UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 117.3
Physics for the Life Sciences

FINAL EXAMINATION

April 26, 2011   Time: 3 hours

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

LECTURE SECTION (please check):

❑   01   B. Zulkoskey

❑   02   Dr. J.-P. St. Maurice

❑   C16   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 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*

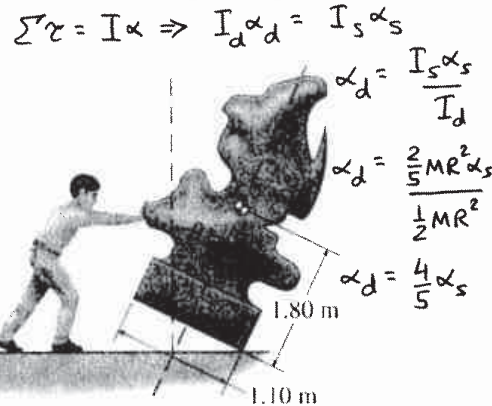| QUESTION NUMBER	TO BE MARKED	MAXIMUM MARKS	MARKS OBTAINED
A1-25	☑	25	
B1	❑	10	
B2	❑	10	
B3	❑	10	
B4	❑	10	
B5	❑	10	
B6	❑	10	
TOTAL		75	

PART A

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

A1. Consider a solid disk and a solid sphere. Each object is mounted on an axle through its centre so that it is free to rotate without friction. The mass and radius of the disk is the same as the mass and radius of the sphere. Equal torques are now applied to the disk and the sphere. How does the angular acceleration of the disk, α_{DISK}, compare to the angular acceleration of the sphere, α_{SPHERE}?

D

(A) $\alpha_{DISK} = \alpha_{SPHERE}$ (B) $\alpha_{DISK} = \frac{1}{2}\alpha_{SPHERE}$ (C) $\alpha_{DISK} = \frac{2}{5}\alpha_{SPHERE}$

(D) $\alpha_{DISK} = \frac{4}{5}\alpha_{SPHERE}$ (E) $\alpha_{DISK} = \frac{5}{4}\alpha_{SPHERE}$

(handwritten) $\sum \tau = I\alpha \Rightarrow I_d \alpha_d = I_s \alpha_s$

$\alpha_d = \dfrac{I_s \alpha_s}{I_d}$

$\alpha_d = \dfrac{\frac{2}{5}MR^2 \alpha_s}{\frac{1}{2}MR^2}$

$\alpha_d = \dfrac{4}{5}\alpha_s$

A2. As shown in the accompanying figure, a sculpture has its centre of gravity located 1.80 m above the centre of its base. The base is a square with a side of 1.10 m. To what angle θ can the sculpture be tipped before it falls over?

A

(A) 17° (B) 23°
(C) 45° (D) 33°
(E) 27°

(handwritten) Tipping occurs when CG moves past the contact point at the base.

$\tan\theta_{max} = \dfrac{0.55}{1.80} \Rightarrow \theta_{max} = 17°$

(figure labels) 1.80 m, 1.10 m

A3. A glass of ice water is filled to the brim with water; the ice cubes stick up above the water surface. After the ice melts, which one of the following statements is **TRUE**?
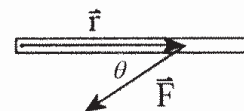
(handwritten) $m_{displaced\ water} = m_{ice}$

displaced ("missing") water

B

(A) The water level is below the top of the glass.
(B) The water level is at the top of the glass but no water has spilled.
(C) Some water has spilled over the sides of the glass.
(D) It is impossible to say what has happened without knowing the initial densities of the water and the ice. *(handwritten)* When the ice melts, the "missing" water is exactly replaced,
(E) The water level is above the glass but the water does not spill over because of the surface tension of water.

(handwritten) ∴ no change in water level.
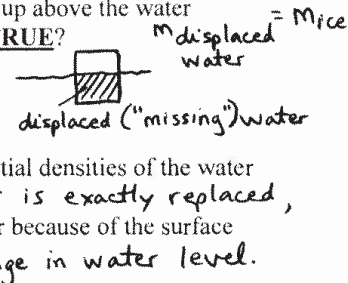
A4. Consider a rigid bar as shown in the diagram to the right. The bar is free to rotate about a fixed axis of rotation at its left end. A force $\vec{F}$ acts on the bar as shown. The point of application of the force relative to the axis of rotation is given by the position vector $\vec{r}$. Which one of the following statements regarding the torque on the bar due to $\vec{F}$ is **FALSE**?

E

(figure labels) $\vec{r}$, θ, $\vec{F}$

(A) The component of $\vec{F}$ that is anti-parallel to $\vec{r}$ does not contribute to the torque. *(handwritten)* T
(B) The magnitude of the torque depends on θ. *(handwritten)* T
(C) According to the sign convention used in class, $\vec{F}$ is exerting a negative torque on the bar. *(handwritten)* T
(D) The magnitude of the torque equals the product of the magnitude of $\vec{r}$ and the magnitude of the component of $\vec{F}$ that is perpendicular to $\vec{r}$, i.e. $|\vec{\tau}| = |\vec{r}| \times |\vec{F}_\perp|$. *(handwritten)* T
(E) If the point of application of the force is moved to the right end of the bar, but the magnitude and direction of $\vec{F}$ remain the same, the torque exerted on the bar remains the same. *(handwritten)* F

A5. A constant power *(handwritten: point)* source is emitting sound uniformly in all directions. The intensity at a distance of r_0 from the source is I_0. At what distance from the source is the intensity $\frac{1}{4}I_0$?

E

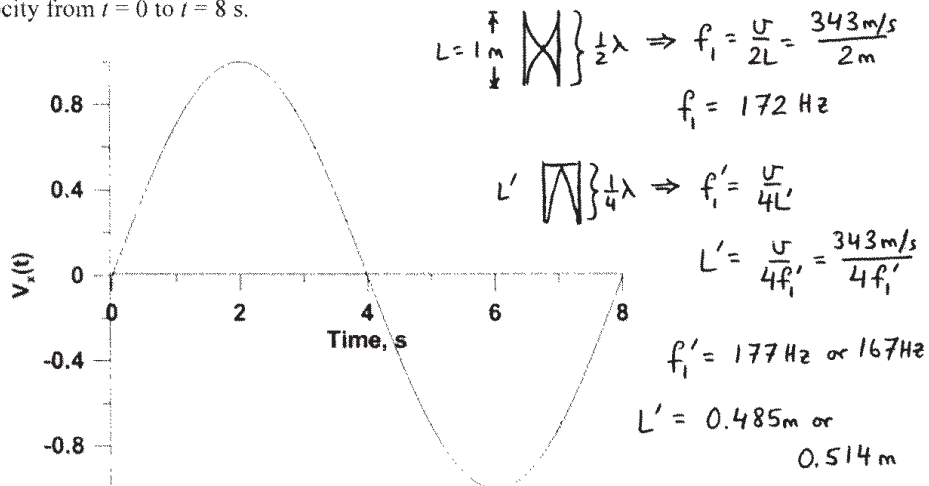(A) $\frac{1}{4}r_0$ (B) $4r_0$ (C) $\frac{1}{2}r_0$ (D) $\frac{1}{16}r_0$ (E) $2r_0$

(handwritten) $I \propto \dfrac{1}{r^2}$

A6. A physical pendulum consists of a circular hoop of radius R and mass M which is anchored to a wall through a nail that goes through a point on the hoop. The hoop is free to oscillate about the anchor point. Its period of oscillation is compared to the period of oscillation of a simple pendulum with a mass exactly equal to $2M$. The two periods of oscillations will be equal if the length of the simple pendulum is equal to

A

Handwritten: $T_1 = T_2 \Rightarrow \omega_1 = \omega_2 \Rightarrow \sqrt{mgd/I} = \sqrt{g/L}$

(A) R. (B) $2R$. (C) $3R/2$. (D) $3R$. (E) $\frac{1}{2}R$.

Handwritten: $\sqrt{MgR/MR^2} = \sqrt{g/L} \Rightarrow R = L$

A7. A moving van and a small car are traveling in the same direction on a two-lane road. The van is moving at twice the speed of the car and overtakes it. The driver of the car sounds his horn, frequency 440 Hz, to signal the van that it is safe to return to the lane. Which one of the following statements is **TRUE**?

B

Handwritten: van moving away ⇒ van driver hears lower frequency.

(A) The car driver and the truck driver both hear the horn frequency as 440 Hz.
(B) The car driver hears 440 Hz but the van driver hears a lower frequency.
(C) The car driver hears 440 Hz but the van driver hears a higher frequency.
(D) Both drivers hear the same frequency and it is lower than 440 Hz.
(E) Both drivers hear the same frequency and it is higher than 440 Hz.

A8. A thin organ pipe open at both ends has a length $L = 1$ m and is producing sound at its fundamental frequency f. A second thin organ pipe sits next to the first and is closed at one end. It too is producing sound at its fundamental frequency. A beat frequency of 5 Hz is heard when the two pipes are played at the same time. A possible value for the length of the second pipe is

B

(A) 0.63 m (B) 0.52 m (C) 1.15 m (D) 1.05 m (E) 0.75 m

The following diagram applies to questions A9 and A10. The diagram shows the graph of velocity versus time for an object in simple harmonic motion. The period of the motion is 8 seconds and the graph shows the velocity from $t = 0$ to $t = 8$ s.

Handwritten: $L = 1\,m$ $\frac{1}{2}\lambda \Rightarrow f_1 = \frac{v}{2L} = \frac{343\,m/s}{2\,m}$

$f_1 = 172\,Hz$

L' $\frac{1}{4}\lambda \Rightarrow f_1' = \frac{v}{4L'}$

$L' = \frac{v}{4f_1'} = \frac{343\,m/s}{4f_1'}$

$f_1' = 177\,Hz$ or $167\,Hz$

$L' = 0.485\,m$ or $0.514\,m$

A9. At what time or times is the object at the equilibrium point? *At the equilibrium point,* $v = v_{max}$

C

(A) 0, 4 s, 8 s (B) 2 s only (C) 2 s, 6 s (D) 6 s only (E) 4 s only

A10. At what time or times does the acceleration have its maximum amplitude? *max. accel'n at max. displacement, where $v = 0$.*

A

(A) 0, 4 s, 8 s (B) 2 s only (C) 2 s, 6 s (D) 6 s only (E) 4 s only

A11. Before starting out on a long drive, you check the air in your car's tires to make sure that they are properly inflated. The pressure gauge reads 199 kPa (an absolute pressure of 300 kPa) and the temperature is 15 °C. After a few hours of highway driving, you stop and check the pressure again. The absolute pressure of the air in the tires is now 10% higher. What is the temperature of the air in the tires now?

D

(A) still 15 °C (B) 16.5 °C (C) 13.5 °C (D) 43.8 °C (E) 150 °C

Handwritten:

$PV = NkT$; V, N, k constant

$P \propto T$

$P_2 = 1.10 P_1 \Rightarrow T_2 = 1.10 T_1 = 1.10(15 + 273.15) - 273.15$

$T_2 = 43.8°C$

A12. Consider an ideal gas whose temperature is increased from 20 °C to 40 °C. Which one of the following statements concerning the change in the average kinetic energy of a gas molecule is correct?

C

(A) The average kinetic energy doubles as the temperature increases from 20 °C to 40 °C.
(B) The average kinetic energy at 40 °C is half of its value at 20 °C.
(C) The average kinetic energy at 40 °C is larger than at 20 °C, but the factor that it increases is less than two.
(D) The average kinetic energy at 40 °C is less than at 20 °C, but the factor relating the kinetic energy at 40 °C to the kinetic energy at 20 °C is greater than ½.
(E) There is no change in the average kinetic energy of the gas molecules.

$$\langle K_t \rangle = \frac{3}{2} k T$$

in Kelvin

A13. If you place your hand underneath, but not touching, a pot of hot water, you mainly feel the presence of heat due to

E

(A) interference. (B) conduction.   (C) diffraction.   (D) convection.   (E) radiation.

A14. A compound microscope is made from a combination of two lenses. Which one of the following statements is **TRUE**?

D

(A) Both lenses form real images.
(B) Both lenses form virtual images.
(C) The lens closest to the object forms a virtual image; the other lens forms a real image.
(D) The lens closest to the object forms a real image; the other lens forms a virtual image.
(E) The lens closest to the object is always a diverging lens.

A15. Which one of the following statements concerning electromagnetic waves is **TRUE**?

D

(A) The electric field is parallel to the direction of propagation of the wave.
(B) The magnetic field is parallel to the direction of propagation of the wave.
(C) The electric and magnetic fields are parallel to each other.
(D) The electric and magnetic fields are perpendicular to each other and to the direction of propagation.
(E) The propagation speed of an electromagnetic wave in a vacuum is different for different wave frequencies.

A16. The critical angle at the interface between a particular liquid and air is 48°. Which one of the following statements best describes what happens to a ray of light, initially in air, that hits the liquid surface at an angle of incidence of 40°?

A

(A) Some of the light reflects and some enters the liquid – the angle of transmission into the liquid is less than 40°.
(B) Some of the light reflects and some enters the liquid – the angle of transmission into the liquid is greater than 40°.
(C) All of the light reflects – none of it transmits into the liquid.
(D) All of the light transmits into the liquid at an angle of 40° – none of it reflects.
(E) All of the light transmits into the liquid at an angle of 48° – none of it reflects.

A17. Which one of the following statements correctly describes the process by which the human eye adjusts to maintain focus on an object that is approaching the eye?

A

(A) The focal length of the eye lens becomes shorter.
(B) The focal length of the eye lens becomes longer.
(C) The lens-retina distance increases.
(D) The lens-retina distance decreases.
(E) The diameter of the pupil increases.

A18. You wish to design a simple magnifier that has the largest possible angular magnification. You have a choice of two converging lenses, the focal length of lens 1 is less than the focal length of lens 2. Which one of the following setups will satisfy your design goal?

C

(A) Use lens 1 and place the object at the near point of the person using the magnifier.
(B) Use lens 2 and place the object at the near point of the person using the magnifier.
(C) Use lens 1 and place the object so that the image formed by the lens is at the near point of the person using the magnifier.
(D) Use lens 2 and place the object so that the image formed by the lens is at the near point of the person using the magnifier.
(E) Use lens 1 and place the object so that the image formed by the lens is at the far point of the person using the magnifier.

$$M = \frac{N}{P} = N\left(\frac{1}{f} - \frac{1}{q}\right) = N\left(\frac{1}{f} - \frac{1}{-N}\right) = \frac{N}{f} + 1$$

A19. If diffraction is the only consideration, which one of the following microscopes will have the best resolution?

A

(A) large diameter lenses used with short wavelength of light
(B) large diameter lenses used with long wavelength of light
(C) small diameter lenses used with short wavelength of light
(D) small diameter lenses used with long wavelength of light
(E) small diameter lenses – wavelength of light has no effect

$a \sin \Delta\theta \geq 1.22\lambda_0$

$\sin \Delta\theta \geq \dfrac{1.22\lambda_0}{a}$

want $\Delta\theta$ to be small.

A20. You have two double-slit slides. Slide 1 has a slit spacing of 0.125 mm and slide 2 has a slit spacing of 0.250 mm. Both slides are illuminated with light of the same wavelength. The interference pattern formed by slide 1 is viewed on a screen at a distance of 1 m from the slide and the interference pattern formed by slide 2 is viewed on a screen that is at a distance of 2 m from the slide. Which one of the following statements is correct concerning the spacing of the bright fringes in the two interference patterns?

A

$m\lambda = d\sin\theta \simeq \dfrac{dy}{L} \Rightarrow$ y is the same if $\dfrac{d}{L}$ is the same.

(A) The fringes have the same spacing in both patterns.
(B) The fringes of the slide 1 pattern are twice as far apart as the fringes of the slide 2 pattern.
(C) The fringes of the slide 1 pattern are 4× as far apart as the fringes of the slide 2 pattern.
(D) The fringes of the slide 2 pattern are twice as far apart as the fringes of the slide 1 pattern.
(E) The fringes of the slide 2 pattern are 4× as far apart as the fringes of the slide 1 pattern.

(y is fringe spacing, L is screen distance)

A21. Why is it necessary that the active medium in a laser have a metastable excited state?

A

(A) The metastable excited state allows for a population inversion to be established, so that stimulated emission occurs more frequently.
(B) The metastable excited state ensures that stimulated emission does not occur.
(C) The metastable excited state ensures that absorption of all photons is maximised.
(D) The metastable excited state ensures that the photons produced by stimulated emission are immediately absorbed.
(E) The metastable excited state ensures that the laser medium does not overheat.

A22. Isotopes of the same element have:

D

(A) the same number of neutrons but different numbers of protons.
(B) the same number of electrons but different numbers of protons.
(C) the same number of neutrons but different numbers of electrons.
(D) the same number of protons but different numbers of neutrons.
(E) the same number of protons but different numbers of electrons.

A23. An isotope of element X has 38 protons and 52 neutrons. Which one of the following is the correct notation for this isotope?

B

(A) $^{90}_{52}X$ (B) $^{90}_{38}X$ (C) $^{38}_{52}X$ (D) $^{52}_{38}X$ (E) $^{52}_{90}X$

A24. Which one of the following statements concerning the strong nuclear force is **TRUE**?

D

(A) The strong nuclear force is attractive between neutrons and repulsive between protons.
(B) The strong nuclear force occurs only between neutrons, it does not act between a neutron and a proton or between two protons.
(C) All of the nucleons in a large nucleus feel the strong nuclear force due to all the other nucleons.
(D) Each nucleon feels the strong nuclear force only due to the nucleons that are closest to it.
(E) The strength of the strong nuclear force between two neutrons is approximately the same magnitude as the gravitational force between two neutrons.

A25. A sample initially contains N_0 nuclei of a particular radioactive isotope. This particular isotope becomes stable following one alpha decay, with a half-life of 2 days. How many radioactive nuclei remain after six days?

E

(A) $\frac{1}{2}N_0$ (B) $\frac{1}{3}N_0$ (C) $\frac{2}{3}N_0$ (D) $\frac{1}{4}N_0$ (E) $\frac{1}{8}N_0$

$6d = 3T_{1/2}$ $\left(\dfrac{1}{2}\right)^3 = \dfrac{1}{8}$.

PART B

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

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

B1. A lunch tray is being held in one hand as shown below. The mass of the tray is 0.200 kg and its centre of gravity is located at its geometric centre. On the tray is a 1.00 kg plate of food and a 0.250 kg cup of coffee. The tray is being held parallel to the floor and all forces on the tray are acting perpendicularly to it.
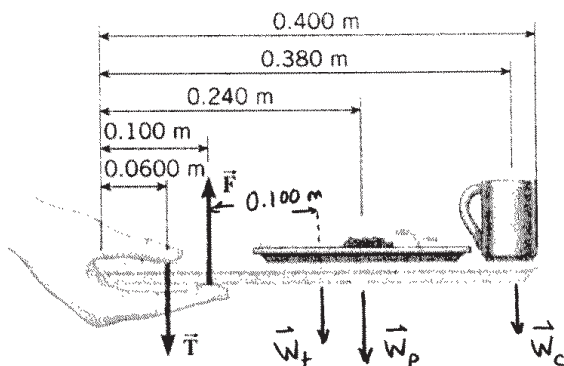
(a) Calculate the magnitude of the force $\vec{T}$ exerted on the tray by the thumb. (5 marks)

$$\boxed{56.4 \text{ N}}$$

Choose axis of rotation at fingers and apply $\Sigma \tau = 0$.

$$\Sigma \tau = \tau_T + \tau_{W_t} + \tau_{W_p} + \tau_{W_c} = 0$$

$$T\ell_T - W_t \ell_t - W_p \ell_p - W_c \ell_c = 0$$

$$T = \left(\frac{(0.200\text{kg})(0.100\text{m}) + (1.00\text{kg})(0.140\text{m}) + (0.250\text{kg})(0.280\text{m})}{0.0400\text{m}} \right) g$$

$$T = 56.4 \text{ N}$$

(b) Calculate the magnitude of the force $\vec{F}$ exerted on the tray by the fingers. If you did not obtain an answer for (a), use a value of 60.0 N. (5 marks)

$$\Sigma \vec{F} = 0$$

$$\boxed{70.6 \text{ N}}$$

$$F - T - W_t - W_p - W_c = 0$$

$$F = (0.200\text{kg} + 1.00\text{kg} + 0.250\text{kg})(9.80\text{m/s}^2) + 56.4\text{N}$$

$$F = 70.6 \text{ N}$$

Alt. answer: 74.2 N

B2. Suppose air, with a density of 1.29 kg/m^3, is flowing into a Venturi meter, as shown in the accompanying figure. The narrow section of the pipe at point A has a diameter that is 1/3 of the diameter of the larger section of the pipe at point B. The U-shaped tube is filled with water and the difference in height, h, between the two sections of pipe is 1.75 cm. You may assume that the air can be treated as an incompressible fluid.
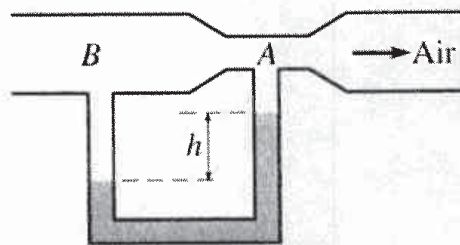
(a) Calculate the pressure difference $P_B - P_A$. (4 marks)

$$P_B = P_A + \rho g h$$

$$P_B - P_A = \rho_w g h = (1000 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(0.0175 \text{ m})$$

$$P_B - P_A = 171.5 \text{ Pa} \simeq 172 \text{ Pa}$$

$$\boxed{172 \text{ Pa}}$$

(b) Calculate x, the factor by which the speed of the air at A, v_A, is related to the speed of the air at B, v_B. i.e. $v_A = x v_B$; calculate x. (3 marks)

$$\text{Continuity} \Rightarrow A_B v_B = A_A v_A$$

$$\frac{\pi d_B^2}{4} v_B = \frac{\pi d_A^2}{4} \cdot v_A \quad \text{and given that} \quad d_A = \frac{d_B}{3}$$

$$\frac{\pi d_B^2}{4} v_B = \frac{\pi}{4}\left(\frac{d_B}{3}\right)^2 \cdot v_A \Rightarrow v_B = \frac{v_A}{9}$$

$$v_A = 9 v_B$$

$$\boxed{9.00}$$

(c) Calculate v_B, the speed of the air at point B. If you did not obtain an answer for (a), use a value of 175 Pa. If you did not obtain an answer for (b), use a value of 6.00. (4 marks)

Bernoulli's Principle : (no change in height)

$$P_B + \frac{1}{2}\rho_a v_B^2 = P_A + \frac{1}{2}\rho_a v_A^2$$

$$P_B - P_A = \frac{1}{2}\rho_a(9 v_B)^2 - \frac{1}{2}\rho_a v_B^2$$

$$P_B - P_A = \frac{1}{2}\rho_a \cdot 80 v_B^2$$

$$v_B = \sqrt{\frac{P_B - P_A}{40 \rho_a}} = \sqrt{\frac{171.5 \text{ Pa}}{40 (1.29 \text{ kg/m}^3)}} = 1.82 \text{ m/s}$$

$$\boxed{1.82 \text{ m/s}}$$

Alt. answer : 2.78 m/s

B3. As shown in the accompanying figure, a 12.0-cm-long cylindrical chamber has an 8.00 cm diameter piston attached to one end. The piston is connected to an ideal spring as shown. Initially, the gas inside the chamber is at atmospheric pressure and 20.0 °C and the spring is not compressed. When 0.0650 mol of gas is added to the chamber at 20.0 °C, the spring compresses a distance of $\Delta x = 5.40$ cm.

8.00 cm

12.0 cm   5.40 cm
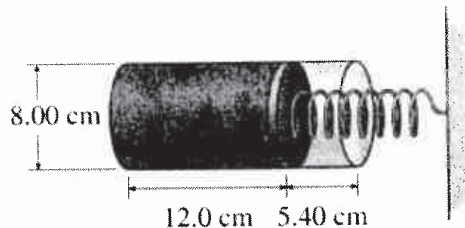
(a) Calculate the initial number of moles of gas in the chamber; i.e. the number of moles in the chamber before the 0.0650 mol are added. Remember that the chamber is initially at atmospheric pressure. (3 marks)

$$P_1 V_1 = n_1 R T_1$$

$$n_1 = \frac{P_1 V_1}{R T_1} = \frac{(1.013 \times 10^5 \, Pa)\left(\pi \left(\frac{0.0800 m}{2}\right)^2 \cdot 0.120 m\right)}{(8.314 \, J/K \cdot mol)(20.0°C + 273.15)}$$

$$\boxed{0.0251 \text{ mol}}$$

$$n_1 = 0.0251 \text{ mol}$$

(b) Calculate the new pressure in the chamber after the spring compresses. If you did not obtain an answer for (a), use a value of 0.0300 moles. (4 marks)

T (and R) do not change.

$$\boxed{2.52 \times 10^5 \, Pa}$$

$$\frac{P_1 V_1}{n_1} = \frac{P_2 V_2}{n_2}$$

$$P_2 = \left(\frac{n_2}{n_1}\right)\left(\frac{V_1}{V_2}\right) \cdot P_1 = \left(\frac{n_1 + 0.0650 mol}{n_1}\right)\left(\frac{\pi d^2/4 \cdot (0.120 m)}{\pi d^2/4 \cdot (0.174 m)}\right) \cdot P_{atm}$$

$$P_2 = 2.52 \times 10^5 \, Pa$$

Alt. Answer: $2.21 \times 10^5 \, Pa$

(c) Calculate the spring constant of the spring. Note that the pressure outside the chamber is atmospheric pressure. If you did not obtain an answer for (b), use a value of 2.21×10^5 Pa. (3 marks)

$$P_2 = P_1 + \frac{F_{spring}}{A} = P_1 + \frac{k x}{A}$$

$$\boxed{1.40 \times 10^4 \, N/m}$$

$$k = \frac{(P_2 - P_1)A}{\Delta x} = \frac{(2.52 - 1.013) \times 10^5 \, Pa \cdot \pi \left(\frac{0.0800 m}{2}\right)^2}{0.0540 m} = 1.40 \times 10^4 \, N/m$$

Alt answer: $1.11 \times 10^4 \, N/m$

B4. Consider two lenses: a converging lens whose focal points are a distance of 10.0 cm from the centre of the lens; and a diverging lens whose focal points are a distance of 16.7 cm from the centre of the lens.

(a) An object is placed a distance of 25.0 cm from the converging lens. Draw the ray diagram showing the location of the image that is formed. To obtain full marks you must draw all three principal rays. (3 marks)
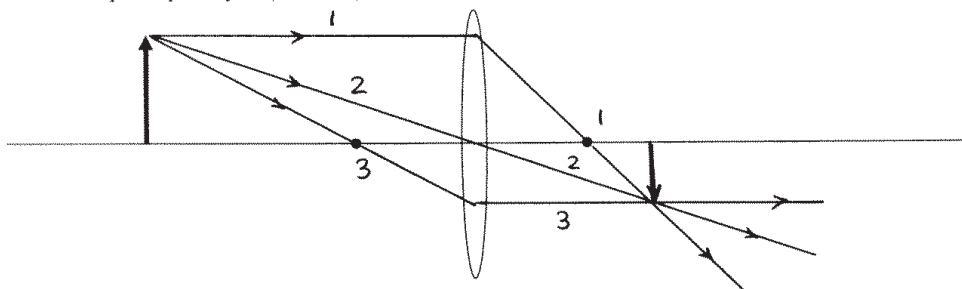
(b) Calculate the distance of the image from the converging lens. (2 marks)

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

$$q = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1} = \left(\frac{1}{+10.0\,cm} - \frac{1}{+25.0\,cm}\right)^{-1} = 16.7\,cm$$

$$\boxed{16.7\,cm}$$

(c) Without changing the position of the object or converging lens, the diverging lens is now placed between the object and the converging lens, a distance of 10.0 cm from the object. Based on the properties of a diverging lens, does the final image form closer to or further from the converging lens? (1 mark)

diverging ⇒ spreading apart

$$\boxed{further}$$

(d) For the situation described in (c), calculate the distance of the final image from the converging lens. (4 marks)
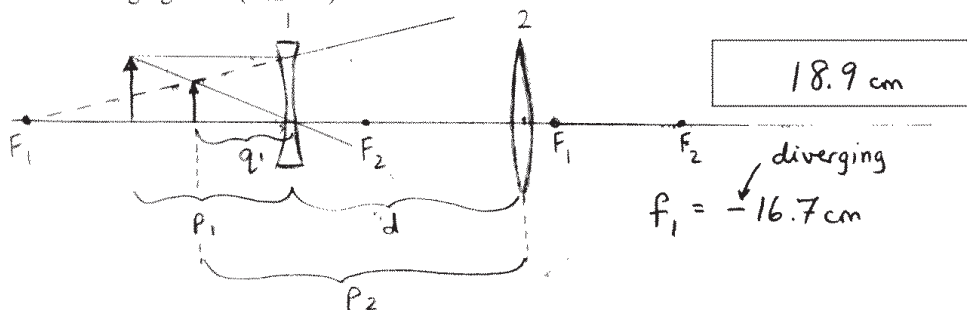
$$f_1 = -16.7\,cm$$

$$q_1 = \left(\frac{1}{f_1} - \frac{1}{p_1}\right)^{-1} = \left(\frac{1}{-16.7\,cm} - \frac{1}{+10.0\,cm}\right)^{-1} = -6.255\,cm$$

$$p_2 = |q_1| + d = 6.255\,cm + 15.0\,cm = 21.25\,cm$$

$$q_2 = \left(\frac{1}{f_2} - \frac{1}{p_2}\right)^{-1} = \left(\frac{1}{+10.0\,cm} - \frac{1}{21.25\,cm}\right)^{-1} = 18.9\,cm$$

$$\boxed{18.9\,cm}$$

B5. A particular grating has 302 slits per mm. Light from a mercury source is used to illuminate the grating. Four of the mercury spectral lines have wavelengths of 405 nm (violet), 435 nm (blue), 580 nm (yellow), and 691 nm (red).

(a) Calculate the slit separation, d, for the grating. (2 marks)

$$d = \frac{1 \text{ mm}}{302} = 3.31 \times 10^{-3} \text{ mm} \times \frac{10^6 \text{ nm}}{\text{mm}}$$

$$= 3.31 \times 10^3 \text{ nm}$$

$$\boxed{3.31 \times 10^{-3} \text{ mm}}$$

(b) Calculate the angular location of the 4th order 435-nm-wavelength spectral line. If you did not obtain an answer for (a) use a value of 3.00×10^{-3} mm. (2 marks)

$$m\lambda = d \sin\theta$$

$$\theta = \text{invsin}\left(\frac{m\lambda}{d}\right) = \text{invsin}\left(\frac{4(435 \text{ nm})}{3.31 \times 10^3 \text{ nm}}\right)$$

$$\boxed{31.7°}$$

$$\theta = 31.7°$$

Alt. Answer : 35.5°

(c) Calculate the maximum value of the order m for which all four wavelengths are visible. (3 marks).

For a given order, red occurs at the largest angle.

$$\boxed{4}$$

$$m_{max} \leq \frac{d \sin\theta_{max}}{\lambda_{red}} = \frac{3.31 \times 10^{+3} \text{ nm} \sin 90°}{691 \text{ nm}} = 4.79$$

m is an integer so $m_{max} = 4$

(Same answer using $d = 3.00 \times 10^{-3}$ mm)

(d) Calculate the speed of an electron that has a de Broglie wavelength of 435 nm. (3 marks).

$$\lambda = \frac{h}{p} \text{ and } p = mv \Rightarrow \lambda = \frac{h}{mv}$$

$$\boxed{1.67 \times 10^3 \text{ m/s}}$$

$$v = \frac{h}{m\lambda} = \frac{6.626 \times 10^{-34} \text{ J·s}}{(9.109 \times 10^{-31} \text{ kg})(435 \times 10^{-9} \text{ m})}$$

$$v = 1.67 \times 10^3 \text{ m/s} = 1.67 \text{ km/s}$$

B6. One of the nuclides produced in a fission power reactor is $^{131}_{53}I$. $^{131}_{53}I$ has a half-life of 8.03 days. $^{131}_{53}I$ is not produced directly by the neutron-induced fission of $^{235}_{92}U$ but rather is a product of the decays of other nuclides.

(a) Consider the following neutron-induced fission reaction: $n + ^{235}_{92}U \rightarrow ^{131}_{50}Sn + ^{A}_{Z}X + 3n$

Calculate the values of A and Z for the reaction product X. (2 marks)

$$1 + 235 = 131 + A + 3 \Rightarrow A = 102$$

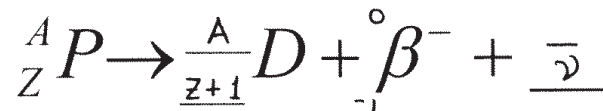$$0 + 92 = 50 + Z + 0 \Rightarrow Z = 42$$

A: | 102 |

Z: | 42 |

(b) Consider the generic β^- decay reaction shown below. P refers to the parent nucleus and D refers to the daughter nucleus. Fill-in the blanks to show the atomic number and mass number of the daughter nucleus, D, in terms of Z and A. Also fill-in the blank to show the third decay product. (2 marks)

$$^A_Z P \rightarrow ^{A}_{Z+1} D + ^{0}_{-1}\beta^- + \bar{\nu}$$

(c) After a series of β^- decays, $^{131}_{50}Sn$ has transformed into $^{131}_{53}I$. Starting with $^{131}_{50}Sn$, how many β^- decays must occur for $^{131}_{53}I$ to be formed? (1 mark)

Each β^- decay increases Z by 1 so 3 β^- decays are required to form $^{131}_{53}I$ from $^{131}_{50}Sn$

| 3 |

(d) The Nuclear Safety Commission has determined that intake of drinking water is to be restricted if the $^{131}_{53}I$ activity in a sample exceeds 300 Becquerel/kg. On March 20, 2011 the activity of $^{131}_{53}I$ in a sample obtained from a water supply near the damaged Fukushima Daiichi reactors in Japan was measured to be 965 Becquerel/kg. Calculate the number of days required for the activity of $^{131}_{53}I$ in the sample to decrease to 300 Becquerel/kg. (5 marks)

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

| 13.5 d |

so $\quad R = R_0 e^{-0.693t/T_{1/2}}$

$$\frac{R}{R_0} = e^{-0.693t/T_{1/2}}; \quad \ln\left(\frac{R}{R_0}\right) = -\frac{0.693t}{T_{1/2}}$$

$$t = -\frac{T_{1/2}}{0.693} \ln\left(\frac{R}{R_0}\right)$$

$$t = -\frac{8.03d}{0.693} \ln\left(\frac{300}{965}\right) = 13.5 \, d$$

END OF EXAMINATION