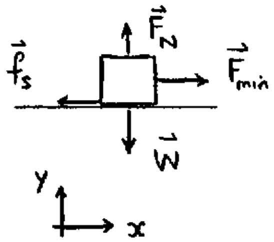
Student No.: ____________________

PART B

FOR EACH OF THE FOLLOWING PROBLEMS, B1 TO B10, ON PAGES 5 TO 8, WORK OUT THE SOLUTION IN THE SPACE PROVIDED AND ENTER YOUR ANSWERS ON PAGE 8.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1. A box of mass 2.25 kg is at rest on a horizontal surface. The coefficient of static friction between the box and the surface is 0.650. Calculate the minimum horizontal force required to move the box.



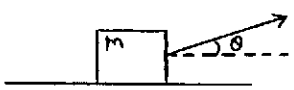
$$\sum \vec{F}_y = 0 \Rightarrow F_N - W = 0 \Rightarrow F_N = mg$$

$$\sum \vec{F}_x = 0 \Rightarrow F_{min} - f_s^{MAX} = 0$$

$$F_{min} = f_s^{MAX} = \mu_s F_N = \mu_s mg$$

$$F_{min} = (0.650)(2.25\text{ kg})(9.80\text{ m/s}^2) = 14.3\text{ N}$$

B2. A rope is pulling a box of mass 50.0 kg across a rough horizontal surface. The tension in the rope is 205 N and the rope makes an angle of 35.0° above the horizontal. Calculate the work done on the box by the rope as the box is pulled through a distance of 2.60 m.



$$W = (F\cos\theta)s$$

$$W = (205\text{ N}\cos 35.0°)(2.60\text{ m})$$

$$W = 437\text{ N}\cdot\text{m}$$

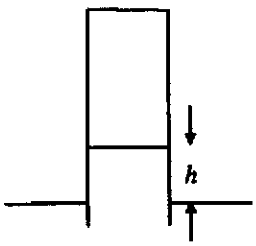
B3. A uniform, solid, horizontal disk of mass 155 kg and radius 1.50 m is set in motion by wrapping a rope about the rim of the disk and pulling on the rope. Calculate the angular acceleration of the disk when the net torque acting on it is 338 N·m.

$$\sum \tau = I\alpha \Rightarrow \alpha = \frac{\sum \tau}{I} = \frac{\sum \tau}{\frac{1}{2}MR^2}$$

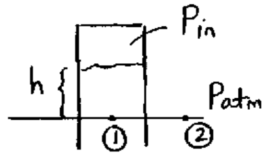
$$\alpha = \frac{338\text{ N}\cdot\text{m}}{\frac{1}{2}(155\text{ kg})(1.50\text{ m})^2} = 1.94\text{ rad/s}^2$$

continued on page 6 ...

B4. A pipe, closed at one end, is held vertically with its open end submerged in a pool of water as shown in the diagram. If the air pressure in the pipe is reduced to one-quarter that of atmospheric pressure, to what height, h, will water rise in the pipe? (atmospheric pressure = 1.01×10^5 Pa, density of water = 1.00×10^3 kg/m^3)



water



$$P_1 = P_2$$

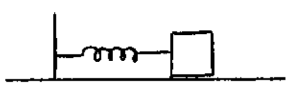
$$P_{in} + \rho g h = P_{atm}$$

$$\rho g h = P_{atm} - P_{in}$$

$$h = \frac{P_{atm} - P_{in}}{\rho g} = \frac{P_{atm} - \frac{1}{4} P_{atm}}{\rho g}$$

$$h = \frac{\frac{3}{4}(1.01 \times 10^5 \text{ N/m}^2)}{(1.00 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)} = 7.73 \text{ m}$$

B5. An object of mass 0.250 kg, attached to an ideal spring of spring constant 550 N/m, is moving in simple harmonic motion on a horizontal frictionless surface. The amplitude of the motion is 0.475 m. Calculate the speed of the object as it passes through the equilibrium position.



Cons. of Mech. Energy:

$$E_{x=0} = E_{x=A}$$

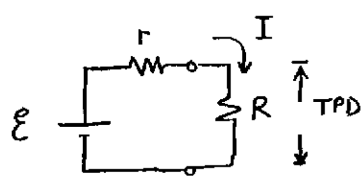
$$KE_{x=0} + PE_{x=0} = KE_{x=A} + PE_{x=A}$$

$$\frac{1}{2} m v^2 + 0 = 0 + \frac{1}{2} kA^2$$

$$v = \sqrt{\frac{k}{m}}\, A = \sqrt{\frac{550 \text{ N/m}}{0.250 \text{ kg}}} \cdot 0.475 \text{ m}$$

$$v = 22.3 \text{ m/s}$$

B6. A flashlight battery of emf 1.50 V has an internal resistance of 0.0550 Ω. Calculate the potential difference across its terminals when the battery is delivering a current of 2.00 A.



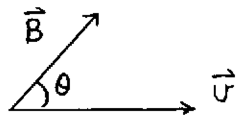
$$TPD = \mathcal{E} - Ir$$

$$TPD = 1.50\text{V} - (2.00\text{A})(0.0550\,\Omega)$$

$$TPD = 1.39\text{V}$$

continued on page 7 ...

B7. A proton moves with a speed of 8.00×10^6 m/s and enters a magnetic field of magnitude 2.50 T directed at an angle of 60.0° to the initial velocity of the proton. Calculate the magnitude of the acceleration of the proton.



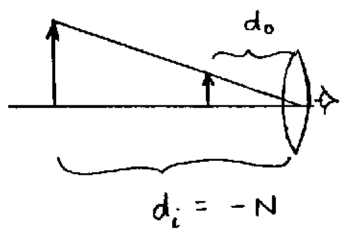
$$F = q_0 v B \sin\theta \quad ; \quad \Sigma \vec{F} = m\vec{a}$$

$$a = \frac{q_0 v B \sin\theta}{m}$$

$$a = \frac{(1.60\times10^{-19}\,C)(8.00\times10^{6}\,m/s)(2.50\,T)(\sin 60.0°)}{1.67\times10^{-27}\,kg}$$

$$a = 1.66\times10^{15}\,m/s^2$$

B8. A jeweller's loupe is a small magnifying glass (converging lens) that is held close to the eye. A particular loupe has a focal length of 4.00 cm. Calculate the distance from the loupe at which an object must be held (the object distance) so that a jeweller with a near point of 30.0 cm achieves maximum angular magnification.



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

$$d_o = \left(\frac{1}{f} - \frac{1}{d_i}\right)^{-1}$$

$$d_o = \left(\frac{1}{4.00\,cm} - \frac{1}{-30.0\,cm}\right)^{-1}$$

$$d_o = 3.53\,cm$$

B9. Calculate the wavelength of the $n = 4$ to $n = 2$ transition in a hydrogen atom. Express your answer in nm.

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\lambda = \left[(1.10\times10^{7}\,m^{-1})(1)^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right)\right]^{-1} = 485\,nm$$

continued on page 8 ...

B10. Calculate the energy released in the following fusion reaction: $^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He$
(Atomic masses: $m(^{2}_{1}H) = 2.014102$ u; $m(^{4}_{2}He) = 4.002603$ u)

$$Q = [2(2.014102u) - 4.002603u] \cdot 931.5 \frac{MeV}{u}$$

$$Q = 23.8 \text{ MeV}$$

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	14.3 N	**B6**	1.39 V
B2	437 N·m	**B7**	1.66×10^{15} m/s²
B3	1.94 rad/s²	**B8**	3.53 cm
B4	7.73 m	**B9**	485 nm
B5	22.3 m/s	**B10**	23.8 MeV

continued on page 9 ...

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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.

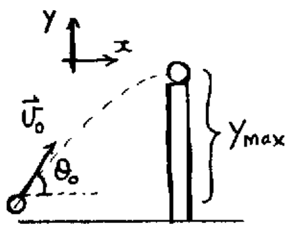
THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

<u>SHOW YOUR WORK</u> – 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 snowball of mass 0.125 kg is thrown at another snowball of mass 0.650 kg that is sitting on top of a post. The thrown ball has an initial speed of 22.0 m/s at an angle of 50.0° above the horizontal. The thrown ball is at its maximum height when it hits the ball on the post.

(a) Calculate the height of the thrown ball above its launch point when it hits the ball on the post.



At max. height, $v_y = 0$

$\boxed{14.5 \text{ m}}$

from $v_y^2 = v_{0y}^2 + 2ay$

$$y_{max} = \frac{v_y^2 - v_{0y}^2}{2a} = \frac{-(v_0 \sin\theta_0)^2}{2a}$$

$$y_{max} = \frac{-[(22.0 \text{ m/s})(\sin 50.0°)]^2}{2(-9.80 \text{ m/s}^2)} = 14.5 \text{ m}$$

(b) Calculate the speed of the thrown ball just before it hits the ball on the post.

Since thrown ball is at max. height just before hitting ball on post,

$\boxed{14.1 \text{ m/s}}$

$$v = v_{0x} = v_0 \cos\theta_0 = (22.0 \text{ m/s})(\cos 50.0°) = 14.1 \text{ m/s}$$

Alternate Sol'n: (Cons. of Energy)

$E_f = E_0$

$KE_f + PE_f = KE_0 + PE_0$

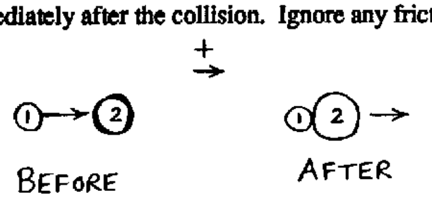
$\frac{1}{2}mv_f^2 + mgh_f = \frac{1}{2}mv_0^2 + 0$

$v_f = \sqrt{v_0^2 - 2gy_{max}}$

$v_f = \sqrt{(22.0 \text{ m/s})^2 - 2(9.80 \text{ m/s}^2)(14.5 \text{ m})}$

$v_f = 14.1 \text{ m/s}$

(c) The collision between the two balls is completely inelastic. Calculate the speed of the balls immediately after the collision. Ignore any frictional effects between the balls and the post.



$\boxed{2.27 \text{ m/s}}$

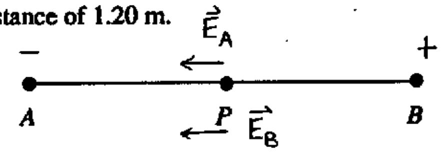
Cons. of Linear momentum

$m_1 v_1 = (m_1 + m_2) v_2'$

$$v_2' = \frac{m_1 v_1}{m_1 + m_2} = \frac{(0.125 \text{ kg})(14.1 \text{ m/s})}{(0.125 \text{ kg} + 0.650 \text{ kg})} = 2.27 \text{ m/s}$$

continued on page 10 ...

C2. Consider two point charges, *A* and *B*, separated by a distance of 1.20 m.
$q_A = -1.50 \times 10^{-6}$ C and $q_B = +4.20 \times 10^{-6}$ C



(a) Calculate the electric field (magnitude and direction) at point *P* midway between the charges. Specify direction as either toward *A* or toward *B*.

$$|\vec{E}_P| = |\vec{E}_A| + |\vec{E}_B|$$

magnitude: $\boxed{1.43 \times 10^5 \text{ N/C}}$

direction: $\boxed{\text{toward A}}$

$$E_P = \frac{k|q_A|}{r_A^2} + \frac{k|q_B|}{r_B^2}$$

$$E_P = \frac{k}{r^2}\left(|q_A| + |q_B|\right) = \frac{\left(9.00 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(|-1.50 \times 10^{-6}\text{C}| + |4.20 \times 10^{-6}\text{C}|\right)}{(0.600\text{ m})^2}$$

$$E_P = 1.43 \times 10^5 \text{ N/C}$$

(b) Calculate the absolute electrostatic potential at point *P*.

$\boxed{4.05 \times 10^4 \text{ V}}$

$$V_P = V_A + V_B$$

$$V_P = \frac{kq_A}{r_A} + \frac{kq_B}{r_B} = \frac{k}{r}(q_A + q_B)$$

$$V_P = \frac{9.00 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2}{0.600\text{ m}}\left(-1.50 \times 10^{-6}\text{C} + 4.20 \times 10^{-6}\text{C}\right)$$

$$V_P = 4.05 \times 10^4 \text{ V}$$

(c) An electron is now released from rest at point *P*. Calculate the acceleration of the electron immediately after its release. Specify direction as either toward *A* or toward *B*. Ignore gravitational effects.

$$\vec{F} = q_o\vec{E} \quad \text{and} \quad \Sigma\vec{F} = m\vec{a}$$

magnitude: $\boxed{2.51 \times 10^{16} \text{ m/s}^2}$

direction: $\boxed{\text{toward B}}$

$$\vec{a} = \frac{\Sigma\vec{F}}{m} = \frac{q_o\vec{E}}{m}$$

$$\vec{a} = \frac{(-1.60 \times 10^{-19}\text{C})(1.43 \times 10^5 \text{ N/C})}{9.11 \times 10^{-31}\text{ kg}} = -2.51 \times 10^{16} \text{ m/s}^2$$

opposite dir'n to $\vec{E}$

continued on page 11 ...

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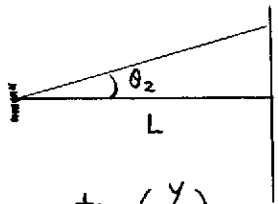
C3. Light falls on a diffraction grating which contains 3.18×10^4 lines/cm. An interference pattern is observed on a screen which is placed at a distance of 2.85 m from the grating.

(a) Calculate the wavelength of light which produces a second-order maximum at a location on the screen which is 2.47 m from the central maximum.



$\boxed{103 \text{ nm}}$

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

$$d = \frac{1}{N} = \frac{1}{3.18\times10^4/\text{cm}} = 3.14\times10^{-5}\text{ cm}$$

$$\theta_2 = \arctan\left(\frac{Y}{L}\right)$$

$$\theta_2 = \arctan\left(\frac{2.47\text{m}}{2.85\text{m}}\right)$$

$$\theta_2 = 40.9^\circ$$

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

$$\lambda = \frac{(3.14\times10^{-5}\text{cm})\sin 40.9^\circ}{2}$$

$$\lambda = 1.03\times10^{-5}\text{cm} = 103\text{ nm}$$

(b) Suppose a slit is cut into the screen at this point, so that only light of this wavelength passes through. This light then falls on a plate made of zinc. Calculate the maximum kinetic energy of the photoelectrons which are emitted from the zinc plate. The work function for zinc is 4.31 eV.

$\boxed{7.75 \text{ eV}}$

$$hf = KE_{max} + W_0$$

$$KE_{max} = hf - W_0 = \frac{hc}{\lambda} - W_0$$

$$KE_{max} = \frac{(4.14\times10^{-15}\text{eV}\cdot\text{s})(3.00\times10^8\text{m/s})}{103\times10^{-9}\text{m}} - 4.31\text{ eV}$$

$$KE_{max} = 7.75\text{ eV}$$

(c) The photoelectrons are accelerated towards an anode by a potential difference of 10,500 V. Calculate the minimum wavelength in the X-ray bremsstrahlung spectrum. *[Hint: the initial KE of the photoelectrons is negligible.]*

$\boxed{1.18\times10^{-10}\text{ m}}$

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

$$\lambda_0 = \frac{(4.14\times10^{-15}\text{eV}\cdot\text{s})(3.00\times10^8\text{ m/s})}{e\,(10{,}500\text{V})} = 1.18\times10^{-10}\text{ m}$$

END OF EXAMINATION