UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 111.6 General Physics

FINAL EXAMINATION

April 13, 2007 — Time: 3 hours

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

LECTURE SECTION (please check):

- ❑ 01 Dr. R. Pywell
- ❑ 02 B. Zulkoskey
- ❑ 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 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...

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 statements correctly expresses the dimensions of power? $[M]\cdot[L]^2/[T]^3$

D

(A) $[M][L][T]^{-2}$ (B) $[M][L][T]^{-1}$ (C) $[M][L]^3[T]^{-1}$
(D) $[M][L]^2[T]^{-3}$ (E) $[M]^2[L][T]^{-2}$

$[P] = \frac{[E]}{[t]} = \frac{J}{s} = \frac{kg\cdot m^2/s^2}{s} = kg\cdot m^2/s^3$

A2. Two cars race along a straight track, both starting from rest at the same time. The accelerations of the cars are constant for the whole race and are denoted a_1 and a_2 respectively. If the final velocity of the first car at the finish line is v_1, what is the final velocity of the second car at the finish line?

D

(A) $v_2 = \frac{a_2}{a_1}v_1$ (B) $v_2 = \left(\frac{a_1}{a_2}\right)^2 v_1$ (C) $v_2 = \frac{a_1 a_2}{v_1}$

(D) $v_2 = \sqrt{\frac{a_2}{a_1}}v_1$ (E) $v_2 = \frac{v_1}{a_1 a_2}$

$v^2 = v_0^2 + 2ax$, $v_{01} = v_{02} = 0$
$x_1 = x_2$: $\frac{v_1^2}{2a_1} = \frac{v_2^2}{2a_2}$ → $v_2^2 = v_1^2\frac{2a_2}{2a_1}$, $v_2 = v_1\sqrt{\frac{a_2}{a_1}}$

A3. Which one of the following statements regarding an object in uniform circular motion is **FALSE**? $a_c = \frac{v^2}{r}$

B

(A) The centripetal acceleration acts towards the centre of rotation. T
(B) The velocity of the object is constant.
(C) The tangential acceleration is zero. T
(D) The centripetal acceleration is proportional to the square of the speed. T
(E) The centripetal acceleration is inversely proportional to the radius of the circle. T

A4. A person lifts an object through a vertical distance of h in a time t. The object is at rest both prior to and after its movement through the vertical distance. The work done on the object by the person is W. If a second person lifts the same object through the same vertical distance h but takes twice the time to do it, the work done by the second person is $W = mgh$

C

(A) $\frac{W}{4}$. (B) $\frac{W}{2}$. (C) W. (D) $2W$. (E) $4W$.

A5. A rock is thrown horizontally from a cliff. Ignoring air resistance, which one of the following statements is **TRUE** during the rock's flight?

B

(A) The rock's speed remains constant.
(B) The rock's acceleration remains constant.
(C) The rock's velocity vector points in the same direction throughout the rock's motion.
(D) The rock's velocity vector points along the horizontal throughout the rock's motion.
(E) The rock's velocity vector points towards the ground throughout the rock's motion.

A6. For an ideal spring, which one of the following statements is **FALSE**? $F = -kx$

D

(A) The magnitude of the restoring force is proportional to the magnitude of the displacement from the unstretched length. $PE_{elas} = \frac{1}{2}kx^2$
(B) The elastic potential energy of the spring is proportional to the square of the magnitude of the displacement from the unstretched length.
(C) The elastic potential energy of the spring may be zero or a positive value.
(D) The restoring force acts in the same direction as the displacement from the unstretched length.
(E) The SI units for the spring constant are N/m.

A7. A simple pendulum has a period T_{earth} when on the earth and it has a period T_{moon} when on the moon. The acceleration due to gravity on the moon is one sixth of the acceleration due to gravity on the earth. Which one of the following statements correctly expresses T_{moon} in terms of T_{earth}?

D

(A) $T_{moon} = \frac{T_{earth}}{6}$ (B) $T_{moon} = \frac{T_{earth}}{36}$ (C) $T_{moon} = \frac{T_{earth}}{\sqrt{6}}$

(D) $T_{moon} = \sqrt{6}\,T_{earth}$ (E) $T_{moon} = 36T_{earth}$

$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{g/L}} = 2\pi\sqrt{\frac{L}{g}}$

$T_{moon} = 2\pi\sqrt{\frac{L}{\frac{1}{6}g}} = 2\pi\sqrt{\frac{6L}{g}} = \sqrt{6}\cdot 2\pi\sqrt{\frac{L}{g}} = \sqrt{6}\cdot T_{earth}$

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A8. A roller coaster has a speed v_A at point A. Point B is a height H above point A. Assuming no frictional losses and no work done by a motor, which one of the following expressions is correct for the speed of the roller coaster at point B?

A

(A) $v_B = \sqrt{v_A^2 - 2gH}$ (B) $v_B = v_A - \sqrt{2gH}$ (C) $v_B = v_A - 2gH$

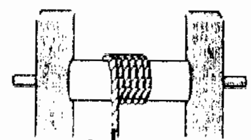
(D) $v_B = v_A + \sqrt{2gH}$ (E) $v_B = \sqrt{v_A^2 + 2gH}$

$E_B = E_A$

$\frac{1}{2}mv_B^2 + mgH = \frac{1}{2}mv_A^2$

$v_B = \sqrt{v_A^2 - 2gH}$

A9. A solid cylinder of weight W is mounted on an axle so that it is fixed in place but free to rotate around its axis. A rope is wrapped around the circumference of the cylinder and pulled with a force equal to the weight of the cylinder. The tangential acceleration of a point on the rim of the cylinder is



A

(A) $2g$. (B) $\frac{W}{g}$. (C) $\frac{g}{2}$.

(D) impossible to determine without knowing the mass of the cylinder.
(E) impossible to determine without knowing the radius of the cylinder.

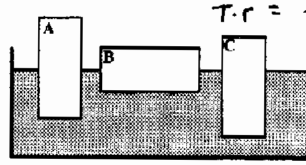
$\Sigma\tau = I\alpha$

$T \cdot r = \frac{1}{2}mr^2\alpha$

$W \cdot r = \frac{1}{2}\frac{W}{g}r^2\alpha$

$2g = r\alpha = a_T$

A10. Three blocks, labeled A, B, and C, are floating in water as shown in the drawing. Blocks A and B have the same mass and volume. Block C has the same volume, but is submerged to a greater depth than the other two blocks. Which one of the following statements concerning this situation is **FALSE**?



E

(A) The density of block A is less than that of block C. T
(B) The buoyant force acting on block A is equal to that acting on block B. T
(C) The volume of water displaced by block C is greater than that displaced by block B. T
(D) The buoyant force acting on block C is greater than that acting on block B. T
(E) The volume of water displaced by block A is greater than that displaced by block B. F

A11. Consider the standing wave in a guitar string and the sound wave produced by that guitar string as a result of its vibration. What do these two waves have in common?

C

(A) They both have the same velocity. F
(B) They both have the same wavelength. F
(C) They both have the same frequency. T
(D) They are both transverse waves. F
(E) They have nothing in common. F

A12. Two objects, A and B, which are very far from any other charges, each have the same charge of magnitude q. The electric force on object A has magnitude F. Without changing the distance between A and B, the charge on object A is now changed to $3q$. The magnitude of the electric force on object B

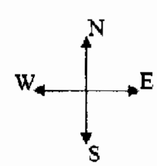
C

(A) is now F. (B) is now $2F$. (C) is now $3F$. (D) is now $4F$.
(E) cannot be determined since we are not given the initial force on B.

A13. An electron is moving toward the South in a region of space where the magnetic field is directed downward (toward the Earth). The magnetic force on the electron is directed

D

(A) down.
(B) toward the South.
(C) toward the East.
(D) toward the West.
(E) up.



A14. A proton, initially at rest, is accelerated through a potential difference of 20 V. After moving through this potential difference, the proton has a kinetic energy of

A

(A) 20 eV. (B) 40 eV. (C) 10 J. (D) 20 J. (E) 40 J.

continued on page 4...

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A15. In an electromagnetic wave

A

(A) the electric and magnetic fields are perpendicular to each other and to the direction of propagation.
(B) the electric and magnetic fields are parallel to each other and perpendicular to the direction of propagation.
(C) the electric field is parallel to the direction of propagation.
(D) the magnetic field is parallel to the direction of propagation.
(E) the electric and magnetic fields and the direction of propagation are all parallel.

A16. Photons with an energy of 8 eV cause electrons to be emitted from the surface of a certain metal with a maximum kinetic energy of 2 eV. If photons with twice the wavelength are incident upon the same metal, which one of the following statements is **TRUE**?

A

(A) No electrons will be emitted.
(B) Electrons will be emitted with a maximum kinetic energy of 2 eV.
(C) Electrons will be emitted with a maximum kinetic energy of 4 eV.
(D) Electrons will be emitted with a maximum kinetic energy of 10 eV.
(E) Electrons will be emitted with a maximum kinetic energy of 14 eV.

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

$hf = KE_{max} + W_o$

$W_o = 6$ eV

A17. Which one of the following phenomena best demonstrates the particle properties of electromagnetic radiation?

E

(A) dispersion
(B) specular reflection
(C) double-slit interference
(D) total internal reflection
(E) Compton effect

A18. In making a transition from the $n = 2$ state to the $n = 1$ state, the hydrogen atom

B

(A) absorbs a photon of energy 10.2 eV.
(B) emits a photon of energy 10.2 eV.
(C) absorbs a photon of energy 3.4 eV.
(D) emits a photon of energy 3.4 eV.
(E) absorbs a photon of energy 10.2 eV and emits a photon of energy 13.6 eV.

A19. A sample of a particular isotope initially contains N_o radioactive nuclei. After a period of time equal to 3 half-lives has elapsed, the number of radioactive nuclei remaining is:

C

(A) $\frac{1}{3}N_o$ (B) $\frac{1}{6}N_o$ (C) $\frac{1}{8}N_o$ (D) $\frac{2}{3}N_o$ (E) $\frac{1}{27}N_o$

$\left(\frac{1}{2}\right)^3 = \frac{1}{8}$

A20. When alpha particles collide with ${}^{14}_{7}N$ nuclei a nuclear reaction can occur, with one of the products being ${}^{17}_{8}O$. What is the other product of this nuclear reaction?

B

(A) neutron (B) proton (C) electron (D) positron (E) alpha particle

$${}^{14}_{7}N + {}^{4}_{2}He = {}^{17}_{8}O + {}^{1}_{1}X$$

↑ proton

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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. Calculate the magnitude of the gravitational force between Saturn (mass 5.69×10^{26} kg) and its satellite Titan (mass 1.35×10^{23} kg). Assume Titan orbits Saturn in a circular orbit of radius 1.22×10^{9} m.

$$F_{grav} = \frac{G m_1 m_2}{r^2} = \frac{\left(6.67\times10^{-11}\frac{N\cdot m^2}{kg^2}\right)(5.69\times10^{26}\,kg)(1.35\times10^{23}\,kg)}{(1.22\times10^{9}\,m)^2}$$

$$F_{grav} = 3.44\times10^{21}\,N$$

B2. A car moves with a constant speed. The magnitude of the total force of friction opposing the car's motion is 1.03×10^4 N. Calculate the average power required to keep the car moving forward with a constant speed of 13.1 m/s.

$$P = Fv = (1.03\times10^{4}\,N)(13.1\,m/s) = 1.35\times10^{5}\,W$$

B3. Calculate the frequency of oscillation for a mass of 0.194 kg suspended from a spring which has a spring constant of 146 N/m.

$$\omega = \sqrt{\frac{k}{m}}\ ;\quad f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{146\,N/m}{0.194\,kg}} = 4.37\,Hz$$

continued on page 6...

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B4. The velocity of an object undergoing simple harmonic motion is defined by the equation $v = -7.17 \sin(1.90\, t)$, where time is measured in seconds and distance is measured in metres. Calculate the magnitude of the maximum displacement of the object from its equilibrium position.

$$v = -A\omega \sin(\omega t)$$

$$\therefore \ \omega = 1.90 \text{ rad/s} \quad \text{and} \quad A\omega = 7.17 \text{ m/s}$$

$$\text{so} \quad A(1.90 \text{ rad/s}) = 7.17 \text{ m/s}$$

$$A = \frac{7.17 \text{ m/s}}{1.90 \text{ /s}} = 3.77 \text{m}$$

B5. The sound intensity level of a bird singing in a field is 59.0 dB. Calculate the intensity of the sound in W/m^2.

$$\beta = 10 dB \log\left(\frac{I}{I_o}\right)$$

$$\frac{\beta}{10 dB} = \log\left(\frac{I}{I_o}\right)$$

$$10^{\beta/10dB} = \frac{I}{I_o} \Rightarrow I = 1.00 \times 10^{-12} \frac{W}{m^2}\, 10^{59.0 dB/10 dB}$$

$$I = 7.94 \times 10^{-7} W/m^2$$

B6. Calculate the fundamental frequency of an organ pipe of length 0.346 m that is open at one end and closed at the other.

$$L = \frac{1}{4}\lambda$$

$$\lambda = 4L$$

$$f = \frac{v}{\lambda} = \frac{v}{4L}$$

$$f = \frac{343 \text{ m/s}}{4(0.346 \text{ m})}$$

$$f = 248 \text{ Hz}$$

B7. The absolute electric potential at a point that is 1.50 m away from a charge q, and very far away from any other charges, is -8.00×10^4 V. Calculate the charge q.

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

$$q = \frac{Vr}{k} = \frac{(-8.00 \times 10^4 V)(1.50 m)}{8.99 \times 10^9 \text{ N}\cdot\text{m}^2/C^2}$$

$$q = -1.33 \times 10^{-5} C$$

continued on page 7...

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B8. A proton is moving with a speed of 2.30×10^5 m/s in a direction perpendicular to a magnetic field of magnitude 0.800 T. Calculate the magnitude of the acceleration experienced by the proton.

$$\Sigma \vec{F} = m\vec{a}$$

$$F_{mag} = ma$$

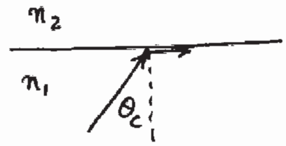
$$qvB \sin\theta = ma$$

$$a = \frac{qvB}{m}$$

$$a = \frac{(1.60 \times 10^{-19} C)(2.30 \times 10^5 m/s)(0.800 T)}{1.67 \times 10^{-27} kg}$$

$$a = 1.76 \times 10^{13} m/s^2$$

B9. The index of refraction of a fibre optic cable is 1.64. The cable is surrounded by air. Calculate the minimum angle of incidence at which light travelling in the cable can strike the side of the cable so that the light remains within the cable.



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1 \sin\theta_c = n_2$$

$$\theta_c = \text{invsin}\left(\frac{n_2}{n_1}\right)$$

$$\theta_c = \text{invsin}\left(\frac{1.00}{1.64}\right) = 37.6°$$

B10. Light from a mercury lamp illuminates a diffraction grating. The rulings of the grating are 1.67×10^{-6} m apart. Calculate the angle of the second order maximum of the mercury green line (546 nm).

$$\sin\theta = \frac{m\lambda}{d}$$

$$\theta = \text{invsin}\left(\frac{m\lambda}{d}\right) = \text{invsin}\left(\frac{2(546 \times 10^{-9} m)}{1.67 \times 10^{-6} m}\right)$$

$$\theta = 40.8°$$

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	3.44×10^{21} N	**B6**	248 Hz
B2	1.35×10^5 W	**B7**	-1.33×10^{-5} C
B3	4.37 Hz	**B8**	1.76×10^{13} m/s^2
B4	3.77 m	**B9**	37.6°
B5	7.94×10^{-7} W/m^2	**B10**	40.8°

continued on page 8...

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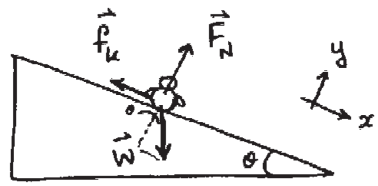
PART C

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 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 penguin slides down an icy incline with a constant speed of 1.45 m/s. The incline is at an angle of 6.90° with the horizontal.

(a) Draw a free body diagram of the forces acting on the penguin.



(b) Calculate the coefficient of kinetic friction between the penguin and the ice.

0.121

$\sum F_x = 0$ and $\sum F_y = 0$ (constant velocity)

$mg\sin\theta - f_k = 0$ $\quad$ $F_N - mg\cos\theta = 0$

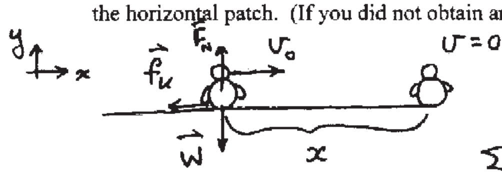
$mg\sin\theta - \mu_k F_N = 0$ $\quad$ $F_N = mg\cos\theta$

$mg\sin\theta - \mu_k(mg\cos\theta) = 0$

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

$\mu_k = \tan\theta = \tan(6.90°) = 0.121$

(c) At the bottom of the incline the penguin slides onto a horizontal patch of ice. The coefficient of kinetic friction between the penguin and the horizontal patch is the same as for the ice on the incline. Calculate the distance for the penguin to slide to a halt after entering the horizontal patch. (If you did not obtain an answer for (b), use a value of 0.150.)



0.887 m

$\sum F_y = 0 \Rightarrow F_N = mg$

$\sum F_x = ma \Rightarrow -\mu_k F_N = ma$

$-\mu_k mg = ma$

$a = -\mu_k g$

$v^2 = v_0^2 + 2ax$

$0 = v_0^2 + 2ax$

$x = \frac{-v_0^2}{2a}$

$x = \frac{-v_0^2}{2(-\mu_k g)} = \frac{v_0^2}{2\mu_k g} = \frac{(1.45\,m/s)^2}{2(0.121)(9.80\,\frac{m}{s^2})} = 0.887\,m$

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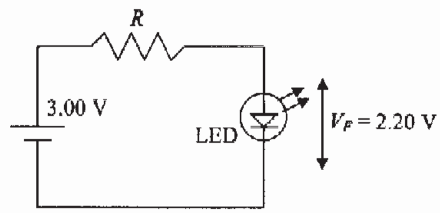
C2. An LED (light emitting diode) is to be used in the circuit shown, which consists of a battery, a resistor R and the LED. The LED may be considered to be a simple resistor. To operate correctly the LED must have a potential difference across it of $V_F = 2.20$ V. It then dissipates a power of 45.0 mW (4.50×10^{-2} W). The battery has an emf of 3.00 V and may be considered to be an ideal battery.



(a) Calculate the current flowing in the circuit.

$P = VI$

$I = \frac{P}{V} = \frac{4.50 \times 10^{-2} W}{2.20 V} = 2.05 \times 10^{-2} A$

205×10^{-2} A

(b) Calculate the resistance of the LED.

107 Ω

$R_{LED} = \frac{V_F}{I} = \frac{2.20 V}{2.05 \times 10^{-2} A} = 107 \Omega$

(c) Calculate the value of the resistor R in the circuit.

$\mathcal{E} = V_R + V_F$

$V_R = \mathcal{E} - V_F$

$R = \frac{V_R}{I} = \frac{\mathcal{E} - V_F}{I} = \frac{3.00V - 2.20V}{2.05 \times 10^{-2} A} = 3.90 \times 10^1 \Omega = 39.0 \Omega$

39.0 Ω

(d) The LED emits green light of wavelength 565 nm. If the LED is assumed to be 100% efficient (i.e. all the energy dissipated in the LED comes out as light) calculate the number of photons emitted in one second.

$E = Pt$

$n \cdot \frac{hc}{\lambda} = Pt$

$n = \frac{Pt\lambda}{hc} = \frac{(4.50 \times 10^{-2} W)(1.00 s)(565 \times 10^{-9} m)}{(6.63 \times 10^{-34} J \cdot s)(3.00 \times 10^{8} m/s)}$

1.28×10^{17}

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C3. The isotope $^{60}_{27}Co$ has an atomic mass of 59.933819 u.

(a) Calculate the binding energy for this isotope.

$$BE = \Delta m \cdot c^2$$

525 MeV

$$BE = \left(Zm_H + Nm_n - \text{atomic mass}\right) \cdot c^2$$

$$BE = \left(27(1.007825u) + 33 \cdot (1.008665u) - 59.933819u\right) \cdot 931.5 \frac{MeV}{u}$$

$$BE = 525 \text{ MeV}$$

(b) $^{60}_{27}Co$ is naturally radioactive, decaying to $^{60}_{28}Ni$. Determine the particle released during this decay.

$$^{60}_{27}Co \rightarrow {}^{60}_{28}Ni + {}^{0}_{-1}X$$

← electron

electron

(and anti-neutrino!)

(c) A device used in cancer radiation therapy initially contains 5.00×10^{21} $^{60}_{27}Co$ nuclei. One year later, the number of $^{60}_{27}Co$ nuclei in the device is 4.38×10^{21}. Calculate the half-life of $^{60}_{27}Co$. (Express your answer in years.)

$N_o = 5.00 \times 10^{21}$ $\quad t = 1.00\,y$

5.23 y

$N = 4.38 \times 10^{21}$

$$N = N_0 e^{-\lambda t}$$

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$\ln\left(\frac{N}{N_0}\right) = -\lambda t$$

$$\lambda = \frac{\ln\left(N/N_0\right)}{-t}$$

$$\lambda = \frac{\ln\left(\frac{4.38 \times 10^{21}}{5.00 \times 10^{21}}\right)}{-1.00\,y} = 0.132\,y^{-1}$$

$$T_{1/2} = \frac{0.693}{\lambda} = \frac{0.693}{0.132\,y^{-1}} = 5.23\,y$$

(d) Calculate the initial activity of the $^{60}_{27}Co$ in the device. Express your answer in Becquerels.

2.09×10^{13} Bq

$$A_o = \lambda N_o$$

$$A_o = \frac{0.132}{y} \cdot 5.00 \times 10^{21} \times \frac{1\,y}{365.25\,d} \times \frac{1\,d}{24\,h} \times \frac{1\,h}{3600\,s}$$

$$A_o = 2.09 \times 10^{13}/s = 2.09 \times 10^{13}\ Bq$$

END OF EXAMINATION