UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 111.6 General Physics

FINAL EXAMINATION

April 20, 2006 Time: 3 hours

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

LECTURE SECTION (please check):

- ☐ 01 Dr. A. Robinson
- ☐ 02 B. Zulkoskey
- ☐ 03 Dr. R. Pywell
- ☐ 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 calculators may be used.

PLEASE DO NOT WRITE ANYTHING ON THIS TABLE

QUESTION NUMBER	MAXIMUM MARKS	MARKS OBTAINED
A1-20	20	
B1-10	20	
C1	10	
C2	10	
C3	10	
TOTAL	70	

continued on page 2...

Student No.: ______________________

PART A

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

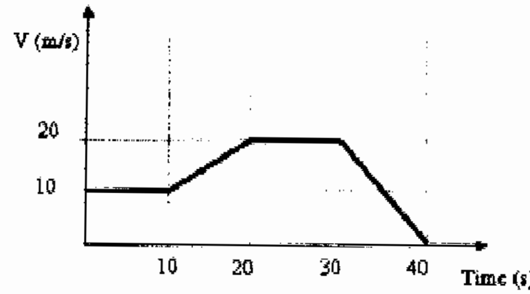
A1. Which one of the following lengths is the shortest?

D

(A) 2.78 m
(B) 0.0278 km 27.8 m
(C) 278 nm 278×10^{-9} m
(D) 2.78×10^{-6} mm 2.78×10^{-9} m
(E) 27.8 cm 0.278 m

A2. Which one of the following statements does ***NOT*** agree with the velocity-time graph?

C



(A) The acceleration is constant between 30 and 40 seconds. T
(B) The displacement is increasing at an increasing rate between 10 and 20 seconds. T
(C) The object's maximum displacement occurs at 30 seconds. F
(D) The displacement increases at a constant rate between 0 and 10 seconds, as well as between 20 and 30 seconds. T
(E) The displacement of the object is increasing at all times before 40 seconds. T

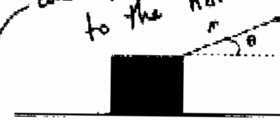
A3. A ball of mass m is thrown vertically upward from the Earth's surface. Ignore any effects due to air resistance. At the highest point of its trajectory, the acceleration of the ball is

B

(A) ~~0~~ zero
(B) g, downward.
(C) g, upward.
(D) non-zero, but less than g, downward.
(E) impossible to determine without knowing the value of m.

A4. A box is pulled along the floor at a constant velocity. There is friction between the box and the floor. The rope that is used to pull the box is attached to the box as shown in the diagram. Which one of the following statements is correct?

and pulled at an angle to the horizontal



diagram

C

(A) The normal force is greater than the weight of the box. F
(B) The normal force is equal to the weight of the box. F
(C) The kinetic frictional force is directed opposite to the displacement of the box. T
(D) The magnitude of the tension in the rope is equal to that of the frictional force. F
(E) All forces acting on the box are conservative forces. F

A5. A centripetal force F is required in order for a car of mass m, moving with speed v, to travel around a flat circular curve of radius r. For this same force F to cause this same car to travel around a flat circular curve of radius $r/2$, the speed of the car must be

C

(A) $\frac{v}{4}$. (B) $\frac{v}{2}$. (C) $\frac{v}{\sqrt{2}}$. (D) $\sqrt{2}\,v$. (E) $4v$.

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

$F = \frac{mv'^2}{r/2}$

$F = \frac{2mv'^2}{r}$

$v'^2 = \frac{Fr}{2m}$

$v'^2 = \frac{v^2}{2}$

$v' = \frac{v}{\sqrt{2}}$

A6. Car 1, of mass m_1, travelling East with speed v, and car 2, of mass m_2, travelling North also with speed v, have a completely inelastic collision. $m_1 > m_2$. Immediately after the collision, the cars will be

E

$\vec{p}_1$ $\vec{p}_2$ $p_1 > p_2$

(A) travelling North.
(B) travelling East.
(C) at rest.
(D) travelling North of East at an angle that is greater than 45 degrees.
(E) travelling North of East at an angle that is less than 45 degrees.

continued on page 3...

A7. Under which one of the following conditions will a 2 N force and a 4 N force produce the same magnitude of non-zero torque? *

B

(A) The 2 N force must have a lever arm that is half that of the 4 N force.
(B) The 2 N force must have a lever arm that is twice that of the 4 N force.
(C) The 2 N force must have a lever arm that is one-quarter that of the 4 N force.
(D) The 2 N force must have a lever arm that is 4 times that of the 4 N force. four
(E) The 2 N force must have a lever arm that is one-eighth that of the 4 N force.

A8. A block of wood and a block of iron have equal volumes. The block of wood is floating in a container of water, and the block of iron is attached to a string and held so that it is completely submerged in a container of water without touching the sides or bottom of the container. Which one of the following statements is correct? *

$F_B = W_{fluid}$

$F_B = \rho_L g V_{dis}$

C

(A) The buoyant force on the wood block equals the buoyant force on the iron block.
(B) The buoyant force on the wood block is greater than the buoyant force on the iron block.
(C) The buoyant force on the wood block is less than the buoyant force on the iron block.
(D) No statement can be made regarding the buoyant forces on the blocks without knowing their volume.
(E) No statement can be made regarding the buoyant forces on the blocks without knowing their masses.

A9. When the sound intensity at a particular location increases by a factor of 100, the sound intensity level (in dB)

B

(A) also increases by a factor of 100.
(B) increases by 20 dB.
(C) increases by an amount dependent on the original intensity.
(D) does not change.
(E) decreases to $\frac{1}{100}$ of the original value.

*

Compared to the frequency detected when both the source and observer are at rest,

A10. Which one of the following statements concerning the Doppler effect is ***FALSE***?

E

(A) An observer moving toward a stationary source detects a higher frequency. T
(B) An observer moving away from a stationary source detects a lower frequency. T
(C) A sound source moving toward a stationary observer results in the observer detecting a higher frequency. T
(D) A sound source moving away from a stationary observer results in the observer detecting a lower frequency. T
(E) When both the source and the observer move away from each other, the frequency detected by the observer is unchanged. F

A11. A wave is travelling with a speed of v along a string in which the tension is T. If the tension is suddenly doubled, the new wave speed is

D

(A) $\frac{v}{4}$. (B) $\frac{v}{2}$. (C) $\frac{v}{\sqrt{2}}$. (D) $\sqrt{2}\,v$. (E) $4v$.

$v = \sqrt{\frac{F}{m/L}}$

$v' = \sqrt{2}\,v$

A12. An organ pipe that is open at one end and has a cap on the other end has a fundamental resonant frequency of f. When the cap is removed so that the pipe is open at both ends, the new fundamental resonant frequency is

D

(A) $\frac{f}{4}$. (B) $\frac{f}{2}$. (C) $\sqrt{2}\,f$. (D) $2f$. (E) $4f$.

$\}L$

$L = \frac{\lambda}{4}$ $L = \frac{\lambda'}{2}$

$\frac{\lambda}{4} = \frac{\lambda'}{2}$

$\lambda = 2\lambda'$

$f = \frac{v}{\lambda}$

$f' = \frac{v}{\lambda'}$

$f' = \frac{v}{\lambda/2} = 2\frac{v}{\lambda}$

$f' = 2f$

A13. Which one of the following statements concerning alternating current circuits is ***FALSE***?

C

(A) The rms voltage is less than the peak voltage. T
(B) The rms current is less than the peak current. T
(C) The average power dissipated in a resistor is zero. F
(D) The direction of the current flow reverses in a periodic fashion. T
(E) The rms voltage obtained from a wall socket in Canada is 120 V. T

A14. When three identical resistors, each of R ohms, are connected in parallel, the equivalent resistance is

A

(A) $\frac{R}{3}$. (B) $\frac{R}{9}$. (C) $3R$. (D) $9R-3$. (E) $\frac{3}{R}$.

$$R_p = \left(\frac{1}{R} + \frac{1}{R} + \frac{1}{R}\right)^{-1} = \left(\frac{3}{R}\right)^{-1} = \frac{R}{3}$$

continued on page 4...

A15. An electron moving with speed v enters a region where there is a magnetic field directed at an angle of 45° to the electron's velocity. Which one of the following statements is correct?

D

(A) The magnetic force on the electron is zero. F
(B) The magnetic force on the electron is parallel to the magnetic field and perpendicular to the electron's trajectory. F
(C) The magnetic force on the electron is perpendicular to the magnetic field and parallel to the electron's trajectory. F
(D) The magnetic force on the electron causes the electron to follow a spiral trajectory. T
(E) The work done on the electron by the magnetic force is non-zero. F

A16. Which one of the following statements concerning the human eye is ***FALSE***?

A

(A) Farsightedness can be corrected by using a diverging lens. F
(B) The near point of the eye is the minimum distance at which an object is still in focus. T
(C) The far point of the eye is infinity for a person with normal vision. T
(D) The focal length of the eye is changed by changing the shape of the lens. T
(E) The eye is most relaxed when viewing distant objects. T

A17. Two beams of coherent monochromatic light travel different paths to arrive at a point P. If the maximum constructive interference is to occur at point P, the two beams must

C

(A) arrive at P 180° out of phase.
(B) arrive at P 90° out of phase.
(C) travel paths that differ in length by a whole number of wavelengths.
(D) travel paths that differ in length by an odd number of half-wavelengths.
(E) travel paths that differ in length by an integer plus one-half wavelengths.

A18. A metal surface is illuminated with blue light and electrons are ejected at a given rate and with a certain maximum kinetic energy. If the intensity of the blue light is increased, the electrons

D

(A) are emitted at the same rate, but with a larger maximum kinetic energy.
(B) are emitted at the same rate, but with a smaller maximum kinetic energy.
(C) are emitted at an increased rate, but with a smaller maximum kinetic energy.
(D) are emitted at an increased rate, with no change in their maximum kinetic energy. ✗
(E) are emitted at an increased rate, but with a larger maximum kinetic energy.

and

A19. Consider the following nuclear reaction:

$17 - 4 = 13$
$8 - 2 = 6$

$${}^{16}_{8}O + {}^{1}_{0}n \rightarrow X + {}^{4}_{2}\alpha$$

A

The unknown isotope 'X' is

(A) ${}^{13}_{6}C$ (B) ${}^{17}_{6}C$ (C) ${}^{13}_{7}N$ (D) ${}^{16}_{7}N$ (E) ${}^{17}_{8}O$

A20. Which one of the following statements best describes the process by which energy is released in a conventional fission nuclear reactor?

D

(A) The radiation given off by a naturally radioactive substance, Uranium, is collected and used to make steam.
(B) Uranium ~~is reacted~~ reacts with Oxygen in a combustion process that releases large amounts of heat and radioactivity. ✗
(C) Deuterium and Tritium are joined to form Helium with the release of energy which is used to make steam.
(D) Neutrons initiate a nuclear reaction in Uranium which splits into fragments and releases two or three neutrons and energy. The released neutrons can initiate more nuclear reactions. The energy is collected to make steam. ✗
(E) A Uranium nucleus is energized to an excited state by neutron bombardment, and it then decays by emitting beta and gamma rays which heat water to make steam. ✗

continued on page 5…

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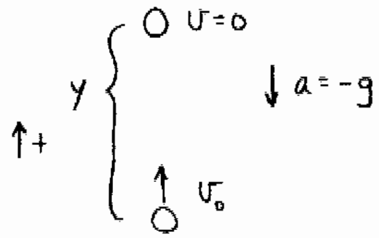
PART B

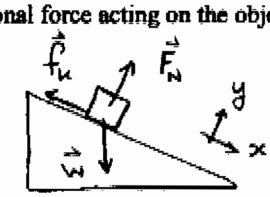
FOR EACH OF THE FOLLOWING PROBLEMS, B1 TO B10, ON PAGES 5, 6 AND 7, WORK OUT THE SOLUTION IN THE SPACE PROVIDED AND ENTER YOUR ANSWERS ON PAGE 7.
ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1. A ball is thrown straight up with an initial velocity of 12.4 m/s. Ignoring any effects due to air resistance, calculate the maximum height of the ball above its release point.



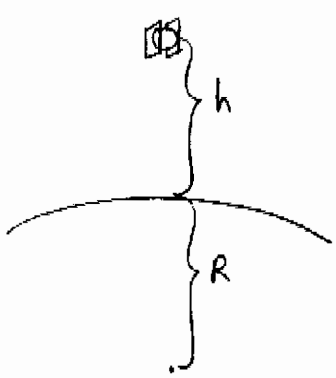
$$v^2 = v_0^2 + 2ay$$
$$0 = v_0^2 + 2ay$$
$$-v_0^2 = 2ay$$
$$y = \frac{-v_0^2}{2a} = \frac{-(12.4\,m/s)^2}{2(-9.80\,m/s^2)}$$
$$y = 7.84\,m$$

B2. An object of mass 0.255 kg is sliding down a ramp that is inclined at an angle of 30.0° above the horizontal. The acceleration of the block is 0.836 m/s^2. Calculate the magnitude of the kinetic frictional force acting on the object.



$$\Sigma F_x = ma \qquad \Sigma F_y = 0$$
$$W\sin\theta - f_k = ma$$
$$W\sin\theta - ma = f_k$$
$$mg\sin\theta - ma = f_k$$
$$f_k = 0.255\,kg\,(9.80\,m/s^2 \sin 30.0° - 0.836\,m/s^2)$$
$$f_k = 1.04\,N$$

B3. A planet has a radius $R = 5.38 \times 10^6$ m. A satellite is in orbit 1.25×10^7 m above the surface of the planet. The period of the satellite's motion is 4.50×10^4 seconds. Calculate the mass of the planet.



$$F_{grav} = \frac{mv^2}{r} = \frac{m\left(\frac{2\pi r}{T}\right)^2}{r} = \frac{4\pi^2 mr}{T^2}$$
$$\frac{GM_p m}{r^2} = \frac{4\pi^2 mr}{T^2}$$
$$M_p = \frac{4\pi^2 r^3}{GT^2}$$
$$M_p = \frac{4\pi^2(5.38\times10^6\,m + 1.25\times10^7\,m)^3}{(6.67\times10^{-11}\,\frac{N\cdot m^2}{kg^2})(4.50\times10^4\,s)^2} = 1.67\times10^{24}\,kg$$

continued on page 6...

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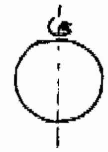
B4. Calculate the angular momentum of a solid sphere of mass 0.192 kg, radius 0.127 m, spinning with angular velocity of 0.945 rad/s with the axis of rotation through the centre of the sphere.

✓*



$$L = I\omega$$

$$L = \left(\frac{2}{5}MR^2\right)\omega = \frac{2}{5}(0.192\,kg)(0.127\,m)^2(0.945\,rad/s)$$

$$L = 1.17 \times 10^{-3}\ kg\cdot m^2/s$$

with an amplitude of 0.202 mm

✓*

B5. The diaphragm of a speaker is moving in simple harmonic motion. The frequency of the sound wave that is produced is 2.52 kHz~~, and its amplitude is 0.202 mm~~. Calculate the maximum acceleration of the diaphragm.

✓*

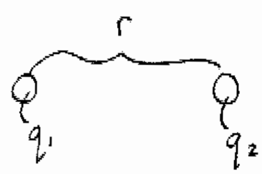
$$a = -A\omega^2 \cos(\omega t)$$

$$a_{max} = A\omega^2$$

$$a_{max} = (0.202\times10^{-3}\,m)\left(2\pi(2.52\times10^3\,Hz)\right)^2$$

$$a_{max} = 5.06 \times 10^4\ m/s^2$$

B6. Consider two charges, q_1 and q_2. $q_1 = +3.25\ \mu C$. The two charges are separated by a distance of 0.225 m. q_1 experiences an attractive force of 3.40 N due to q_2. Calculate the magnitude and sign of q_2.



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

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

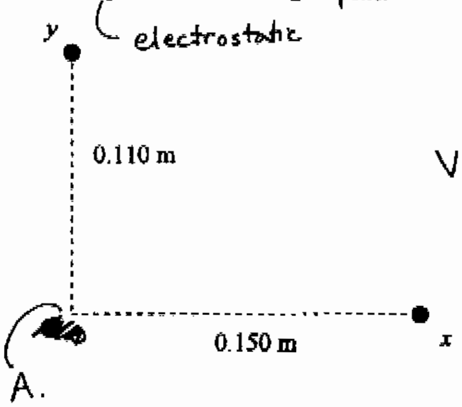
$$|q_2| = \frac{(3.40\,N)(0.225\,m)^2}{8.99\times10^9\,\frac{N\cdot m^2}{C^2}\,|3.25\times10^{-6}\,C|} = 5.89\times10^{-6}\,C$$

$$q_2 = -5.89\,\mu C$$

for attractive force

B7. Two point charges, each of $+1.00 \times 10^{-6}$ C, are located on the x and y axes as shown. Calculate the electrostatic potential at ~~the origin~~ point A.

✓*



$$V = \frac{kq_1}{r_1} + \frac{kq_2}{r_2}$$

$$V = \left(8.99\times10^9\,\frac{N\cdot m^2}{C^2}\right)(1.00\times10^{-6}\,C)\left[\frac{1}{0.110\,m} + \frac{1}{0.150\,m}\right]$$

$$V = 1.42 \times 10^5\ V$$

✓*

continued on page 7...

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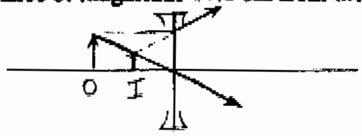
B8. An object placed at a distance of 30.0 cm from a diverging lens forms an image that is at a distance of magnitude 17.0 cm from the lens. Calculate the focal length of the lens.



$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$f = \left(\frac{1}{30.0\,cm} + \frac{1}{-17.0\,cm}\right)^{-1} = -39.2\,cm$$

~~5000~~ 5.00×10^3

B9. In a diffraction grating experiment using a grating with ~~2500~~ lines/cm, a second order fringe is located at an angle of 26.0° from the 0^{th} order fringe. Calculate the wavelength of the light.

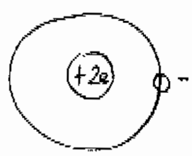
$$\sin\theta = \frac{m\lambda}{d} \quad \text{where} \quad d = \frac{1}{N} \Rightarrow \sin\theta = m\lambda N$$

$$\lambda = \frac{\sin\theta}{mN} = \frac{\sin(26.0°)}{2(5000\,/cm)} = 4.38 \times 10^{-5}\,cm \times \frac{1\,m}{100\,cm} \times \frac{10^9\,nm}{m}$$

$$\lambda = 438\,nm$$

B10. Singly-ionized helium (i.e. a helium atom ($Z = 2$) with only one electron in orbit around the nucleus) has been observed in the absorption spectrum from the Sun. Calculate the wavelength of the light absorbed by singly-ionized helium when its electron makes a transition from the $n = 3$ orbit to the $n = 4$ orbit.

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$



$$\lambda = \left[(1.10 \times 10^7\,m^{-1})(2)^2\left(\frac{1}{9} - \frac{1}{16}\right)\right]^{-1}$$

$$\lambda = 4.68 \times 10^{-7}\,m = 468\,nm$$

ANSWERS FOR PART B

ENTER THE ANSWERS FOR THE PART B PROBLEMS IN THE BOXES BELOW.
THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.
ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1	7.84 m	**B6**	$-5.89\,\mu C$
B2	1.04 N	**B7**	$1.42 \times 10^5\,V$
B3	$1.67 \times 10^{24}\,kg$	**B8**	$-39.2\,cm$
B4	$1.17 \times 10^{-3}\,kg \cdot m^2/s$	**B9**	438 nm
B5	$5.06 \times 10^4\,m/s^2$	**B10**	468 nm

continued on page 8...

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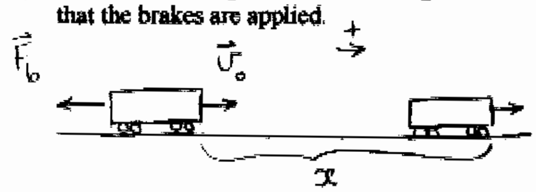
PART C

IN EACH OF THE PART C 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 ~~(FIVE SIGNIFICANT FIGURES FOR C3)~~ AND THE UNITS MUST BE GIVEN. SHOW 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. ✱

C1. A train of mass 6.84×10^6 kg is initially moving forward with a speed of 80.0 km/h along a straight horizontal track. The brakes, which produce a net backward force of 1.93×10^6 N, are then applied for 25.0 seconds. ✱

(a) Calculate the magnitude of the change in the momentum of the train during the 25.0 seconds that the brakes are applied.



$$\boxed{4.83 \times 10^7\ \mathrm{N \cdot s}}$$

Impulse - Momentum Theorem

$$\vec{F}\Delta t = \Delta\vec{p}$$

$$\Delta p = F\Delta t = (1.93 \times 10^6\,\mathrm{N})(25.0\,\mathrm{s}) = 4.83 \times 10^7\ \mathrm{N\cdot s}$$

(b) Calculate the speed of the train at the end of the 25.0 seconds.

$$\boxed{15.1\ \mathrm{m/s}}$$

$$v_0 = 80.0\,\frac{\mathrm{km}}{\mathrm{h}} \times \frac{1\,\mathrm{h}}{3600\,\mathrm{s}} \times \frac{1000\,\mathrm{m}}{\mathrm{km}} = 22.2\,\mathrm{m/s}$$

$$v = v_0 + at \quad \text{and} \quad a = \frac{|\Sigma\vec{F}|}{m}$$

$$v = v_0 + \frac{|\Sigma\vec{F}|}{m}t = 22.2\,\mathrm{m/s} - \frac{1.93 \times 10^6\,\mathrm{N}}{6.84 \times 10^6\,\mathrm{kg}} \cdot 25.0\,\mathrm{s} = 15.1\,\mathrm{m/s}$$

(c) Calculate the distance traveled by the train during the 25.0 seconds.

$$\boxed{467\ \mathrm{m}}$$

$$x = v_0 t + \frac{1}{2}at^2$$

$$x = v_0 t + \frac{1}{2}\left(-\frac{|\Sigma\vec{F}|}{m}\right)t^2$$

$$x = (22.2\,\mathrm{m/s})(25.0\,\mathrm{s}) + \frac{1}{2}\left(-\frac{1.93 \times 10^6\,\mathrm{N}}{6.84 \times 10^6\,\mathrm{kg}}\right)(25.0\,\mathrm{s})^2 = 467\,\mathrm{m}$$

(d) Calculate the work done by the brake force during the 25.0 seconds. (Remember to include the sign.)

$$\boxed{-9.01 \times 10^8\ \mathrm{J}}$$

$$W = Fs\cos\theta$$

$$W = (1.93 \times 10^6\,\mathrm{N})(467\,\mathrm{m})(\cos 180^\circ)$$

$$W = -9.01 \times 10^8\,\mathrm{J}$$

continued on page 9...

 Student No.: ____________________

C2. A hot filament is used to produce electrons in an X-ray tube.

(a) The filament is a tungsten wire of circular cross section and has a resistance of 0.0400 Ω. The resistivity of tungsten is 5.60×10^{-8} Ω.m and the diameter of the wire is 0.200 m. $\times 10^{-3}$ Calculate the length of the wire filament.

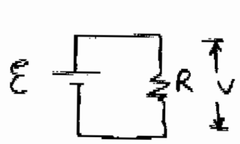
$$R = \rho\frac{L}{A} \Rightarrow L = \frac{RA}{\rho} \ ; \ r = d/2$$

$$\boxed{2.24 \text{ cm}}$$

$$L = \frac{(0.0400\Omega)(\pi(0.100\times10^{-3}m)^2)}{5.60\times10^{-8}\Omega\cdot m} = 2.24\times10^{-2} m$$

$$L = 2.24 \text{ cm}$$

(b) The filament is connected to a 12.0 V dc power supply. Calculate the power dissipated in the filament.

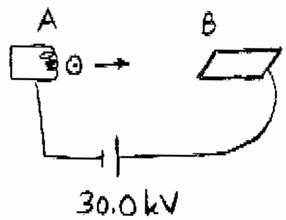


$$P = \frac{V^2}{R} = \frac{\varepsilon^2}{R}$$

$$\boxed{3.60\times10^3 W}$$

$$P = \frac{(12.0V)^2}{0.0400\Omega} = 3.60\times10^3 W$$

(c) The electrons released at the filament are now accelerated using a potential difference of +30.0 kV. Assuming they start from rest, calculate the final speed of the electrons.



$$\boxed{1.03\times10^8 m/s}$$

$$E_B = E_A$$

$$KE_B + EPE_B = \cancel{KE_A}^{\,0} + EPE_A$$

$$KE_B = EPE_A - EPE_B = -e(V_A - V_B) = e(V_B - V_A)$$

$$KE_B = e(30.0kV) = 30.0\times10^3V\,(1.60\times10^{-19}C) = \frac{1}{2}mv^2$$

$$v = \left(\frac{2(30.0\times10^3V)(1.60\times10^{-19}C)}{9.11\times10^{-31}kg}\right)^{1/2} = 1.03\times10^8 m/s$$

(d) The electrons then strike a platinum target. Calculate the minimum wavelength of the X-rays that are produced.

$$\lambda_0 = \frac{hc}{eV}$$

$$\boxed{4.14\times10^{-11} m}$$

$$\lambda_0 = \frac{(4.14\times10^{-15} eV\cdot s)(3.00\times10^8 m/s)}{e(30.0\times10^3V)} = 4.14\times10^{-11} m$$

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C3. The radioactive isotope of Radon, $^{222}_{86}Rn$, is a gas which is radioactive and decays by α-particle emission to Polonium, $^{218}_{84}Po$, with a half life of 3.82 days.

The atomic mass of $^{222}_{86}Rn$ is 222.017571 u
The atomic mass of $^{218}_{84}Po$ is 218.008966 u
The atomic mass of $^{4}_{2}He$ is 4.002602 u

(a) Calculate the approximate radius of the $^{222}_{86}Rn$ nucleus.

$$r \approx R_0 A^{1/3}$$

$$\boxed{7.3 \times 10^{-15} m}$$

$$r \simeq (1.2 \times 10^{-15} m)(222)^{1/3} = 7.3 \times 10^{-15} m$$

(b) Calculate the energy released (in MeV) when a $^{222}_{86}Rn$ atom decays.

$$^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$$

$$\boxed{5.59 \text{ MeV}}$$

$$Q = \left(\text{initial mass} - \text{final mass}\right) \cdot c^2$$

$$Q = \left(222.017571u - (218.008966u - 4.002602u)\right) \cdot \frac{931.5 \text{ MeV}}{u}$$

(c) A sample of the Radon gas is collected in a container. The sample is measured to have an activity of 9.62×10^4 Bq (2.60 μCi). Calculate the number of $^{222}_{86}Rn$ atoms in the container

$$A = \lambda N, \quad T_{1/2} = \frac{0.693}{\lambda}$$

$$\boxed{4.58 \times 10^{10}}$$

$$\therefore N = \frac{A}{\lambda} = \frac{A T_{1/2}}{0.693} = \frac{(9.62 \times 10^4 \text{ Bq})(3.82d \times \frac{24h}{d} \times \frac{3600s}{h})}{0.693}$$

$$N = 4.58 \times 10^{10}$$

(d) Calculate how long (in days) it will take before the number of $^{222}_{86}Rn$ atoms in the container is exactly one-tenth the original amount.

$$N = \frac{1}{10} N_0$$

$$\boxed{12.7 d}$$

$$N = N_0 e^{-\lambda t} = N_0 e^{-0.693t/T_{1/2}}$$

$$\frac{N_0}{10} = N_0 e^{-0.693t/T_{1/2}}$$

$$\ln\left(\frac{1}{10}\right) = -\frac{0.693t}{T_{1/2}}$$

$$t = \frac{-\ln(1/10)\, T_{1/2}}{0.693}$$

$$t = \frac{-\ln(1/10)(3.82d)}{0.693}$$

END OF EXAMINATION

$$t = 12.7 d$$