UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
Physics for the Life Sciences

FINAL EXAMINATION

April 15, 2009 Time: 3 hours

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

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 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 11 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	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
B5	❑	10	
B6	❑	10	
TOTAL		75	

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PART A

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

$\tau = rF_\perp$

A1. Consider two forces of magnitudes F_1 and F_2 applied to a door. $F_2 = 2F_1$. If both forces are applied perpendicularly to the door and $\mathbf{F_2}$ is applied at a distance r from the axis of rotation, how far from the axis should $\mathbf{F_1}$ be applied so that the net torque on the door is zero?

D

$r_2F_2 = r_1F_1$

(A) ¼ *r* (B) ½ *r* (C) *r* (D) 2*r* (E) 4*r*

$r_1 = \frac{rF_2}{F_1} = 2r$

A2. Consider a ship that is floating in fresh water. The bottom of the ship is a depth d_f below the surface. If the same ship is floating in sea water, the bottom of the ship is a depth d_s below the surface. Given that the density of sea water is greater than the density of fresh water, which one of the following statements is correct?

B

$F_B = \rho_f g V_f = \rho_s g V_s \Rightarrow V_s < V_f$

(A) $d_s > d_f$ (B) $d_s < d_f$ (C) $d_s = d_f$

$\Rightarrow d_s < d_f$

(D) The relationship between d_s and d_f cannot be determined without knowing the mass of the ship.
(E) The relationship between d_s and d_f cannot be determined without knowing the volume of the ship.

A3. A bowling ball made for a child has half the radius of an adult bowling ball. The balls are solid and made of the same material. By what factor is the rotational inertia of the adult's ball larger than that of the child's ball?

E

$I = \frac{2}{5}MR^2$

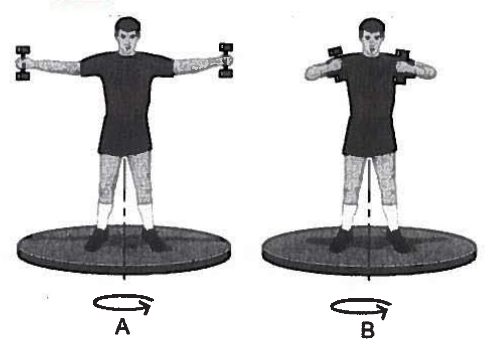
(A) 2 (B) 4 (C) 8 (D) 16 (E) 32

$I = \frac{2}{5}\rho \frac{4}{3}\pi R^3 \cdot R^2$

A4. A student holding weights in each hand is standing on a platform that is free to rotate around a frictionless vertical axis. The student is then given a push so that he and the platform rotate as shown in A. The student ~~then pulls~~ the weights closer to his body as shown in B. Which one of the following statements is **FALSE**?

$I \propto R^5$

~~C~~ E



Cons. of Angular Momentum

(A) The student has a greater rotational inertia in situation A.
(B) The student has a lower rotational speed in situation A.
(C) The student has the same angular momentum in both A and B.
(D) The student has to do work to move the weights from the position in A to that in B.
(E) The rotational kinetic energy of the student is the same in figures A and B.

A5. Which one of the following statements best explains why ultrasonic (rather than audible) frequencies are used for medical imaging?

E

(A) Ultrasonic frequencies penetrate deeper into the tissue than audible frequencies.
(B) Audible frequencies could damage the hearing of a fetus.
(C) Audible frequencies could damage the hearing of the ultrasound technician.
(D) Audible frequencies do not reflect from tissue, so no imaging signal would be obtained.
(E) Ultrasonic frequencies enable the resolution of small details.

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A6. A sound wave is described by the equation $y = (2.5\times10^{-10}\ \text{m})\cos\left((512\pi\ \text{rad/s})t - \left(\frac{2\pi}{1.30}\text{m}^{-1}\right)x\right)$

Which one of the following statements is **FALSE**?

(A) The wave is travelling in the positive x direction.
(B) The amplitude of the wave is 2.5×10^{-10} m.
(C) The wavelength of the wave is 1.30 m.
(D) The frequency of the wave is 256 Hz.
(E) The speed at which the wave propagates is 240 m/s.

A7. A standing sound wave in tube A, open at one end, has a fundamental frequency (first harmonic) of f_{A1}. What is the new fundamental frequency, in terms of f_{A1}, if the tube is lengthened by 15%?

(A) $1.15f_{A1}$ (B) $0.15f_{A1}$ (C) $\frac{f_{A1}}{1.15}$ (D) $\frac{f_{A1}}{0.15}$ (E) $\frac{f_{A1}}{2.15}$

A8. Which one of the following statements regarding an object performing simple harmonic motion is **FALSE**?

(A) When the object is at the maximum displacement, the acceleration is a maximum.
(B) When the object is at the maximum displacement, the potential energy of the object is at a maximum.
(C) When the object is at the position of zero displacement, the kinetic energy is at a maximum.
(D) When the object is at the position of zero displacement, the acceleration is zero.
(E) The object has a maximum speed when at the position of maximum displacement.

A9. Consider oxygen molecules moving near the Earth's surface and oxygen molecules moving in the Earth's ionosphere. The absolute temperature in the ionosphere is three times greater than the absolute temperature at the Earth's surface. Which one of the following is the correct ratio of the rms translational speed of oxygen molecules in the ionosphere compared to oxygen molecules at the Earth's surface?

(A) $\sqrt{3}$ (B) $2\sqrt{3}$ (C) $\frac{2\sqrt{3}}{3}$ (D) $\frac{\sqrt{3}}{2}$ (E) $\frac{2}{\sqrt{3}}$

A10. The coefficient of thermal expansion for brass is greater than for steel. Consider a bimetallic strip made of brass on the left and steel on the right. The strip is fixed in place at its bottom and its top end is free to move. If the strip is straight at room temperature, what happens to the strip at temperatures below room temperature?

(A) The top end of the strip bends to the left.
(B) The top end of the strip bends to the right.
(C) The direction that the top end bends depends on the length of the strip.
(D) The strip shortens but remains straight.
(E) The strip elongates but remains straight.

A11. Which one of the following statements concerning the absolute temperature of an ideal gas is **TRUE**?

(A) The absolute temperature of an ideal gas is directly proportional to the average speed of the gas molecules.
(B) The absolute temperature of an ideal gas is directly proportional to the square of the mass of the gas molecules.
(C) The absolute temperature of an ideal gas is inversely proportional to the average speed of the gas molecules.
(D) The absolute temperature of an ideal gas is inversely proportional to the average translational kinetic energy of the gas molecules.
(E) The absolute temperature of an ideal gas is directly proportional to the average translational kinetic energy of the gas molecules.

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A12. The absolute temperature of a blackbody is doubled. What effect does this have on the rate at which the blackbody emits thermal radiation?

D

$P = \sigma \epsilon A T^4$

$(2)^4 = 16$

(A) The rate of emission of thermal radiation also doubles.
(B) The rate of emission of thermal radiation increases by a factor of four.
(C) The rate of emission of thermal radiation increases by a factor of eight.
(D) The rate of emission of thermal radiation increases by a factor of sixteen.
(E) The rate of emission of thermal radiation increases by a factor of thirty-two.

A13. In a certain time interval, light travels 6.20 km in a vacuum. During the same time interval, light travels only 3.40 km in a liquid. The refractive index of the liquid is

E

$n = \frac{c}{v}$

(A) 1.50 (B) 1.31 (C) 1.46 (D) 1.69 (E) 1.82

A14. A beam of visible light passes from the air into the corneal tissue. Assuming that the refractive index of the corneal tissue is 1.380, and the refractive index of air is 1.008, which one of the following expressions correctly relates the incident angle and the angle of refraction?

D

$n = \frac{6.20\text{ km}/t}{3.40\text{ km}/t}$

$n = 1.82$

(A) $\theta_r = \sin\left(\frac{1.380}{1.008}\sin\theta_i\right)$ (B) $\theta_r = \frac{1.008}{1.380}\sin^2\theta_i$ (C) $\theta_r = \frac{1.008}{1.380}\theta_i$

(D) $\theta_r = \sin^{-1}\left(\frac{1.008}{1.380}\sin\theta_i\right)$ (E) $\theta_r = \sin^{-1}\left(\frac{1.380}{1.008}\sin\theta_i\right)$

$n_i \sin\theta_i = n_r \sin\theta_r$

$\theta_r = \sin^{-1}\left(\frac{n_i}{n_r}\sin\theta_i\right)$

A15. Which one of the following statements about the human eye is **FALSE**? Assume that the eye has perfect vision.

C

(A) The focal length of the eye can be changed by changing the shape of the lens. T
(B) The distance from the lens to the retina is a fixed distance. T
(C) A focused image can be produced for all object distances from the lens. F
(D) A focused image can be produced for an object at infinity. T
(E) The image on the retina is inverted and smaller than the object. T

A16. Which region in the EM spectrum has the lowest frequency?

E

(A) red light (B) violet light (C) X-rays (D) gamma rays (E) radio waves

A17. A pulsed laser emits light in a series of short pulses, each having an energy, E, of 1.25×10^{-4} J. There are 4.00×10^{14} photons in each pulse. The wavelength of the light is

C

$E = \frac{hc}{\lambda} \cdot N$

$\lambda = \frac{hc}{E} \cdot N$

(A) 575 nm (B) 610 nm (C) 636 nm (D) 712 nm (E) 787 nm

A18. Which one of the following values of phase difference (in radians) between two coherent waves will result in **destructive** interference?

D

(A) 0 (B) ½ π (C) (3/2)π (D) π (E) 2π

A19. A grating consists of a large number of parallel, narrow, evenly-spaced slits. Consider two gratings, identical except that one has more slits than the other, illuminated with light from identical monochromatic sources. Which one of the following statements correctly describes the interference pattern for the grating with more slits compared to the pattern for the grating with fewer slits?

D

(A) The bright fringes are closer together and narrower.
(B) The bright fringes are further apart and narrower.
(C) The bright fringes are closer together and wider.
(D) The spacing of the bright fringes is the same but the fringes are narrower.
(E) The spacing of the bright fringes is the same but the fringes are wider.

A20. Which one of the following is **not** a property of a beam of laser light?

D

(A) coherent (B) monochromatic (C) parallel
(D) produced by spontaneous emission
(E) produced by stimulated emission

A21. Which one of the following particles is released when $^{215}_{83}\text{Bi}$ decays and becomes $^{215}_{84}\text{Po}$?

B

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

Z ↑ 1, A unchanged
↳ $^{1}_{0}n \rightarrow {^{1}_{1}p} + {^{0}_{-1}e}$

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 Student No.: ____________________

A22. The activity of a radioactive sample with a single radioactive nuclide decreases to one eighth its initial value in 96 days. What is the half life of this radioactive nuclide?

B

(A) 6 days (B) 32 days (C) 12 days (D) 16 days (E) 8 days

$\frac{1}{8} = \left(\frac{1}{2}\right)^3$ ⇓ $3 \cdot T_{1/2}$ $\therefore T_{1/2} = \frac{96}{3}$

A23. By what factor does the nucleon number of a nucleus have to increase in order for the nuclear radius to double? $r = r_0 A^{1/3}$

C

(A) 2 (B) 4 (C) 8 (D) 10 (E) 16

A24. Which one of the following statements concerning ionizing radiation is **FALSE**?

E

(A) The QF is a relative measure of the damage done by ionizing radiation to biological tissue compared to 200 keV x-rays. T
(B) The absorbed dose of radiation in grays is the amount of energy in Joules absorbed by 1 kg of the tissue. T
(C) Alpha particles are a form of ionizing radiation. T
(D) Beta particles are a form of ionizing radiation. T
(E) Gamma ray photons are not a form of ionizing radiation. F

A25. Which one of the following statements regarding radioactive decay is **TRUE**?

C

(A) In beta-plus decay, an electron and an antineutrino are emitted. F
(B) Gamma decay results in the parent nucleus changing into a different daughter nucleus. F
(C) The decay rate is proportional to the number of nuclei. T
(D) The decay rate is constant with time. F
(E) In alpha decay, the daughter nucleus has more protons than the parent nucleus. F

$R = \lambda N$

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PART B

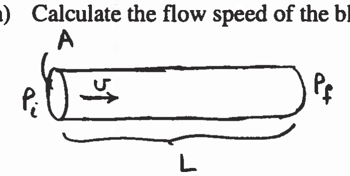
ANSWER <u>FIVE</u> PART B QUESTIONS AND INDICATE YOUR CHOICES ON THE COVER PAGE.

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. The volume flow rate of blood from the heart of a small dog is 4.10×10^{-3} m^3/s. It flows through a circular cross-section blood vessel (the aorta) of radius 0.500 cm, and length 40.0 cm. The density of blood at body temperature is 1060 kg/m^3 and the viscosity is 4.00×10^{-3} Pa·s.

(a) Calculate the flow speed of the blood.

52.2 m/s



$$\frac{\Delta V}{\Delta t} = Av \Rightarrow v = \frac{\Delta V/\Delta t}{A} = \frac{4.10\times10^{-3}\ \text{m}^3/\text{s}}{\pi(0.00500\ \text{m})^2}$$

$$v = 52.2\ \text{m/s}$$

(b) Calculate the pressure drop across the aorta of the dog.

2.67×10^4 Pa

$$\frac{\Delta V}{\Delta t} = \frac{\pi}{8}\frac{\Delta P/L}{\eta} r^4$$

$$\Delta P = \left(\frac{\Delta V}{\Delta t}\right)\cdot\frac{8\eta L}{\pi r^4}$$

$$\Delta P = \frac{(4.10\times10^{-3}\ \text{m}^3/\text{s})(8)(4.00\times10^{-3}\ \text{Pa}\cdot\text{s})(0.400\ \text{m})}{\pi(0.00500\ \text{m})^4}$$

$$\Delta P = 2.67\times10^4\ \text{Pa}$$

(c) Calculate the mass flow rate of the blood.

4.35 kg/s

$$\frac{\Delta m}{\Delta t} = \rho\frac{\Delta V}{\Delta t}$$

$$\frac{\Delta m}{\Delta t} = (1060\ \text{kg/m}^3)(4.10\times10^{-3}\ \text{m}^3/\text{s}) = 4.35\ \text{kg/s}$$

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B2. A sound wave with a sound intensity level of 77.0 dB is incident on your eardrum, which has an area of 0.600×10^{-4} m^2.

(a) If the source of the sound wave is 5.00 metres from your eardrum, what is the power of the sound source?

1.57×10^{-2} W

$$I = \frac{P}{4\pi r^2} \Rightarrow P = 4\pi r^2 I$$

$$\beta = 10\log\left(\frac{I}{I_0}\right)$$

$$\frac{\beta}{10} = \log\left(I/I_0\right) \Rightarrow 10^{\beta/10}\cdot I_0 = I$$

$$P = 4\pi r^2\left(I_0\cdot 10^{\beta/10}\right)$$

$$P = 4\pi\,(5.00\,m)^2\left(1.00\times10^{-12}\,W/m^2\right)\left(10^{77/10}\right)$$

$$P = 1.57\times10^{-2}\,W$$

(b) If the sound wave has 10.0 seconds duration and energy is transferred from the wave to your eardrum with 90% efficiency, how much energy is transferred to your eardrum during the 10.0 seconds? (If you did not obtain an answer for (a), use 1.60×10^{-2} W.)

2.71×10^{-8} J

$$E = 0.900\,P\,t$$

$$E = 0.900\,IA\cdot t$$

$$E = 0.900\,I_0\cdot 10^{\beta/10}\cdot A\cdot t$$

$$E = 0.900\left(1.00\times10^{-12}\,W/m^2\right)\left(10^{77/10}\right)\cdot\left(0.600\times10^{-4}\,m^2\right)\left(10.0\,s\right)$$

$$E = 2.71\times10^{-8}\,J$$

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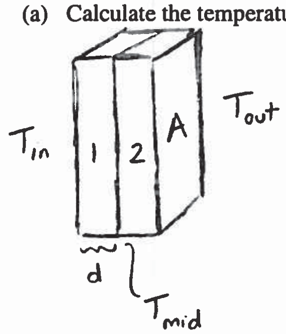
 Student No.: ____________________

B3. Two building materials, plasterboard [$\kappa = 0.312$ J/(s·m·C°)] and brick [$\kappa = 0.603$ J/(s·m·C°)], are put together to form a wall of a house. The temperatures at the inside and outside surfaces of the wall are 27.7 °C and 1.15 °C respectively. Each material has the same thickness (11.5 cm) and cross-sectional area (12.5 m^2).

plasterboard brick

(a) Calculate the temperature at the plasterboard-brick interface.



$$\mathcal{P} = \text{constant} = \kappa A \frac{\Delta T}{d}$$

10.2 °C

$$\frac{\kappa_1 A_1 (T_{in} - T_{mid})}{d_1} = \frac{\kappa_2 A_2 (T_{mid} - T_{out})}{d_2}$$

$$\kappa_1 T_{in} - \kappa_1 T_{mid} = \kappa_2 T_{mid} - \kappa_2 T_{out}$$

$$\frac{\kappa_1 T_{in} + \kappa_2 T_{out}}{\kappa_1 + \kappa_2} = T_{mid}$$

$$T_{mid} = \frac{(0.312)(27.7°C) + (0.603)(1.15°C)}{(0.312 + 0.603)} = 10.2°C$$

(b) Calculate the rate of heat flow through the wall due to conduction. (If you did not obtain an answer for (a), use 10.5 °C.)

593 W

$$\mathcal{P} = \frac{\Delta Q}{\Delta t} = \frac{\kappa_1 A_1 (T_{in} - T_{mid})}{d_1}$$

$$\mathcal{P} = \frac{\left(0.312 \frac{J}{s \cdot m C°}\right)(12.5 m^2)(27.7°C - 10.2°C)}{0.115 m}$$

$$\mathcal{P} = 593 \text{ J/s} = 593 \text{ W}$$

(c) The plasterboard wall is painted flat black – it behaves like a blackbody. Calculate the rate at which thermal radiation is emitted from the side of the wall that is at 27.7 °C.

5.81×10^3 W

$$\mathcal{P} = e \sigma A T^4$$

$$\mathcal{P} = (1)(5.670 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4)(12.5 m^2)(27.7 + 273.15)^4$$

$$\mathcal{P} = 5.81 \times 10^3 \text{ W}$$

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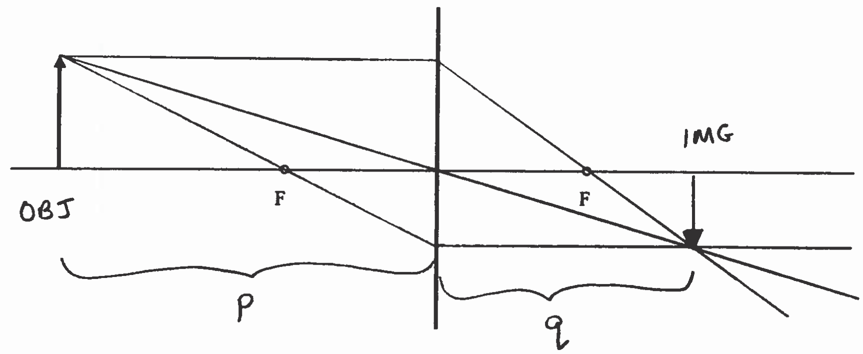
B4. A 2.00-cm-tall object is placed 50.0 cm from a converging lens with a focal length of 20.0 cm.

(a) Draw a ray-tracing diagram of the situation, showing the location of the image. Include all three principal rays.



(b) Calculate the distance of the image from the lens.

$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$

33.3 cm

$q = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1} = \left(\frac{1}{20.0\text{cm}} - \frac{1}{50.0\text{cm}}\right)^{-1} = 33.3\text{ cm}$

(c) Is the image **REAL** or **VIRTUAL** ? (circle your choice)

(d) Calculate the height of the image. (If you did not obtain a value for (b), use 34.0 cm.)

$m = -\frac{q}{p} = \frac{h'}{h}$

1.33 cm

$h' = -\frac{q}{p} \cdot h = -\frac{(33.3\text{cm})}{50.0\text{cm}} \cdot (2.00\text{cm}) = -1.33\text{cm}$

↑ inverted

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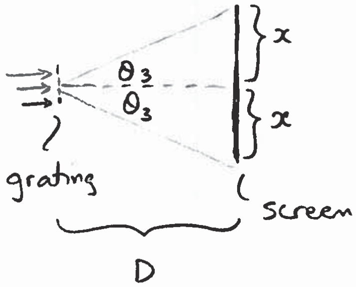
B5. There are 5620 lines per centimeter in a grating that is used with violet light whose wavelength is 471 nm. A flat observation screen is located at a distance of 0.750 m from the grating.

(a) Calculate the separation between consecutive slits of the grating.



$d = \frac{1}{N}$

$d = \frac{1 \text{ cm}}{5620 \text{ lines}} = 1.78 \times 10^{-4} \text{ cm} \times \frac{10^7 \text{ nm}}{\text{cm}}$

$d = 1.78 \times 10^3 \text{ nm}$

Answer: 1.78×10^3 nm

(b) Calculate the angular location of the first order maximum of the violet light. (If you did not obtain a value for (a), use 1.50×10^{-6} m.)

$d \sin\theta = m\lambda$

$\theta_1 = \text{invsin}\left(\frac{m\lambda}{d}\right)$

$\theta_1 = \text{invsin}\left(\frac{1(471 \text{ nm})}{1780 \text{ nm}}\right) = 15.3°$

Answer: 15.3°

(c) Calculate the order that corresponds to the maximum (bright fringe) with the largest angular location.

$\theta_{max} = 90° \Rightarrow m_{max} = \frac{d \sin(90°)}{\lambda}$

$m_{max} = \frac{d}{\lambda} = \frac{1780 \text{ nm}}{471 \text{ nm}} = 3.78$

but m is an integer.

$\therefore m_{max} = 3$

Answer: 3

(d) Calculate the minimum width that the screen must have so that the **centres** of all the principal maxima formed on either side of the central maximum fall on the screen.

See diagram in (a).

min. width = $2x$. and $\tan\theta_3 = \frac{x}{D}$

$\therefore$ min. width = $2D \tan\theta_3$

$= 2D \tan\left(\text{invsin}\left(\frac{3(471 \text{ nm})}{1780 \text{ nm}}\right)\right)$

$= 1.96 \text{ m}$

Answer: 1.96 m

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Student No.: ____________________

B6. The isotope $^{60}_{27}Co$ has an atomic mass of 59.933819 u.

(a) Calculate the binding energy of this isotope.

$$E_B = (\Delta m)c^2$$

$$E_B = (Zm_p + Nm_n - M_{nucleus})\cdot c^2$$

$$E_B = [Zm_p + Nm_n - (M_{atomic} - Zm_e)]\cdot c^2$$

$$E_B = [27(1.0072765u) + 33(1.0086649u) - (59.933819u - 27(0.00054858 0u))]\cdot 931.494 \text{ MeV}/c^2 u$$

$E_B =$ ~~497~~ MeV 525

Answer: ~~497~~ 525 MeV

(b) The $^{60}_{27}Co$ isotope is radioactive and decays into $^{60}_{28}Ni$. ~~What particle is released in this decay?~~ Identify the type of decay.

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

Answer: beta-minus

(c) A sample of $^{60}_{27}Co$ contains 5.00×10^{21} nuclei. One year later the number of $^{60}_{27}Co$ nuclei in the sample is 4.38×10^{21}. Calculate the half life of $^{60}_{27}Co$.

$N_0 = 5.00 \times 10^{21}$

$t = 1.00y$

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

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

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

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

$$\ln\left(\frac{N}{N_0}\right) = -\frac{0.693t}{T_{1/2}}$$

$$T_{1/2} = -\frac{0.693t}{\ln(N/N_0)} = -\frac{0.693(1.00y)}{\ln(4.38/5.00)} = 5.23y$$

Answer: 5.23y

END OF EXAMINATION