UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3 – Physics and the Universe

FINAL EXAMINATION

December 9, 2011 Time: 3 hours

NAME: MASTER ____________ STUDENT NO.: ____________
(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 Dr. R. Pywell
- ❑ 03 Dr. K. McWilliams
- ❑ C15 F. Dean

INSTRUCTIONS:

1. This is a closed book examination.
2. The test package includes a test paper (this document), a formula sheet, and an OMR sheet. The test paper consists of 11 pages. **It is the responsibility of the student to check that the test paper is complete.**
3. Only Hewlett-Packard HP 10s or HP 30s or Texas Instruments TI-30X series calculators, or a calculator approved by your instructor, may be used.
4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your student number in the top right-hand corner of each page of the test paper.
5. Enter your name and STUDENT NUMBER on the OMR sheet.
6. The test paper, the formula sheet and the OMR sheet must all be submitted.
7. None of the test materials will be returned.

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	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
B5	❑	10	
B6	❑	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. The magnitude of the force F exerted by a spring that is stretched a distance x from its equilibrium length is given by the equation $F = kx$. The constant k has dimensions of

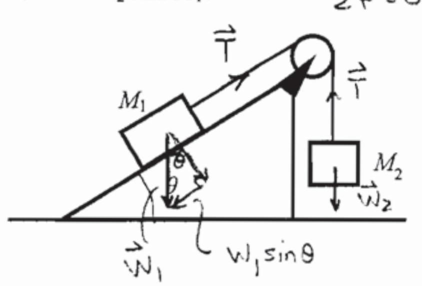
(A) kg/m. (B) kg/s^2. (C) N/s. (D) kg·m/s. (E) m/N.

A2. An object, with mass m, is moving on a horizontal plane at a constant velocity. Its speed is v. The net force acting on the object is

(A) mg. (B) mv. (C) $v^2/2m$. (D) g/m. (E) zero.

A3. A mass M_1 rests on a frictionless plane which is inclined at an angle θ to the horizontal. It is connected with a light string over a pulley, which has negligible mass and negligible friction, to a hanging mass M_2, as shown in the diagram. The system remains stationary. Which one of the following is the correct relationship between M_2 and M_1?

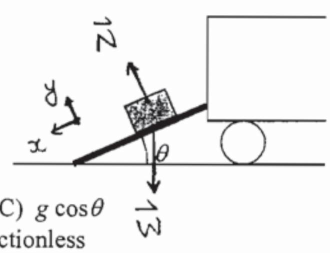
(A) $M_2 = \dfrac{M_1}{\cos\theta}$
(B) $M_2 = \dfrac{M_1}{\sin\theta}$
(C) $M_2 = M_1$
(D) $M_2 = M_1\cos\theta$
(E) $M_2 = M_1\sin\theta$



A4. A rock is thrown vertically upward. Air resistance may be ignored. When the rock reaches its maximum height, which one of the following statements concerning the acceleration of the rock is **TRUE**?

(A) The acceleration of the rock is zero.
(B) The acceleration of the rock is g downward.
(C) The acceleration of the rock is g upward.
(D) The acceleration of the rock is less than g, downward.
(E) The acceleration of the rock is greater than g, upward.

A5. A box of mass m slides down a frictionless plank that makes an angle of θ with the horizontal, as shown in the diagram. Which one of the following expressions is correct for the magnitude of the reaction force exerted on the box by the ramp?



(A) $g\sin\theta$ (B) $mg\sin\theta$ (C) $g\cos\theta$
(D) $mg\cos\theta$ (E) zero, because the ramp is frictionless

A6. A child is playing with a stone tied to a piece of string. The child is holding one end of the string and causing the stone to move in a horizontal circle around her head. The string now breaks. Which one of the following best describes the trajectory of the stone after the string breaks, as viewed from above the child?

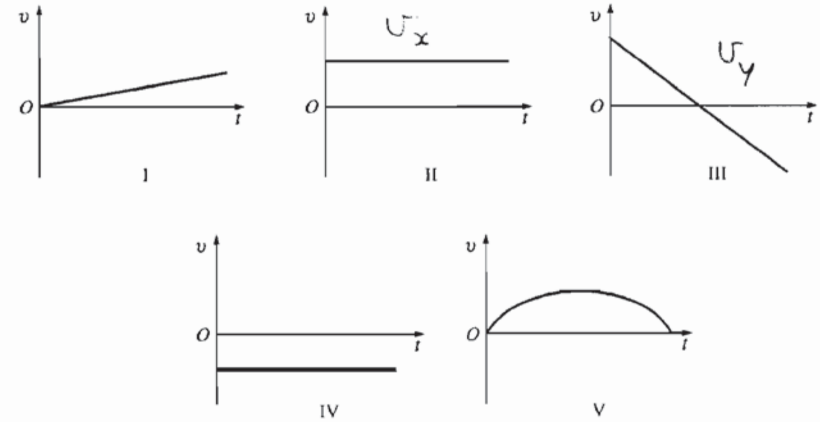
(A) The stone orbits around the child as if the string had not broken.
(B) The stone spirals inward toward the child.
(C) The stone moves off in an ever-widening spiral.
(D) The stone moves radially outward from the child.
(E) The stone moves in a straight line tangent to its initial circular trajectory.

A7. Two balls of equal size are dropped from the same height from the roof of a building. One ball has twice the mass of the other. If air resistance is ignored, when the balls reach the ground how do the kinetic energies of the two balls compare?

(A) The lighter one has one fourth as much kinetic energy as the other has.
(B) The lighter one has one half as much kinetic energy as the other has.
(C) The lighter one has the same kinetic energy as the other has.
(D) The lighter one has twice the kinetic energy as the other has.
(E) The lighter one has four times the kinetic energy as the other has.

continued on page 3...

 Student No.: ____________________



A8. A stone is thrown at an angle of 45° above the horizontal. The $+x$-axis is horizontal along the direction in which the ball was thrown. The $+y$-axis is vertically up. If air resistance is ignored, which of the velocity versus time graphs shown above best represent v_x versus t and v_y versus t, respectively?

	v_x vs. t	v_y vs. t
(A)	I	IV
(B)	II	I
(C)	II	III
(D)	II	V
(E)	IV	V

C

v_x = constant and +ve
accel^n of $-g$ in y-dir^n, so v_y is initially +ve and then decreases linearly

A9. A hiker walks from the top of a hill down to a cabin at the bottom. The work done by gravity on the hiker is

(A) positive and depends on the path taken by the hiker.
(B) negative and depends on the path taken by the hiker.
(C) zero.
(D) positive and independent of the path taken by the hiker.
(E) negative and independent of the path taken by the hiker.

D

$\vec{F}_{grav}$ is down and displacement has a downward component

A10. Two objects undergo a perfectly inelastic collision. There are no external forces acting on the objects. Which one of the following statements is **<u>TRUE</u>**?

(A) Both momentum and kinetic energy are conserved for the two-object system.
(B) Neither the momentum nor the kinetic energy of the two-object system is conserved.
(C) The kinetic energy is conserved but not the momentum.
(D) The momentum is conserved but not the kinetic energy.
(E) There is not enough information to determine which quantities are conserved.

D

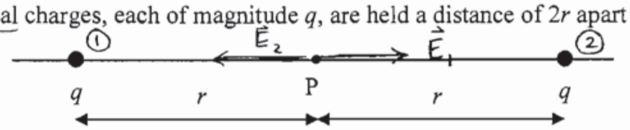
A11. Two astronauts are floating in space, initially at rest. Astronaut 1 of mass m pushes on Astronaut 2 of mass $2m$. As a result of the push, Astronaut 2 moves away with a speed v and Astronaut 1

(A) moves in the same direction as Astronaut 2 with a speed v.
(B) moves in the opposite direction as Astronaut 2 with a speed v.
(C) moves in the opposite direction as Astronaut 2 with a speed $2v$.
(D) moves in the same direction as Astronaut 2 with a speed $2v$.
(E) remains at rest.

C

Linear momentum is conserved.
$P_{tot_i} = P_{tot_f}$
$0 = m_1\vec{v}_1 + m_2\vec{v}_2$
$0 = mv_1 + 2mv$
$v_1 = -2v$

A12. Two identical charges, each of magnitude q, are held a distance of $2r$ apart on the x-axis:



A

Which one of the following is the correct expression for the electric field at point P midway between the charges?

(A) zero
(B) $k\frac{|q|}{4r^2}$ to the right
(C) $k\frac{|q|}{4r^2}$ to the left
(D) $2k\frac{|q|}{r^2}$ to the right
(E) $2k\frac{|q|}{r^2}$ to the left

continued on page 4...

 Student No.: ____________________

A13. A charge of $+Q$ and a charge of $+2Q$ are separated by a distance r. The electric force on $+Q$ due to $+2Q$ has a magnitude of F and is directed to the right. Which one of the following statements is **TRUE** regarding the electric force on $+2Q$ due to $+Q$?

B

(A) The electric force on $+2Q$ due to $+Q$ has a magnitude F and is directed to the right.
(B) The electric force on $+2Q$ due to $+Q$ has a magnitude F and is directed to the left.
(C) The electric force on $+2Q$ due to $+Q$ has a magnitude $2F$ and is directed to the right.
(D) The electric force on $+2Q$ due to $+Q$ has a magnitude $2F$ and is directed to the left.
(E) The electric force on $+2Q$ due to $+Q$ is zero.

A14. At a distance r from a charge q the electric potential due to q is V. At a distance of $2r$ from q the electric potential due to q is

B $\quad V = \frac{kq}{r}$

(A) ¼ V. (B) ½ V. (C) V. (D) $2V$. (E) $4V$.

A15. A particle with charge q is released from rest from a position in space, A, where the electric potential is V_A. After some time, the particle has moved, under the influence of electric forces, to a position, B, where it has kinetic energy K. We may ignore all forces on the particle except electric forces. The electric potential at position B is

B $\quad E_A = E_B$

(A) $V_B = qV_A - K$. (B) $V_B = V_A - K/q$. (C) $V_B = qV_A + K$.
(D) $V_B = V_A + K/q$. (E) $V_B = K/q - V_A$.

$qV_A = K + qV_B$
$V_B = V_A - \frac{K}{q}$

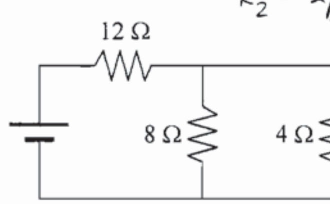
A16. An electrician replaces a copper wire, which has resistance R, with a wire that has the same length. The replacement wire is made from a metal that has twice the resistivity of copper. The replacement wire also has two times the diameter of the copper wire. What is the resistance of the replacement wire?

B $\quad R = \rho L / A$

(A) ¼ R (B) ½ R (C) R (D) $2R$ (E) $4R$

$R_2 = \frac{2\rho_1 L_1}{4A_1} = \frac{1}{2}R_1$

A17. Consider the circuit shown at the right:

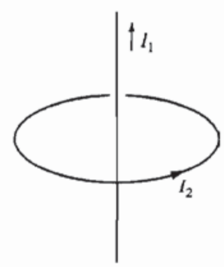


The current through the 8 Ω resistor is I_8. The current through the 4 Ω resistor is

D

(A) ¼ I_8. (B) ½ I_8. (C) I_8.
(D) $2 I_8$. (E) $4 I_8$.

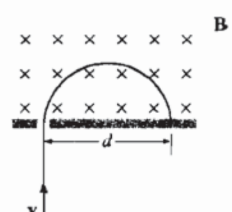
A18. A long, straight wire carrying current I_1 passes through the centre of a circular loop of wire carrying current I_2, as shown. The long wire is perpendicular to the plane of the loop. Which one of the following correctly describes the magnetic force on the loop carrying current I_2?



E

(A) Outward, along the radius of the loop.
(B) Inward, along the radius of the loop.
(C) Upward, along the axis of the loop.
(D) Downward, along the axis of the loop.
(E) There is no magnetic force on the loop.

A19. A particle with mass m and charge q, moving with a speed v, enters a region of uniform magnetic field B, as shown. The particle strikes the wall at a distance d from the entrance slit. If the particle's speed stays the same, but the charge-to-mass ratio, q/m, is doubled, at what distance from the entrance slit will the particle strike the wall?



E

(A) $2d$ (B) $\sqrt{2}d$ (C) d $\quad qvB = \frac{mv^2}{r}$
(D) $\frac{1}{\sqrt{2}}d$ (E) $\frac{1}{2}d$

$qvB = \frac{mv^2}{d/2} \Rightarrow d = \frac{2mv}{qB} = \frac{2v}{(q/m)B}$

A20. A metal surface has a work function ϕ. The threshold wavelength for emission of photoelectrons from this surface is

E

(A) $\lambda_o = \frac{\phi}{hc}$. (B) $\lambda_o = \frac{\phi}{e}$. (C) $\lambda_o = \frac{hf}{\phi}$. (D) $\lambda_o = \frac{\phi}{hf}$. (E) $\lambda_o = \frac{hc}{\phi}$.

$K_{max} = hf - \phi = \frac{hc}{\lambda} - \phi$

$0 = \frac{hc}{\lambda_o} - \phi \Rightarrow \phi = \frac{hc}{\lambda_o} \Rightarrow \lambda_o = \frac{hc}{\phi}$

continued on page 5...

 Student No.: ____________________

A21. Complete the following sentence regarding the graph of the relative intensity of electromagnetic radiation as a function of frequency for a blackbody: As the temperature of a blackbody increases,

A

(A) the peak of the radiation curve shifts to higher frequencies and the radiated power increases dramatically.
(B) the peak of the radiation curve shifts to lower frequencies and the radiated power increases dramatically.
(C) the peak of the radiation curve remains at the same frequency and the radiated power increases dramatically.
(D) the peak of the radiation curve shifts to higher frequencies and the radiated power decreases dramatically.
(E) the peak of the radiation curve shifts to lower frequencies and the radiated power decreases dramatically.

A22. When a photon is scattered from an electron there will be an increase in the photon's

E

(A) energy. (B) momentum. (C) frequency. (D) speed. (E) wavelength.

A23. In the photoelectric effect, the number of electrons per second ejected from a metal is proportional to

A

(A) the intensity of the incident light. (B) the frequency of the incident light.
(C) the wavelength of the incident light. (D) the threshold frequency of the metal.
(E) the work function of the metal.

A24. An electron in a hydrogen atom can emit a photon when

C

(A) it collides with another electron in the atom.
(B) it makes a transition from a low energy state to a higher energy state.
(C) it makes a transition from a high energy state to a lower energy state.
(D) it loses its charge.
(E) it is ionized.

A25. The energy of the ground state (the lowest energy state) of an electron in the hydrogen atom is −13.6 eV. Which one of the following is the best description of the state of the electron?

D

(A) The electron is moving backwards so it has negative kinetic energy. F
(B) The electron is stationary but its electric potential energy is negative because of our choice that potential energy is zero when the electron is an infinite distance away from the nucleus. F
(C) The electron is in an orbit around the nucleus with the largest possible radius. F
(D) The electron has positive kinetic energy but negative potential energy because of our choice that potential energy is zero when the electron is an infinite distance away from the nucleus.
(E) Energy must be taken away from the electron to remove it from the hydrogen atom. F

PART B

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

FOR EACH OF YOUR CHOSEN PART B QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWERS IN THE BOXES 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.

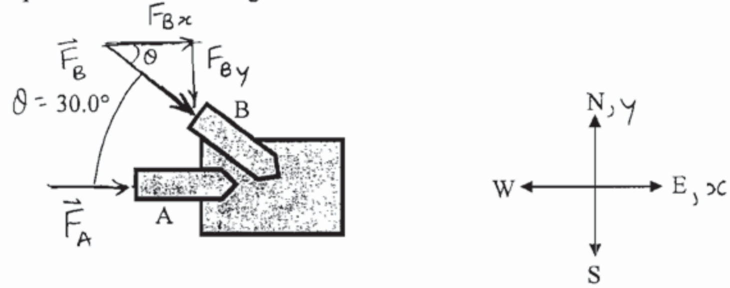
EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

continued on page 6…

 Student No.: ____________

B1. Some intrepid physics students are trying to test the effect of two rockets. They attach the rockets to a box, which is in the centre of a large frozen lake. The box is free to slide in any direction and friction between the box and the ice can be neglected. Rocket A is attached to the box so that it points toward the East and rocket B is attached to the box so that it points in the direction of 30.0° South of East. When rocket A is running it provides a force of magnitude 155 N and when rocket B is running it provides a force of magnitude 108 N. The total mass of the box and rockets is 21.0 kg.



(a) Calculate the magnitude and direction of the acceleration of the box when both rockets are running. (*6 marks*)

magnitude: $12.1\ m/s^2$

direction: 12.3° S of E

Newton II:

$\sum \vec{F} = m\vec{a} \Rightarrow \sum F_x = ma_x$ and $\sum F_y = ma_y$

Choose x: EAST and y: NORTH

$\sum F_x = ma_x$ $\quad$ $\sum F_y = ma_y$

$F_{Ax} + F_{Bx} = ma_x$ $\quad$ $F_{Ay} + F_{By} = ma_y$

$F_A + F_B\cos\theta = ma_x$ $\quad$ $0 - F_B\sin\theta = ma_y$

$a_x = \frac{F_A + F_B\cos\theta}{m}$ $\quad$ $a_y = -\frac{F_B\sin\theta}{m}$

$a_x = \frac{155N + 108N\cos 30.0°}{21.0 kg}$ $\quad$ $a_y = -\frac{108N\sin 30.0°}{21.0 kg}$

$a_x = 11.835\ m/s^2$ $\quad$ $a_y = -2.571\ m/s^2$

$a = \sqrt{a_x^2 + a_y^2}$

$a = 12.1\ m/s^2$

ϕ = angle with +x-axis:

$\phi = \text{invtan}\left(\frac{a_y}{a_x}\right)$

$\phi = -12.3°$

ϕ = 12.3° S of E

If you did not obtain an answer for (a), use a value of 10.0 m/s² for the magnitude of the acceleration of the box in both parts (b) and (c).

(b) If the box starts from rest, calculate the magnitude of the box's velocity after the rockets have been running for 3.00 s. (*2 marks*)

36.3 m/s

$v_f - v_i = a\Delta t$; $v_i = 0$

$v_f = a\Delta t$

$v_f = (12.1\ m/s^2)(3.00 s)$

$v_f = 36.3 m/s$

ALT. ANS.: 30.0 m/s

(c) If the box starts from rest, calculate the magnitude of the box's displacement from its initial position after the rockets have been running for 3.00 s. (*2 marks*)

54.5 m

$\Delta r = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$; $v_i = 0$

$\Delta r = \frac{1}{2}a(\Delta t)^2$

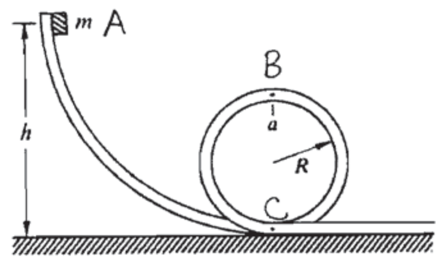
$\Delta r = \frac{1}{2}(12.1\ m/s^2)(3.00 s)^2 = 54.5 m$

ALT. ANS.: 45.0 m

continued on page 7...

Student No.: ______________________

B2. An object is released from rest at a height h above the surface of a table. The object slides along the inside of the loop-the-loop track consisting of a ramp and a circular loop of radius $R = 0.275$ m, as shown in the figure. Assume that the track is frictionless. While going around the loop-the-loop, the object momentarily loses contact with the track at the top of the loop.



(a) Calculate the speed of the object at the instant when it just barely loses contact with the track at the top of the loop. *(4 marks)*

At top of loop: $(\vec{N} = 0)$, $\vec{W}$

$$\Sigma F_r = ma_r$$

$$W = \frac{mv_{top}^2}{R}$$

$$mg = \frac{mv_{top}^2}{R}$$

$$v_{top} = \sqrt{gR}$$

$$v_{top} = \sqrt{(9.80\,m/s^2)(0.275\,m)} = 1.64\,m/s$$

Answer: 1.64 m/s

If you did not obtain an answer for (a), then in both parts (b) and (c) use a value of 1.50 m/s for the speed of the object at the instant when it just barely loses contact with the track at the top of the loop.

(b) Calculate the height h from which the object must be released, in order for it to just barely lose contact with the track at the top of the loop. *(3 marks)*

Energy is conserved b/w A and B $(W_{nc} = 0)$

$$E_A = E_B$$

$$mgh = \frac{1}{2}mv_{top}^2 + mg(2R)$$

$$h = \frac{1}{2}\frac{v_{top}^2}{g} + 2R = \frac{1}{2}\frac{(1.64\,m/s)^2}{9.80\,m/s^2} + 2(0.275\,m)$$

$$h = 0.687\,m$$

ALT. ANS: 0.665 m

Answer: 0.687 m

(c) Calculate the speed at which the object is moving at the bottom of the loop, in order for it to barely lose contact with the track at the top of the loop. *(3 marks)*

Energy is conserved b/w B and C $(W_{nc} = 0)$

$$E_B = E_C$$

$$\frac{1}{2}mv_{top}^2 + mg(2R) = \frac{1}{2}mv_c^2$$

$$v_{top}^2 + 2g(2R) = v_c^2$$

$$v_c = \sqrt{v_{top}^2 + 4gR} = \left[(1.64\,m/s)^2 + 4(9.80\,m/s^2)(0.275\,m)\right]^{1/2}$$

$$v_c = 3.67\,m/s$$

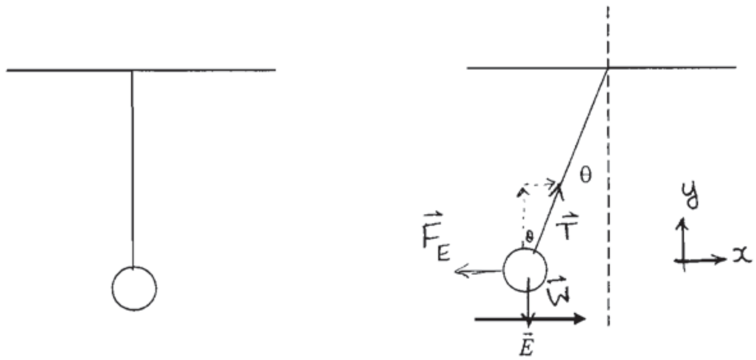
Answer: 3.67 m/s

ALT. ANS.: 3.61 m/s

continued on page 8...

Student No.: ______________________

B3. A small plastic ball is attached to a string and hanging vertically at rest. The ball has a net charge of magnitude of 5.74 mC. A horizontal electric field of 106 N/C is turned on, and the ball is deflected and then comes to rest with the string making an angle of $\theta = 30.0°$ with the vertical, as shown.



(a) What is the sign of the charge on the ball? (*1 mark*)

negative

$\vec{F}_E = q\vec{E}$ since $\vec{F}_E$ is opposite to $\vec{E}$, q is −ve

(b) Calculate the magnitude of the electric force on the ball. (*3 marks*)

0.608N

$F_E = qE$

$F_E = (5.74 \times 10^{-3}\,\text{C})(106\,\text{N/C})$

$F_E = 0.608\,\text{N}$

(c) Calculate the mass of the ball. If you did not obtain an answer for (b), use a value of 0.650 N for the magnitude of the electric force on the ball. (*6 marks*)

0.107 kg

ball is in equilibrium, so $\sum \vec{F} = 0$.

ALT. ANS.: 0.115 kg

$\sum F_x = 0$ | $\sum F_y = 0$

$F_{Ex} + T_x = 0$ | $T_y + W_y = 0$

$-F_E + T\sin\theta = 0$ | $+T\cos\theta - W = 0$

$T = \dfrac{F_E}{\sin\theta}$ | $T = \dfrac{W}{\cos\theta}$

$$\frac{F_E}{\sin\theta} = \frac{W}{\cos\theta}$$

$$F_E = \frac{mg\sin\theta}{\cos\theta} = mg\tan\theta$$

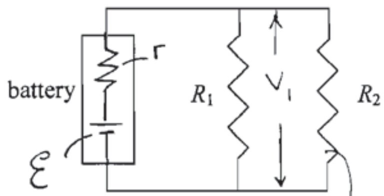
$$m = \frac{F_E}{g\tan\theta} = \frac{0.608\,\text{N}}{(9.80\,\text{m/s}^2)(\tan 30.0°)} = 0.107\,\text{kg}$$

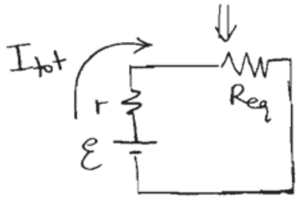
continued on page 9...

Student No.: ____________________

B4. A real battery of emf 9.21 V and internal resistance 0.125 Ω is connected to two light bulbs as described below. The resistance of light bulb 1 is $R_1 = 1.475\ \Omega$ and the resistance of light bulb 2 is $R_2 = 2.364\ \Omega$.

(a) The light bulbs are connected in parallel across the battery as shown. Calculate the current flowing through light bulb 1. (*4 marks*)





5.49 A

Calculate R_{eq} for the light bulbs.

$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{1.475\Omega} + \frac{1}{2.364\Omega}\right)^{-1}$$

$$R_{eq} = 0.908\ \Omega$$

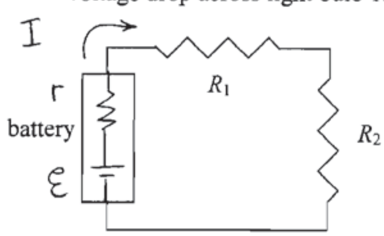
$$I_{tot} = \frac{\mathcal{E}}{r + R_{eq}} = \frac{9.21\text{V}}{(0.125\Omega + 0.908\Omega)} = 8.91\text{A}$$

$$V_1 = I_1 R_1 \text{ and } V_1 = \mathcal{E} - I_{tot} r$$

$$\mathcal{E} - I_{tot} r = I_1 R_1$$

$$I_1 = \frac{\mathcal{E} - I_{tot} r}{R_1} = \frac{9.21\text{V} - (8.91\text{A})(0.125\Omega)}{1.475\ \Omega} = 5.49\text{A}$$

(b) The light bulbs are now connected in series across the same battery, as shown. Calculate the voltage drop across light bulb 1. (*3 marks*)



3.43 V

$$I = \frac{\mathcal{E}}{r + R_1 + R_2}$$

$$I = 2.32\text{A}$$

$$V_1 = IR_1 = (2.32\text{A})(1.475\Omega)$$

$$V_1 = 3.43\text{V}$$

(c) In which connection (parallel or series) does light bulb 1 burn brighter? Show the appropriate calculations or algebra to justify your answer. (*3 marks*)

Parallel

Brightness depends on Power.

Parallel: $P_1 = I_1^2 R_1 = (5.49\text{A})^2(1.475\Omega) = 44.5\text{W}$

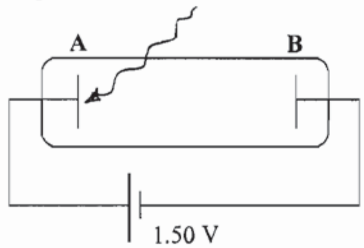
Series: $P_1 = \frac{V_1^2}{R_1} = \frac{(3.43\text{V})^2}{1.475\Omega} = 7.98\text{W}$

$$P_{1\,parallel} > P_{1\,series}$$

continued on page 10...

Student No.: ____________________

B5. Consider the phototube circuit shown below. The work function of the material of electrode A is 2.82 eV.



(a) Calculate the maximum kinetic energy (in eV) of the electrons released when electrode A is illuminated with ultraviolet light of wavelength 227 nm. (*4 marks*)

$K_{max} = hf - \phi$

$K_{max} = \frac{hc}{\lambda} - \phi$

$K_{max} = \frac{(4.136\times10^{-15}\,eV\cdot s)(2.998\times10^{8}\,m/s)}{227\times10^{-9}\,m} - 2.82\,eV$

$K_{max} = 2.64\,eV$

Answer: 2.64 eV

(b) Calculate the maximum speed of the electrons when released from electrode A. (*3 marks*)

$K_{max} = \frac{1}{2} m v_{max}^2$

$v_{max} = \sqrt{\frac{2K_{max}}{m}} = \left(\frac{2(2.64\,eV)(1.602\times10^{-19}\,C/e)}{9.109\times10^{-31}\,kg}\right)^{1/2}$

$v_{max} = 9.64\times10^{5}\,m/s$

Answer: 9.64×10^{5} m/s

(c) Calculate the maximum kinetic energy (in eV) of the electrons arriving at electrode B. If you did not obtain an answer for (a), use a value of 2.50 eV. (*3 marks*)

$E_B = E_A$ (electric force is conservative)

$K_{max_B} + qV_B = K_{max_A} + qV_A$

$K_{max_B} = K_{max_A} + q(V_A - V_B)$

$K_{max_B} = K_{max_A} - e(V_A - V_B)$

$K_{max_B} = 2.64\,eV - e(1.50\,V) = 1.14\,eV$

Answer: 1.14 eV

ALT. ANS.: 1.00 eV

continued on page 11...

Student No.: ______________________

B6.

(a) In an x-ray machine, the electrons are accelerated through a potential difference of 55.0 kV before they hit a tungsten target. Calculate the wavelength of the shortest wavelength x-ray that can be produced from this x-ray machine. Express your answer in nm. (*5 marks*)

Shortest wavelength corresponds to highest energy of photon.

0.0225 nm

$$E_{photon_{max}} = K_{electron}$$

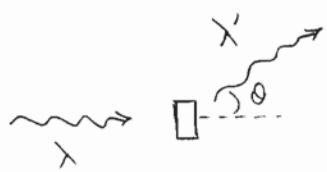
$$\frac{hc}{\lambda_{min}} = eV \Rightarrow \lambda_{min} = \frac{hc}{eV}$$

$$\lambda_{min} = \frac{(4.136 \times 10^{-15}\, eV \cdot s)(2.998 \times 10^{8}\, m/s)}{e(55.0 \times 10^{3}\, V)} = 2.25 \times 10^{-11}\, m$$

$$\lambda_{min} = 2.25 \times 10^{-11}\, m \times \frac{10^{9}\, nm}{m} = 0.0225\, nm$$

(b) A photon with a wavelength of 0.00103 nm hits a piece of metal and is Compton-scattered so that it emerges at an angle of 33.0° to the incident photon direction. Calculate the wavelength of the Compton-scattered photon. Express your answer in nm. (*5 marks*)

0.00142 nm



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

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

$$\lambda' = 1.03 \times 10^{-12}\, m + \frac{6.626 \times 10^{-34}\, J \cdot s}{(9.109 \times 10^{-31}\, kg)(2.998 \times 10^{8}\, m/s)}(1 - \cos 33.0^{\circ})$$

$$\lambda' = 1.42 \times 10^{-12}\, m \times \frac{10^{9}\, nm}{m} = 0.00142\, nm$$

END OF EXAMINATION