

# UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

## Physics 115.3 General Physics

### FINAL EXAMINATION

December 17, 2008

Time: 3 hours

NAME: MASTER STUDENT NO.: \_\_\_\_\_  
(Last) Please Print (Given)

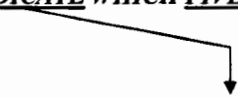
LECTURE SECTION (please check):

- 01 B. Zulkoskey
- 02 Dr. C. Mitchell
- 03 Dr. A. Robinson
- C15 F. Dean

### INSTRUCTIONS:

1. You should have a test paper, a formula sheet, and an OMR sheet. The test paper consists of 10 pages. **It is the responsibility of the student to check that the test paper is complete.**
2. Enter your name and STUDENT NUMBER on the OMR sheet.
3. The test paper, the formula sheet and the OMR sheet must all be submitted.
4. None of the test materials will be returned.
5. This is a closed book examination.
6. Only Hewlett-Packard HP 30S or Texas Instruments TI-30X series calculators may be used.

***ONLY THE FIVE PART B QUESTIONS THAT YOU INDICATE WILL BE MARKED***  
***PLEASE INDICATE WHICH FIVE PART B QUESTIONS ARE TO BE MARKED***



| QUESTION NUMBER | TO BE MARKED             | MAXIMUM MARKS | MARKS OBTAINED |
|-----------------|--------------------------|---------------|----------------|
| A1-25           | -                        | 25            |                |
| B1              | <input type="checkbox"/> | 10            |                |
| B2              | <input type="checkbox"/> | 10            |                |
| B3              | <input type="checkbox"/> | 10            |                |
| B4              | <input type="checkbox"/> | 10            |                |
| B5              | <input type="checkbox"/> | 10            |                |
| B6              | <input type="checkbox"/> | 10            |                |
| TOTAL           |                          | 75            |                |

continued on page 2...

**PART A**

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

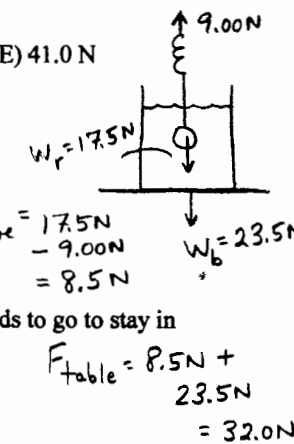
- A1. If a distance is expressed as 35.00 m then the number of significant figures is  
 (A) 1 (B) 2 (C) 3 (D) 4 (E) ambiguous

- A2. Which one of the following expressions gives the correct dimensions of energy?  
 (A)  $[M][L]^{-1}$  (B)  $[M][L][T]^{-2}$  (C)  $[M][L]^{-1}[T]^{-1}$   
 (D)  $[M][L]^2[T]^{-2}$  (E)  $[M][L]^{-3}$   $N \cdot m = kg \cdot m^2/s^2 \equiv [M][L]^2[T]^{-2}$

- A3. An aircraft has an initial mass of  $m_0$  and an initial acceleration of  $a_0$ . After flying for 2 hours, the mass of the aircraft has decreased by 11%, due to the burning of the fuel. If the propulsive force provided by the engines is constant, what is the expression for the new acceleration,  $a_2$ , at this time? You may assume that the aircraft is in level flight at all times and that air resistance is negligible.  
 $F = ma = \text{constant}$   $m_0 a_0 = m_2 a_2 \Rightarrow a_2 = \frac{m_0 a_0}{m_2} = \frac{m_0 a_0}{0.89 m_0}$   
 (A)  $a_2 = 0.89 a_0$  (B)  $a_2 = 1.89 a_0$  (C)  $a_2 = \frac{a_0}{0.89}$  (D)  $a_2 = \frac{a_0}{1.11}$  (E)  $a_2 = 1 + 0.11 a_0$

- A4. A beaker of water is sitting on a table. A rock of weight 17.5 N is immersed in the water while suspended from a spring scale that is reading 9.00 N. The rock is at rest. The weight of the beaker and water together is 23.5 N. What is the magnitude of the normal force of the table on the beaker?  
 (A) 17.5 N (B) 23.5 N (C) 28.5 N (D) 32.0 N (E) 41.0 N

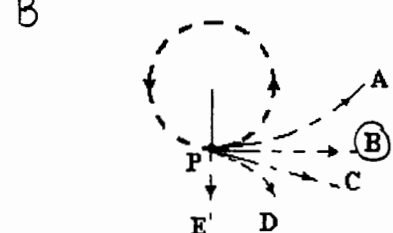
- A5. A ball is thrown straight up into the air. At the top of its trajectory  
 (A) the velocity is nonzero and the acceleration is zero.  
 (B) the velocity is zero and the acceleration is zero.  
 (C) the velocity and the acceleration are in opposite directions.  
 (D) the velocity is zero and the acceleration is nonzero.  
 (E) the velocity is nonzero and the acceleration is nonzero.



- A6. A rollercoaster is travelling around a vertical circular loop, faster than it needs to go to stay in contact with the track at the top. At the top of the loop  
 (A) the net force on the rollercoaster is zero.  
 (B) the normal force and the gravitational force are in opposite directions.  
 (C) the normal force and the gravitational force are in the same direction.  
 (D) the normal force is zero.  
 (E) the normal force is directed up.

- A7. A student walks down the hill from the university to the South Saskatchewan River. During this walk, the work done by gravity on the student is  
 (A) positive and depends on the path taken.  
 (B) negative and depends on the path taken.  
 (C) positive and independent of the path taken.  
 (D) negative and independent of the path taken.  
 (E) zero.

- A8. Consider a ball tied to a string and being whirled in a horizontal circular path. In the following top-view diagram, which path (A, B, C, D, or E) best represents the one followed by the ball if the string breaks at point P?



A9. If the kinetic energy of an object doubles, the momentum of the object

$$K = \frac{1}{2}mv^2 \quad \left. \begin{array}{l} K = \frac{1}{2}mv^2 \\ p = mv \end{array} \right\} K = \frac{1}{2} \frac{p^2}{m}$$

$$p = \sqrt{2mK}$$

- (A) is 0.500 times larger. (B) is 0.707 times larger. (C) remains the same.  
 (D) is 1.41 times larger. (E) also doubles.

A10. The electrostatic force between two charged particles is  $F$ . If the distance between the two particles is reduced by a factor of two and the charge on one of the particles is doubled then the electrostatic force will

- (A) increase by a factor of 4. (B) increase by a factor of 8. (C) remain the same. (D) decrease by a factor of 4. (E) decrease by a factor of 2.

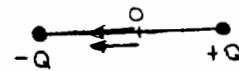
$$F = \frac{k|q_1||q_2|}{r^2}$$

A11. A proton is moving in a uniform electric field. The acceleration of the proton

- (A) must be in the direction of the velocity of the proton.  
 (B) must be opposite to the direction of the velocity of the proton.  
 (C) must be perpendicular to the direction of the velocity of the proton.  
 (D) is in the direction of the electric field.  
 (E) is opposite to the direction of the electric field.

A12. Consider two point charges located on the  $x$ -axis. A charge  $-Q$  is located at  $x = -1.0$  cm and a charge  $+Q$  is located at  $x = +1.0$  cm. The net electric field at the origin, due to these two charges, is

- (A) zero. (B) in the  $-x$  direction. (C) in the  $+x$  direction.  
 (D) in the  $-y$  direction. (E) in the  $+y$  direction.



A13. Which one of the following statements regarding electric current is FALSE?

- (A) The current is the rate of flow of electric charge.  $\top$   
 (B) A potential difference must exist in order for a current to flow through a wire.  $\top$   
 (C) The charge carriers in metals are protons. **F**  
 (D) The conventional current direction assumes that the charge carriers are positive.  $\top$   
 (E) The SI unit of current is the Ampère.  $\top$

A14. The resistivity of a material is  $\rho_{20}$  at  $20^\circ\text{C}$ . It has a resistivity  $\rho_T$  at an unknown temperature  $T^\circ\text{C}$ . Which equation gives the coefficient of resistivity  $\alpha$  for the material?

- (A)  $\alpha = \frac{\rho_T - \rho_{20}}{(T - 20)}$  (B)  $\alpha = \frac{\rho_T - \rho_{20}}{\rho_{20}(T - 20)}$  (C)  $\alpha = \frac{\rho_T - \rho_{20}}{T} - 20$   
 (D)  $\alpha = \frac{(T - 20)}{\rho_T - \rho_{20}}$  (E)  $\alpha = \frac{\rho_T - \rho_{20}}{20 - T}$

$$\rho_T = \rho_{20} [1 + \alpha(T - 20)]$$

$$\frac{\rho_T - \rho_{20}}{\rho_{20}(T - 20)} = \alpha$$

A15. Three resistors are connected in parallel across an ideal voltage source. Two of the resistors have values of  $4.0 \Omega$  and the third is  $2.0 \Omega$ . Which one of the following statements is FALSE?

- (A) The potential difference across each resistor is the same.  $\top$   
 (B) More current will flow through the  $2.0 \Omega$  resistor than through either of the  $4.0 \Omega$  resistors.  $\top$   
 (C) The same current will flow through the two  $4.0 \Omega$  resistors.  $\top$   
 (D) The equivalent resistance is greater than  $2.0 \Omega$ , but less than  $4.0 \Omega$  **F**  
 (E) The power dissipated in the  $2.0 \Omega$  resistor is equal to the total power dissipated in both of the  $4.0 \Omega$  resistors  $\top$

A16. A piece of conducting wire has a resistance  $R$ . Another piece of wire of the same material is twice as long and has twice the diameter. The resistance of the second piece of wire is

- (A)  $\frac{1}{2}R$  (B)  $2R$  (C)  $4R$  (D)  $\frac{1}{4}R$  (E)  $R$

$$R_1 = \frac{\rho L_1}{A_1}$$

A17. You are standing at a distance  $r$  from a power line carrying  $8.00 \times 10^2$  A of current. If you double your distance from the power line, the magnitude of the magnetic field that you feel changes as follows:

- (A) increases by a factor of 2 (B) decreases by a factor of 2 (C) increases by a factor of 4 (D) decreases by a factor of 4 (E) remains the same

$$R_2 = \frac{\rho(2L_1)}{4A_1}$$

$$R_2 = \frac{1}{2}R_1$$

$$B = \frac{\mu_0 I}{2\pi r}$$

A18. A charged particle is moving perpendicularly to a uniform magnetic field. Which one of the following statements is **FALSE**?

- C (A) There is a nonzero magnetic force on the charged particle. T  
 (B) The magnetic force vector is perpendicular to the magnetic field vector and to the particle's velocity vector. T  
 (C) The magnetic force changes the speed of the particle. F  
 (D) The magnetic force causes the particle to move on a circular path. T  
 (E) The particle accelerates in the magnetic field. T

A19. Photons of frequency  $5.13 \times 10^{15}$  Hz are incident on a copper surface (work function of 4.70 eV). What is the range of kinetic energies of the photoelectrons emitted?

- A (A) 0 to 16.5 eV (B) 0 to 20.5 eV (C) 0 to 50.0 eV (D) 0 to 5.40 eV (E) No photoelectrons are emitted.  $K_{max} = hf - \phi$

A20. Which one of the following statements related to blackbody radiation is **FALSE**?

- B (A) All objects whose temperatures are above 0 K radiate electromagnetic waves. T  
 (B) For an object at a constant temperature, the graph of electromagnetic wave intensity versus wavelength is flat, i.e. there is no dependence of the intensity of emitted electromagnetic waves on wavelength. F is independent of wavelength.  
 (C) A perfect blackbody at a constant temperature absorbs and re-emits all of the electromagnetic radiation that falls on it. T  
 (D) Hotter stars appear to be blue. T  
 (E) Cooler stars appear to be red. T

A21. An X-ray tube produces X-rays of minimum wavelength 12 pm. The potential difference across the X-ray tube is increased by 25%. The minimum wavelength X-rays produced by the tube is now

- A (A) 9.6 pm (B) 15 pm (C) 8.8 pm (D) 11 pm (E) 42 pm  $hf_{max} = \frac{hc}{\lambda_{min}} = K = eV$   
 change options  $\lambda_{min} = \frac{hc}{eV}$

A22. Which one of the following statements related to Compton scattering is **FALSE**?

- C (A) Compton scattering involves the collision of a photon and an electron. T  
 (B) Energy and momentum are conserved. T  
 (C) The energy of the photon does not change. F  
 (D) The momentum of the photon changes. T  
 (E) The 'Compton shift' is the change in the photon's wavelength. T  $\lambda_{min_2} = \frac{\lambda_{min_1}}{1.25}$   
 $\lambda_{min_2} = \frac{20 \text{ pm}}{1.25}$   
 $\lambda_{min_2} = 16 \text{ pm}$

A23. Calculate the wavelength of the photon emitted when an electron makes a transition from the first excited state of hydrogen to the ground state.

- D (A) 218.4 nm (B) 206.5 nm (C) 155.7 nm (D) 121.5 nm (E) 114.6 nm  $\frac{1}{\lambda} = R \left( \frac{1}{1} - \frac{1}{4} \right)$

A24. In the Bohr model of the atom, the ratio of the radii of the  $(n+1)^{th}$  orbit and the  $n^{th}$  orbit is given by which one of the following equations?

- D (A)  $\frac{r_{n+1}}{r_n} = \frac{n+1}{n}$  (B)  $\frac{r_{n+1}}{r_n} = \frac{n+1}{n^2}$  (C)  $\frac{r_{n+1}}{r_n} = \frac{n^2+1}{n^2}$  (D)  $\frac{r_{n+1}}{r_n} = \frac{n^2+2n+1}{n^2}$  (E)  $\frac{r_{n+1}}{r_n} = \frac{n^2}{(n+1)^2}$   $r \propto n^2$   
 $\frac{r_{n+1}}{r_n} = \frac{(n+1)^2}{n^2} = \frac{n^2+2n+1}{n^2}$

A25. A laser has an output power of  $P$  watts. The wavelength of the photons produced is  $\lambda$  metres. Which one of the following expressions is correct for the number of photons produced per second,  $N$ ?

- B (A)  $N = Phc\lambda$  (B)  $N = \frac{P\lambda}{hc}$  (C)  $N = \frac{hc}{P\lambda}$  (D)  $N = \frac{P\lambda h}{c}$  (E)  $N = \frac{\lambda}{Phc}$

$$P = \frac{E}{t} = N \cdot E_{\text{photon}} = N \frac{hc}{\lambda} \Rightarrow N = \frac{P\lambda}{hc}$$

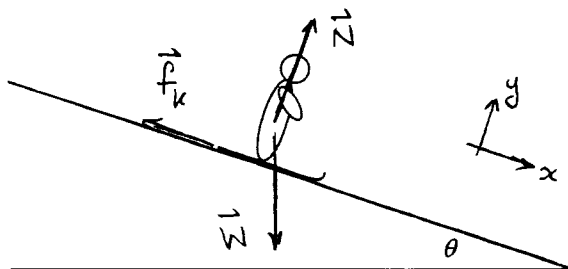
**PART B**

ANSWER FIVE PART B QUESTIONS AND INDICATE YOUR CHOICES ON THE COVER PAGE.

IN EACH OF THE PART B QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED. THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN. SHOW AND EXPLAIN YOUR WORK – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY. EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED. USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

B1. A skier is sliding down a hill at a constant velocity. The hill makes an angle of  $\theta$  with the horizontal.

(a) Using the diagram below, draw the forces acting on the skier. Also show your choice of coordinate system.



(b) Derive an expression for the coefficient of kinetic friction between the skis and the hill by resolving the forces into components. You may ignore any effects due to air resistance.

constant velocity  $\Rightarrow \Sigma \vec{F} = 0 \Rightarrow \Sigma F_x = 0$  and  $\Sigma F_y = 0$

|                                    |                          |                       |
|------------------------------------|--------------------------|-----------------------|
| $\Sigma F_x = 0$                   | $\Sigma F_y = 0$         | $\mu_k = \tan \theta$ |
| $W_x - f_k = 0$                    | $N - W_y = 0$            |                       |
| $W \sin \theta - \mu_k N = 0$      | $N - W \cos \theta = 0$  |                       |
| $mg \sin \theta = \mu_k N$         | $N - mg \cos \theta = 0$ |                       |
| $\mu_k = \frac{mg \sin \theta}{N}$ | $N = mg \cos \theta$     |                       |

so  $\mu_k = \frac{mg \sin \theta}{mg \cos \theta} = \frac{\sin \theta}{\cos \theta} = \tan \theta$

(c) Using your result from (b), calculate the coefficient of kinetic friction if the hill is at an angle of  $11.2^\circ$  with the horizontal.

$\mu_k = \tan(11.2^\circ) = 0.198$   $0.198$

(d) The skier now goes to a different hill that is at an angle of  $16.2^\circ$ . Assuming that the coefficient of kinetic friction is the same as for the first hill, calculate the acceleration of the skier down the second hill. If you did not obtain an answer for (c), use a value of 0.200 for the coefficient of kinetic friction.

$\Sigma F_x = ma$  and  $\Sigma F_y = 0$

$W_x - f_k = ma$   $0.871 \text{ m/s}^2$

$mg \sin \theta - \mu_k N = ma$  and  $N = mg \cos \theta$  from (b)

$mg \sin \theta - \mu_k mg \cos \theta = ma$

$a = g \sin \theta - \mu_k g \cos \theta = g (\sin \theta - \mu_k \cos \theta)$

$a = 9.80 \text{ m/s}^2 (\sin(16.2^\circ) - (0.198) \cos(16.2^\circ))$  continued on page 6...

$a = 0.871 \text{ m/s}^2$

**B2.** Victoria Falls in Africa are by some measures the largest waterfall in the world. They have a height of 108 m, and a width of 1.71 km.

- (a) Calculate the change in gravitational potential energy of 1.00 kg of water as it falls from the top to the bottom of Victoria Falls.

$$\Delta U = mg\Delta y$$

$$\boxed{-1.06 \times 10^3 \text{ J}}$$

$$\Delta U = (1.00 \text{ kg})(9.80 \text{ m/s}^2)(-108 \text{ m})$$

$$\Delta U = -1.06 \times 10^3 \text{ J}$$

- (b) What is the magnitude of the velocity of the 1.00 kg packet of water when it hits the bottom of the falls? Assume that the water is moving so slowly before it goes over the falls, that you can set  $v_i = 0$ . Ignore any effects due to air resistance.

$$W_{nc} = 0 \text{ so } K + U \text{ is conserved.}$$

$$\boxed{46.0 \text{ m/s}}$$

$$K_i + U_i = K_f + U_f$$

$$0 + U_i = K_f + U_f \Rightarrow K_f = U_i - U_f = -\Delta U$$

$$\frac{1}{2}mv_f^2 = -mg\Delta y$$

$$v_f = \sqrt{-2g\Delta y} = \sqrt{-2(9.80 \text{ m/s}^2)(-108 \text{ m})}$$

$$v_f = 46.0 \text{ m/s}$$

- (c) At what rate is gravitational potential energy lost by the water flowing over Victoria Falls, when the flow rate is a maximum? A maximum flow rate of  $6.00 \times 10^6 \text{ kg/s}$  has been recorded.

$$\frac{\Delta U}{\Delta t} = \frac{\Delta U}{\text{kg}} \cdot \text{flow rate (in kg/s)}$$

$$\boxed{-6.36 \times 10^9 \text{ W}}$$

$$\begin{aligned} \frac{\Delta U}{\Delta t} &= (-1.06 \times 10^3 \text{ J/kg})(6.00 \times 10^6 \text{ kg/s}) = -6.36 \times 10^9 \text{ J/s} \\ &= -6.36 \times 10^9 \text{ W} \end{aligned}$$

- (d) If Victoria Falls were used to provide hydroelectric power, and 10% of its power could be converted into electrical power, how many households would the electricity supply, assuming 1.00 kW per household?

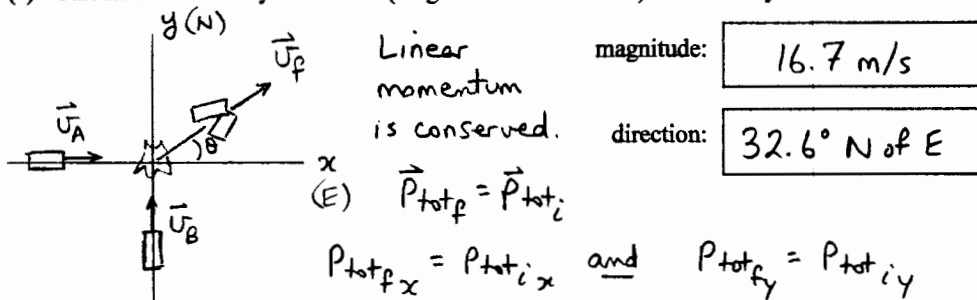
$$\text{Useful power} = 10\% (6.36 \times 10^9 \text{ W})$$

$$= 6.36 \times 10^8 \text{ W}$$

$$\boxed{6.36 \times 10^5}$$

$$\# \text{ households} = \frac{6.36 \times 10^8 \text{ W}}{1.00 \times 10^3 \text{ W/household}} = 6.36 \times 10^5$$

- B3. Two cars collide at an intersection on a horizontal road. One car, with a mass of  $1.12 \times 10^3$  kg, is initially moving east with a speed of 30.9 m/s and the other car, with a mass of  $1.34 \times 10^3$  kg, is initially moving north with a speed of 16.5 m/s. The two cars stick together after the collision.
- (a) Calculate the velocity of the cars (magnitude and direction) immediately after the collision.



$$(m_A + m_B)u_{fx} = m_A u_A + 0$$

$$u_{fx} = \frac{m_A u_A}{(m_A + m_B)}$$

$$u_{fx} = \frac{(1.12 \times 10^3 \text{ kg})(30.9 \text{ m/s})}{(1.12 \times 10^3 \text{ kg} + 1.34 \times 10^3 \text{ kg})}$$

$$u_{fx} = 14.07 \text{ m/s}$$

$$(m_A + m_B)u_{fy} = 0 + m_B u_B$$

$$u_{fy} = \frac{m_B u_B}{(m_A + m_B)}$$

$$u_{fy} = \frac{(1.34 \times 10^3 \text{ kg})(16.5 \text{ m/s})}{(1.12 \times 10^3 \text{ kg} + 1.34 \times 10^3 \text{ kg})}$$

$$u_{fy} = 8.988 \text{ m/s}^2$$

$$u_f = \sqrt{u_{fx}^2 + u_{fy}^2} = 16.7 \text{ m/s}$$

$$\theta = \text{invtan}\left(\frac{u_{fy}}{u_{fx}}\right) = 32.6^\circ$$

- (b) The coefficient of kinetic friction between the tires and the road surface is 0.812. Calculate the distance that the cars slide after the collision before coming to rest.

$$W_{\text{total}} = \Delta K \quad \text{and} \quad \sum F_z = 0$$

" (z is vertical)

$$f_k \Delta r \cos 180^\circ$$

$$N - W = 0$$

$$N = W$$

$$N = mg = (m_A + m_B)g$$

17.5 m

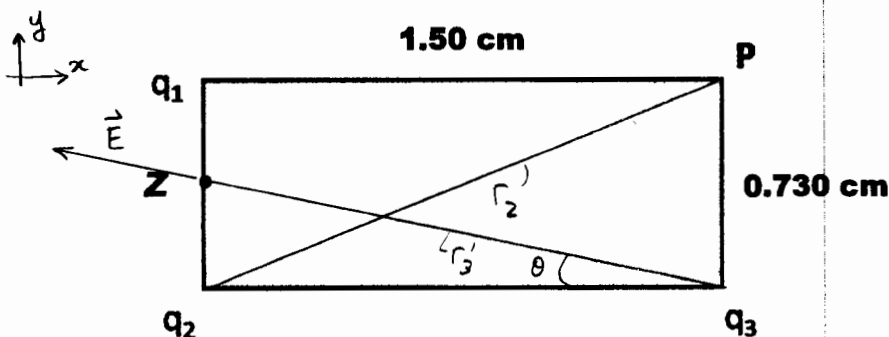
$$f_k \Delta r \cos 180^\circ = 0 - K_i$$

$$\mu_k N \Delta r \cos 180^\circ = 0 - \frac{1}{2}(m_A + m_B)u_f^2$$

$$\mu_k (m_A + m_B)g \Delta r \cos 180^\circ = -\frac{1}{2}(m_A + m_B)u_f^2$$

$$\Delta r = \frac{-\frac{1}{2}u_f^2}{\mu_k g \cos 180^\circ} = \frac{(16.7 \text{ m/s})^2}{2(0.812)(9.80 \text{ m/s}^2)} = 17.5 \text{ m}$$

**B4.** Three point charges,  $q_1$ ,  $q_2$ , and  $q_3$  are arranged at three corners of a rectangle (see figure).  
 $q_1 = q_2 = q_3 = +2.30 \text{ nC}$ .



(a) Calculate the electric potential at point  $P$  (the upper right corner of the rectangle).

$$V_p = V_1 + V_2 + V_3$$

$5.45 \times 10^3 \text{ V}$

$$V_p = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} + \frac{kq_3}{r_3}$$

$$V_p = 5.45 \times 10^3 \text{ V}$$

$$r_1 = 0.0150 \text{ m}$$

$$r_2 = \sqrt{(0.0150 \text{ m})^2 + (0.00730 \text{ m})^2}$$

$$r_2 = 0.0167 \text{ m}$$

$$r_3 = 0.00730 \text{ m}$$

$$q_1 = q_2 = q_3 = +2.30 \times 10^{-9} \text{ C}$$

(b) Calculate the magnitude and direction of the electric field at a point  $Z$  midway between charges  $q_1$  and  $q_2$ .

$$\vec{E}_z = \vec{E}_3 \text{ note that } \vec{E}_2 \text{ and } \vec{E}_1 \text{ are equal magnitude, opposite direction.}$$

magnitude:

$8.67 \times 10^4 \text{ N/C}$

direction:

$13.7^\circ \text{ above } -x \text{ axis}$

$$r'_3 = \sqrt{\left(\frac{0.00730 \text{ m}}{2}\right)^2 + (0.0150 \text{ m})^2} = 0.01544 \text{ m}$$

$$E_z = \frac{k|q_3|}{r_3'^2} = \frac{(8.99 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2})(2.30 \times 10^{-9} \text{ C})}{(0.01544 \text{ m})^2} = 8.67 \times 10^4 \text{ N/C}$$

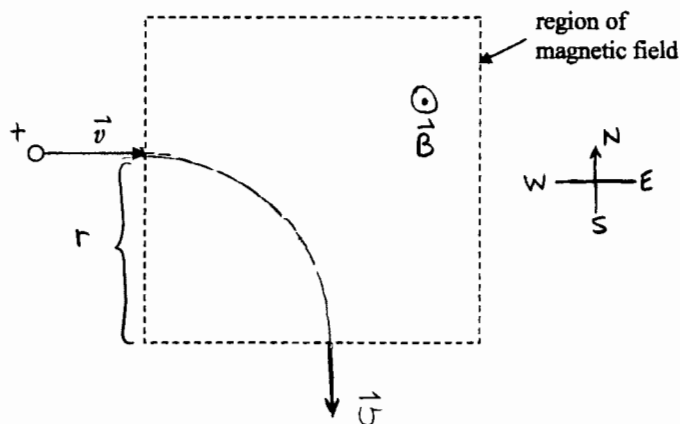
$$\theta = \text{invtan}\left(\frac{0.00730 \text{ m}/2}{0.0150 \text{ m}}\right) = 13.7^\circ \text{ above } -x \text{ axis}$$

(see diagram)



**B5.** A positively-charged particle of mass  $7.20 \times 10^{-8}$  kg is traveling horizontally due east with a speed of  $85.0$  m/s when it enters a region where there is a  $0.310$  T uniform magnetic field. The particle then moves through one quarter of a horizontal circle in  $2.20 \times 10^{-3}$  s, at which time it leaves the region of magnetic field heading due south. Throughout the motion the particle moves perpendicularly to the magnetic field.

(a) On the diagram below, draw the path followed by the particle while it is in the magnetic field.



(b) What is the direction of the magnetic field? (Enter your answer in the box and show the magnetic field on the diagram.)

UP, OUT OF PAGE

(c) Calculate the magnitude of the charge on the particle.

Newton II for circular motion

$1.66 \times 10^{-4} \text{ C}$

$$\sum F_r = ma_r$$

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

$$qvB \sin\theta = \frac{mv^2}{r}$$

$$qB \sin 90^\circ = \frac{mv}{r}$$

$$qB = \frac{mv}{r}$$

$$q = \frac{mv}{Br}$$

uniform circular motion:

$$v = \frac{2\pi r}{T} \Rightarrow \frac{v}{r} = \frac{2\pi}{T}$$

Given time  $t$  for  $\frac{1}{4}$  circle,

$$\therefore T = 4t.$$

$$q = \frac{m}{B} \left( \frac{v}{r} \right) = \frac{m}{B} \left( \frac{2\pi}{T} \right) = \frac{m}{B} \left( \frac{2\pi}{4t} \right)$$

$$q = \frac{m}{B} \left( \frac{\pi}{2t} \right)$$

$$q = \frac{(7.20 \times 10^{-8} \text{ kg}) \pi}{(0.310 \text{ T})(2)(2.20 \times 10^{-3} \text{ s})} = 1.66 \times 10^{-4} \text{ C}$$

**B6.** In a Compton scattering experiment, it is observed that the scattered x-rays have a wavelength of 4.0500 nm when they are scattered at an angle of 34.500° with respect to the direction of the incident x-rays. *Perform all calculations to 5 significant figures using the following values of fundamental constants:*

$$h = 6.6261 \times 10^{-34} \text{ J}\cdot\text{s}, \quad m_e = 9.1095 \times 10^{-31} \text{ kg}, \quad c = 2.9979 \times 10^8 \text{ m/s}$$

(a) Calculate the energy of a scattered x-ray photon.

$$E' = \frac{hc}{\lambda'}$$

$$4.9048 \times 10^{-17} \text{ J}$$

$$E' = \frac{(6.6261 \times 10^{-34} \text{ J}\cdot\text{s})(2.9979 \times 10^8 \text{ m/s})}{4.0500 \times 10^{-9} \text{ m}} = 4.9048 \times 10^{-17} \text{ J}$$

(b) Calculate the momentum of a scattered x-ray photon.

$$p' = \frac{h}{\lambda'} = \frac{6.6261 \times 10^{-34} \text{ J}\cdot\text{s}}{4.0500 \times 10^{-9} \text{ m}}$$

$$1.6361 \times 10^{-25} \text{ kg}\cdot\text{m/s}$$

$$p = 1.6361 \times 10^{-25} \text{ kg}\cdot\text{m/s}$$

(c) Calculate the wavelength of an incident x-ray photon.

$$\lambda' - \lambda = \frac{h}{m_e c} (1 - \cos\theta)$$

$$4.0496 \times 10^{-9} \text{ m}$$

$$\lambda = \lambda' - \frac{h}{m_e c} (1 - \cos\theta)$$

$$\lambda = 4.0500 \times 10^{-9} \text{ m} - \frac{6.6261 \times 10^{-34} \text{ J}\cdot\text{s} (1 - \cos(34.500^\circ))}{(9.1095 \times 10^{-31} \text{ kg})(2.9979 \times 10^8 \text{ m/s})}$$

$$\lambda = 4.0496 \times 10^{-9} \text{ m}$$

(d) Calculate the kinetic energy of a recoiling electron.

$$K = E - E'$$

$$5.0331 \times 10^{-21} \text{ J}$$

$$K = \frac{hc}{\lambda} - E' = \frac{(6.6261 \times 10^{-34} \text{ J}\cdot\text{s})(2.9979 \times 10^8 \text{ m/s})}{4.0496 \times 10^{-9} \text{ m}} - 4.9048 \times 10^{-17} \text{ J}$$

$$K = 5.0331 \times 10^{-21} \text{ J}$$

**END OF EXAMINATION**