vertical displace. $d_y = V_{0y}t + \frac{1}{2}a_y t^2$*

$V_{0y} = 0$, $a_y = \frac{F_E}{m} = \frac{QE}{m}$, $d_y = \frac{1}{2}\frac{QE}{m}t^2$ exponential w/ t. $d_x = V_{0x}t$

ii. What is the direction of the electric field?

____To the left ____To the top of the page ____Into the page
____To the right X To the bottom of the page ____Out of the page

Justify your answer. *$\vec{E}$ is defined as direction a +ve charge will move, if e^- deflects up + deflects down ... changes x & y*

(b)
i. Which of the following describes the shape of the portion of path 3 between the plates?

✓ Circular ____Parabolic ____Hyperbolic ____Exponential

Justify your answer.

ii. What is the direction of the magnetic field?

____To the left ____To the top of the page ____Into the page
____To the right ____To the bottom of the page X Out of the page

Justify your answer. *according to Right hand rule, current flows oppositely to e^-, force vertically down gives B: out of page*

Between the plates the magnitude of the electric field is 3.4×10^4 V/m, and the magnitude of the magnetic field is 2.0×10^{-3} T.

(c) Calculate the speed of the electrons given that they are undeflected when both fields are present.

$F_B = F_E$, $QVB = QE$, $v = \frac{E}{B} = 1.7 \times 10^7 \frac{m}{s}$

(d) Calculate the potential difference V_0 required to accelerate the electrons to the speed determined in part (c).

$qV = \frac{1}{2}mv_f^2$, $V = \frac{\frac{1}{2}mv_f^2}{q} = 823$ V

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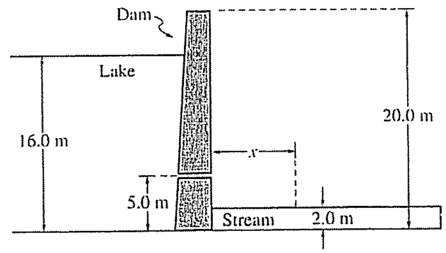
(a) $P_{TOT} = P_{air} + P_{H_2O}$
$= 101.3$ kPa $+ \rho g h$
$= 101.3 + (1000)(9.8)16$
$= (101.3 + 156.8)$ kPa
$= 2.58 \times 10^5$ Pa

(b) $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$
$(P_1 - P_2) + \rho g h_1 - \rho g h_2 = \frac{1}{2}\rho v_2^2$
$9800(16-5) = \frac{1}{2}\,v_2^2$
$\sqrt{\frac{9.8 \times 11}{(.5)}} = V = 14.7 \frac{m}{s}$



4. (10 points)
A 20 m high dam is used to create a large lake. The lake is filled to a depth of 16 m as shown above. The density of water is 1000 kg/m^3.

(a) Calculate the absolute pressure at the bottom of the lake next to the dam.

A release valve is opened 5.0 m above the base of the dam, and water exits horizontally from the valve.

(b) Use Bernoulli's equation to calculate the initial speed of the water as it exits the valve.

(c) The stream below the surface of the dam is 2.0 m deep. Assuming that air resistance is negligible, calculate the horizontal distance x from the dam at which the water exiting the valve strikes the surface of the stream.

(d) Suppose that the atmospheric pressure in the vicinity of the dam increased. How would this affect the initial speed of the water as it exits the valve?

____It would increase. ____It would decrease. ✓ It would remain the same.

Justify your answer. *this is b/c the air pressure above the lake ≈ air pressure at the valve*

c) $d_y = \frac{1}{2}a_y t^2$, $\sqrt{\frac{2d_y}{a_y}} = t = \sqrt{\frac{2 \times 3}{9.8}} = .78$ s
$d_x = V_{0x}t = 14.7t = 11.5$ m

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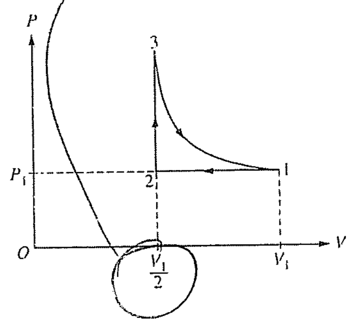
ai $P_1V_1 = nRT_1$, $T_1 = \frac{P_1V_1}{nR}$

ii $T_3 = T_1$, $\frac{P_3V_3}{nR} = \frac{P_1V_1}{nR}$, $P_3 = \frac{P_1V_1}{V_3}$, $V_3 = V_2 = \frac{1}{2}V_1$, $P_3 = \frac{P_1V_1}{\frac{1}{2}V_1}$, $P_3 = 2P_1$



5. (10 points)
A sample of n moles of an ideal gas, originally at a pressure P_1 and volume V_1, undergoes the three processes shown on the PV diagram above:

Process 1 → 2: The volume is halved while the pressure remains constant.
Process 2 → 3: The pressure is increased while the volume remains constant until the temperature reaches its original value.
Process 3 → 1: The volume is increased while the temperature remains constant until the volume reaches its original value.

(a) Determine expressions for each of the following in terms of P_1, V_1, n, and fundamental constants. [ON] = +

i. The temperature of the gas in state 1

ii. The pressure of the gas in state 3

iii. The total work done on the gas during processes 1 → 2 and 2 → 3

$W = \text{area} = P\Delta V = P_1(V_1 - \frac{1}{2}V_1) = \frac{P_1V_1}{2}$; area = 0 = W ; Total = $\frac{P_1V_1}{2}$

(b) Indicate below whether heat is added to the gas, removed from the gas, or neither during the process 2 → 3.

✓ Added to ___ Removed from ___ Neither added to nor removed from

Justify your answer.

Since $P_3 > P_2 = P_1$, $T_3 > T_2$ meaning ΔU has increased. Since $\Delta U = Q + W$ & $W = 0$, Q must be + & ∴ added

(c) Indicate below whether heat is added to the gas, removed from the gas, or neither during the process 3 → 1.

___ Added to ___ Removed from ___ Neither added to nor removed from

Justify your answer.

$\Delta U = 0$ (isothermic) $= Q + W$ (area); gas is expanding ∴ doing work ∴ − so internal energy drops; must be positive to offset loss of internal energy to set $\Delta U = 0$

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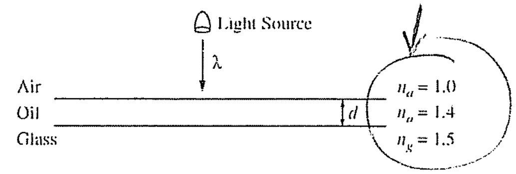
ai const $\frac{c}{\lambda} = f = 5.77 \times 10^{14}$ Hz

ii freq. is const ∴ 5.77×10^{14} Hz

iii $v = \frac{c}{n} = 2.14 \times 10^8$ m/s ; $\frac{c}{f} = \lambda_0 = 3.71 \times 10^{-7}$ m, 371 nm

b) flip, flip (IN PHASE) $2d = m\lambda$, $d = \frac{1\lambda}{2} = 1.85 \times 10^{-7}$ m

TRICKY



6. (10 points)
In a classroom demonstration of thin films, your physics teacher takes a glass plate and places a thin layer of transparent oil on top of it. The oil film is then illuminated by shining a narrow beam of white light perpendicularly onto the oil's surface, as shown above. The indices of refraction of air, the oil, and the glass plate are given in the diagram. Standing near the light source, you observe that the film appears green. This corresponds to a wavelength of 520 nm.

(a) Determine each of the following for the green light.

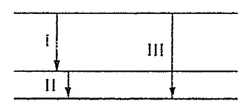
i. The frequency of the light in air

ii. The frequency of the light in the oil film

iii. The wavelength of the light in the oil film

(b) Calculate the minimum thickness of the oil film (other than zero) such that the observed green light is the most intense. m = 1

(c) As your teacher changes the angle of the light source, the light you observe from the film changes color. Give an explanation for this phenomenon. As θ increases (from normal) the extra distance needed to travel surface increases (d) as such constructive interf. occurs at longer λ longer



7. (10 points)
The diagram above shows a portion of the energy-level diagram for a particular atom. When the atom undergoes transition I, the wavelength of the emitted radiation is 400 nm, and when it undergoes transition II, the wavelength is 700 nm.

(a) Calculate the wavelength of the emitted radiation when the atom undergoes transition III.

A photon emitted during transition III is then incident on a metal surface of work function 2.1 eV.

(b) Calculate the maximum kinetic energy of the electron ejected from the metal by the photon.

(c) Calculate the de Broglie wavelength of the ejected electron.

$E_3 = E_1 + E_2 = hf_1 + hf_2 = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = hc\left(\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right) = 7.84 \times 10^{-19}$ J ⟶ 4.88 eV

$\lambda_3 = \frac{hc}{E}$, $\lambda_3 = 2.55 \times 10^{-7}$ m

$E_k + W_0 = hf$; $E_k = 4.88 - 2.1 = 2.78$ eV

$p = \frac{h}{\lambda}$, $\lambda = \frac{h}{mv}$, $\frac{1}{2}mv^2$ continue

STOP

END OF EXAM