UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3 – Physics and the Universe

FINAL EXAMINATION

December 14, 2013 Time: 3 hours

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

LECTURE SECTION (please check):

- ❑ 01 B. Zulkoskey
- ❑ 02 Dr. R. Pywell
- ❑ 03 Dr. M. Ghezelbash
- ❑ 97 Dr. R. Kleiv
- ❑ C15 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, including this cover page. **It is the responsibility of the student to check that the test paper is complete**.
3. Only a basic scientific calculator (e.g. Texas Instruments TI-30X series, Hewlett-Packard HP 10s or 30S) may be used. Graphing or programmable calculators, or calculators with communication capability, are **not** allowed.
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 NSID 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	

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. You use a tape measure to find the width of a room. You can read the tape measure to the nearest millimetre. The width of the room is approximately 3 metres. How many significant digits will be in your measured width of the room?

C

$3\ \text{m} = 3000\ \text{mm}$

(A) 2 (B) 3 (C) 4 (D) 5
(E) The answer depends on the units used to quote the answer (e.g. metres or millimetres).

A2. A car is travelling in a straight line with an initial speed υ_0. The car accelerates with a constant acceleration a for a time interval t. Which one of the following statements is correct?

D

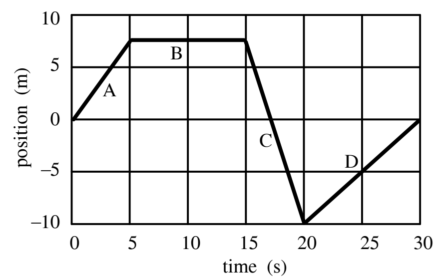
(A) The distance moved by the car in the time interval t is $\frac{1}{2}at^2$.
(B) The final speed of the car is at^2.
(C) The distance moved by the car in the time interval t is $\frac{\upsilon_0^2}{2a}$.
(D) The change in the velocity of the car in the time interval t is at.
(E) The average velocity of the car in the time interval t is $\frac{1}{2}(\upsilon_0 + at)$.

$\upsilon = \upsilon_0 + at \Rightarrow \upsilon - \upsilon_0 = at$

$\Delta x = \upsilon_0 t + \frac{1}{2}at^2$

$\upsilon^2 = \upsilon_0^2 + 2a\Delta x$

A3. An object is moving along a straight line in the positive x direction. The graph shows its position from the starting point as a function of time. During which interval(s) did the object move in the negative x direction?



C

(A) only during interval A
(B) only during interval B
(C) only during interval C
(D) only during interval D
(E) during both intervals C and D

A4. Two students are on the roof of a building. One of the students throws a heavy red ball horizontally from the top of the building with an initial speed υ_0, while at the same time the other student drops a lighter blue ball from rest straight down. Neglecting air resistance, which one of the following statements is true?

D

vertical motion is identical

$\Delta y = \upsilon_{0y}t + \frac{1}{2}a_y t^2 = \frac{1}{2}(-g)t^2$

$t = \sqrt{\frac{2\Delta y}{-g}}$

(A) The blue ball reaches the ground first.
(B) The red ball reaches the ground first.
(C) Both balls hit the ground with the same speed.
(D) Both balls reach the ground at the same time.
(E) Both balls hit the ground with the same velocity.

A5. A constant force F is applied to a mass m on a horizontal frictionless surface. As the speed of the mass increases at a constant rate, the power delivered to the mass by the force…

B

(A) remains constant.
(B) increases in proportion to the time.
(C) decreases in proportion to the time.
(D) increases in proportion to the square of the time.
(E) decreases in proportion to the square of the time.

$P = F\upsilon = ma\upsilon$

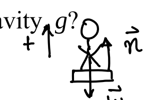
m and a are constant

$P \propto \upsilon$ and υ increases in proportion to the time (constant $\vec{a}$)

A6. A person stands on a scale in an elevator. As the elevator accelerates upward, the reading on the scale is 1.2 times the reading when the elevator was at rest. What is the magnitude of the acceleration of the elevator, in relation to the magnitude of the acceleration due to gravity, g?

A

(A) $0.2g$ (B) $0.1g$ (C) $1.1g$ (D) $1.2g$ (E) $2.2g$



$n - mg = ma$

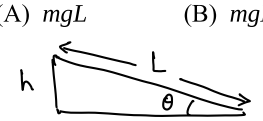
$1.2mg - mg = ma$

$0.2g = a$

A7. A brick of mass m slides down a ramp that has length L and is inclined at an angle θ to the horizontal. If the brick slides down the entire ramp, what is the work done by gravity on the brick?

C

(A) mgL (B) $mgL\cos\theta$ (C) $mgL\sin\theta$ (D) $mgL\tan\theta$ (E) $mgL\cot\theta$



$W_{grav} = -\Delta PE_{grav} = -(0 - mgh)$

$W_{grav} = mgh = mgL\sin\theta$

continued on page 3...

A8. Two objects undergo a completely elastic collision. Which one of the following statements is **FALSE**?

D

(A) The change in the momentum of one object is equal and opposite to the change in the momentum of the other object. T (Cons. of Momentum)
(B) The net external force acting on the objects during the collision is zero. T
(C) Momentum is conserved in the collision. T
(D) The total kinetic energy increases as a result of the collision. F $\Delta KE = 0$ for an elastic collision
(E) The magnitude of the impulse acting on each object is the same. T

A9. A motor causes a merry-go-round and its riders to rotate at a constant angular speed. As a rider moves from the rim of the merry-go-round toward its centre, the magnitude of the centripetal force acting on the rider… $F_r = ma_c = mr\omega^2$; ω constant, so $F_r \downarrow$ as $r \downarrow$

B

(A) increases.
(B) decreases.
(C) remains the same.
(D) is always zero.
(E) changes depending on the direction of rotation.

A10. Consider an object sitting on a rotating disk a distance *r* from the disk's centre. The object is held in place on the disk by static friction. Which one of the following statements is **FALSE**?

B

(A) If the angular speed is constant, the object must have constant tangential speed. T
(B) If the angular speed is constant, the object has no acceleration. F $a_c = r\omega^2 \neq 0$
(C) The object has a tangential acceleration only if the disk has an angular acceleration. T $a_t = r\alpha$
(D) If the disk has an angular acceleration, the object has both a centripetal and a tangential acceleration. T
(E) The object always has a centripetal acceleration except when the angular speed is zero. T

A11. A stunt rider is driving a motorcycle around a vertical loop-the-loop at constant speed. Which one of the following statements is correct concerning the normal force of the loop on the motorcycle?

B

(A) The normal force has greatest magnitude at the top of the loop.
(B) The normal force has greatest magnitude at the bottom of the loop.
(C) The normal force is the same everywhere on the loop.
(D) The normal force has greatest magnitude when the motorcycle is moving vertically upward.
(E) The normal force has greatest magnitude when the motorcycle is moving vertically downward.

F_r is constant in magnitude and $\vec{w}$ is exactly opposite $\vec{F}_r$ at the bottom
$\therefore$ $\vec{n}$ must have max magnitude at bottom

A12. A satellite is moving in a stable, circular orbit around the Earth. Which one of the following statements is **FALSE**?

A

(A) The speed of the satellite depends on the mass of the satellite.
(B) The speed of the satellite depends on the mass of the Earth.
(C) The speed of the satellite depends on the radius of the orbit.
(D) The speed of the satellite depends on the universal gravitational constant.
(E) The speed of the satellite depends on the acceleration due to gravity at its location.

$F_r = ma_c$
$\frac{GM_E m}{r^2} = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{GM_E}{r}}$
$a_c = g_{eff} = \frac{v^2}{r}$
$v = \sqrt{g_{eff} \cdot r}$

A13. An object with mass *m* and moment of inertia *I* is spinning with an angular momentum *L*. The kinetic energy is equal to… $KE = \frac{1}{2}I\omega^2 = \frac{1}{2}\frac{(I\omega)^2}{I} = \frac{1}{2}L^2/I$

B

(A) $\frac{I^2}{2L}$. (B) $\frac{L^2}{2I}$. (C) $\frac{L^2}{2m}$. (D) $\frac{I^2}{2m}$. (E) none of the above.

A14. A stick of length *L* and mass *M*, with its lower end attached to a table by a hinge, is allowed to fall from a vertical position. What is the angular speed of the stick when it hits the table? Cons. of Energy

E

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

$KE_f = PE_i$
$\frac{1}{2}I\omega^2 = Mg\frac{L}{2}$
$\frac{1}{2}\left(\frac{1}{3}ML^2\right)\omega^2 = \frac{MgL}{2}$
$\omega = \sqrt{\frac{3g}{L}}$

A15. You are trying to remove a lug nut to change a flat tire. A wrench is used to apply a perpendicular force of magnitude *F* at a distance of *r* from the centre of the nut but it doesn't rotate. You then obtain a pole that you attach to the end of your wrench and apply the same perpendicular force of magnitude *F* at a distance of 3*r* from the nut. By what factor is the torque, τ_2, that you are now applying to the lug nut increased compared to the original torque, τ_1?

B

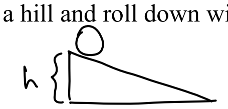
(A) $\tau_2 = 2\tau_1$ (B) $\tau_2 = 3\tau_1$ (C) $\tau_2 = 4\tau_1$ (D) $\tau_2 = 6\tau_1$ (E) $\tau_2 = 9\tau_1$

$\tau = rF\sin\theta$
$\tau_1 = rF$ $\tau_2 = (3r)F \Rightarrow \tau_2 = 3\tau_1$

continued on page 4...

A16. Consider two uniform, solid spheres: a large, massive sphere and a smaller, lighter sphere. They are simultaneously released from rest at the top of a hill and roll down without slipping. Which one reaches the bottom of the hill first?

D



(A) The large sphere reaches the bottom first.
(B) The small sphere reaches the bottom first.
(C) The sphere with the greater density reaches the bottom first.
(D) The spheres reach the bottom at the same time.
(E) The answer depends on the values of the spheres' masses and radii.

$KE_f = PE_i$

$\frac{1}{2}mv_f^2 + \frac{1}{2}I\omega_f^2 = mgh$

$\frac{1}{2}\cancel{m}v_f^2 + \frac{1}{2}\left(\frac{2}{5}\cancel{m}\cancel{R^2}\right)\frac{v_f^2}{\cancel{R^2}} = \cancel{m}gh$

A17. A star originates as a large body of slowly rotating gas. Because of gravitational attraction, this large body of gas slowly decreases in size. Which one of the following statements correctly describes what happens as the radius of the body of gas decreases?

E

(A) Both the angular momentum and the angular velocity increase.
(B) The angular momentum increases and the angular velocity decreases.
(C) Both the angular momentum and the angular velocity decrease.
(D) Both the moment of inertia and the angular velocity increase.
(E) The angular momentum remains constant and the angular velocity increases.

Cons. of Angular Momentum

$I_i\omega_i = I_f\omega_f$

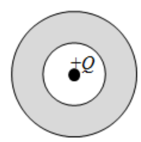
$I_f < I_i \Rightarrow \omega_f > \omega_i$

A18. A conducting sphere is initially uncharged. A negative charge is brought near to the sphere, but does not touch it. While the negative charge is near the sphere, a wire connected to ground is momentarily touched to the sphere on the side that is furthest from the charge. The negative charge is then removed. What will be the final state of the sphere?

E

(A) It will have a positive charge on the side that was near the charge brought near it, and a negative charge on the other side.
(B) It will have a negative charge on the side that was near the charge brought near it, and a positive charge on the other side.
(C) It will be uncharged.
(D) It will have a net negative charge.
(E) It will have a net positive charge.

A19. A small positively-charged sphere is located at the centre of an uncharged spherical conducting shell. Which one of the following statements is correct?



A

(A) In the interior of the conducting shell (the shaded part) the electric field is zero. T (no $\vec{E}$ inside a conductor)
(B) In the interior of the conducting shell (the shaded part) the electric field lines point radially outward from the centre.
(C) In the interior of the conducting shell (the shaded part) the electric field lines point radially inward to the centre.
(D) There is a negative charge distributed uniformly throughout the conducting shell (the shaded part).
(E) There is a positive charge distributed uniformly throughout the conducting shell (the shaded part).

A20. A proton (charge $+e$) is released from rest in a region where the electric field is uniform and has a magnitude of E. After moving a distance d, the kinetic energy of the proton is…

C

(A) eE (B) $\frac{eE}{d}$ (C) eEd (D) Ed (E) $\frac{E}{d}$

$|\Delta KE| = |\Delta PE_{el}|$
$= q|\Delta V|$
$= qEd$
$= eEd$

A21. Which one of the following options correctly describes the result when a charged insulator is placed near an uncharged conductor?

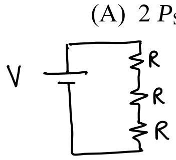
B

(A) They repel each other.
(B) They attract each other.
(C) They may repel or attract each other, depending on whether the charge on the insulator is positive or negative.
(D) They exert no electrostatic force on each other.
(E) The charged insulator always spontaneously discharges.

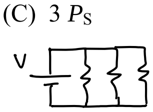
A22. Three resistors, each of which has resistance R, are connected to a battery. When all three resistors are connected in series, the total power dissipated in the resistors is P_S. In terms of P_S, what is the total power dissipated in the resistors when all three are connected in parallel?

E

(A) $2\,P_S$ (B) $P_S / 3$ (C) $3\,P_S$ (D) $P_S / 9$ (E) $9\,P_S$



$P_s = \frac{V^2}{R_{tot}} = \frac{V^2}{3R}$;



$P_p = \frac{V^2}{R_{eq}} = \frac{V^2}{R/3} = 3V^2/R = 9P_s$

continued on page 5...

 Student No.: ______________________

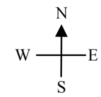
A

A23. Two resistors are made from different materials and both are made in the shape of a cylindrical wire. The one with resistance R_1 has resistivity ρ_1, length L_1, and radius r_1. The other with resistance R_2 has resistivity ρ_2, length $L_2 = 2L_1$, and radius $r_2 = 2r_1$. If $R_1 = R_2$, what is the relationship between the resistivities of the two materials? $R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2} \Rightarrow \frac{\rho_1 L_1}{\pi r_1^2} = \frac{\rho_2 (2L_1)}{\pi (2r_1)^2} = \frac{1}{2}\frac{\rho_2 L_1}{\pi r_1^2}$

(A) $\rho_2 = 2\rho_1$ (B) $\rho_2 = \frac{1}{2}\rho_1$ (C) $\rho_2 = 4\rho_1$ (D) $\rho_2 = \frac{1}{4}\rho_1$ (E) $\rho_2 = 8\rho_1$

D

A24. During a lightning strike, negative charges move vertically from a cloud to the ground. In what direction is the lightning strike deflected by the Earth's magnetic field? Assume that the Earth's magnetic field is directed toward the North.



(A) North (B) East (C) South (D) West
(E) The lightning strike is not deflected.

E

A25. A charged particle moves through a constant uniform magnetic field. Which one of the following statements is correct concerning the effect of the magnetic force on the particle and in the absence of any other forces? (Gravity can be neglected.)

(A) The kinetic energy of the particle increases regardless of the sign of the charge on the particle.
(B) The change in the kinetic energy of the particle is positive if the charge is positive, and negative if the charge is negative.
(C) There is only a change in the kinetic energy of the particle if its velocity has a component in the direction of the magnetic field direction.
(D) The change in kinetic energy of the particle depends on the magnitude of the magnetic field.
(E) The kinetic energy of the particle does not change.

$\vec{F}_{mag} \perp \vec{v} \Rightarrow$ Work $= 0 \Rightarrow \Delta KE = 0$.

PART B

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

FOR EACH OF YOUR CHOSEN PART B QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWERS IN THE BOXES PROVIDED.

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

<u>SHOW AND EXPLAIN YOUR WORK</u> – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY.

EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

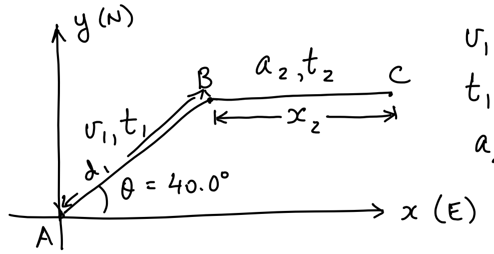
USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

continued on page 6…

Student No.: ______________________

B1. A driver of a car starts from a road intersection and travels at a constant speed of 16.7 m/s along a road in the direction of 40.0° North of East. After travelling for 30.0 s the car reaches a turn in the road and from that point the road is due East. At the turn in the road the driver starts accelerating the car at 0.700 m/s^2. The car continues with this constant acceleration and reaches a gas station 25.0 s after making the turn.

(a) Calculate the distance from the turn in the road to the gas station. (*4 marks*)

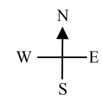


$v_1 = 16.7$ m/s

$t_1 = 30.0$ s

$a_2 = 0.700$ m/s^2, $t_2 = 25.0$ s

$\boxed{636 \text{ m}}$



$$x_2 = v_1 t_2 + \tfrac{1}{2} a_2 t_2^2$$

$$x_2 = (16.7 \text{ m/s})(25.0 \text{ s}) + \tfrac{1}{2}(0.700 \text{ m/s}^2)(25.0 \text{ s})^2$$

$$x_2 = 636 \text{ m}$$

(b) If there was a straight road that went directly from the intersection to the gas station, how long would that road be? If you did not obtain an answer for (a), use a value of 650 m. (*6 marks*)

$\boxed{1.07 \times 10^3 \text{ m}}$

i.e. What is the magnitude of the displacement from A to C?

$$AC_x = AB_x + BC_x \quad \text{and} \quad AC_y = AB_y + \underset{0}{\underset{\shortparallel}{BC_y}}$$

$$AB = d_1 = v_1 t_1 = (16.7 \text{ m/s})(30.0 \text{ s}) = 501 \text{ m}$$

$$AC_x = (501 \text{ m}) \cos 40.0° + 636 \text{ m} = 1.020 \times 10^3 \text{ m}$$

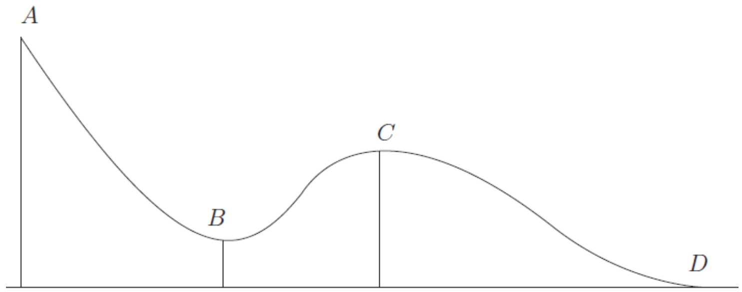
$$AC_y = (501 \text{ m}) \sin 40.0° = 322 \text{ m}$$

$$AC = \sqrt{(AC_x)^2 + (AC_y)^2} = 1.070 \times 10^3 \text{ m} = 1.07 \text{ km}$$

continued on page 7...

Student No.: ____________________

B2. A design for a water slide is shown in the diagram below. Points *A*, *B*, *C*, and *D* are 25.0 m, 5.00 m, 15.0 m, and 0.00 m above the ground level, respectively, and the water slide is frictionless. A 70.0 kg rider starts from rest at point *A*.



(a) Calculate the rider's speed at point *C*. (*3 marks*)

Frictionless $\Rightarrow$ $W_{nc} = 0$ so $E_i = E_f$

$\boxed{14.0 \text{ m/s}}$

$$KE_i + PE_{g_i} = KE_f + PE_{g_f}$$

$$\tfrac{1}{2}\cancel{m}v_A^2 + \cancel{m}gh_A = \tfrac{1}{2}\cancel{m}v_C^2 + \cancel{m}gh_C$$

$$0 + gh_A = \tfrac{1}{2}v_C^2 + gh_C \Rightarrow v_C = \sqrt{2g(h_A - h_C)}$$

$$v_C = \sqrt{2(9.80\text{ m/s}^2)(25.0\text{ m} - 15.0\text{ m})} = 14.0 \text{ m/s}$$

(b) Calculate the net work done by gravity on the rider between points *B* and *D*. (*2 marks*)

$$W_{grav_{BD}} = -\Delta PE_{grav_{BD}} = -(PE_{grav_D} - PE_{grav_B})$$

$\boxed{3.43 \times 10^3 \text{ J}}$

$$W_{grav_{BD}} = PE_{grav_B} - PE_{grav_D} = mg(h_B - h_D)$$

$$W_{grav_{BD}} = (70.0\text{ kg})(9.80\text{ m/s}^2)(5.00\text{ m} - 0) = 3.43 \times 10^3 \text{ J}$$

(c) Calculate the net work done by the normal force on the rider between points *B* and *D*. (*2 marks*)

$\vec{n}$ is alway $\perp$ to $\vec{v}$ (and displacement)

$\boxed{0}$

$\therefore$ $\theta = 90°$ in $W = (F\cos\theta)d$

$$W_n = 0$$

(d) If the design is changed so that point *C* is 10.0 m above ground level, does the rider's speed at point *D* increase, decrease, or remain the same? To obtain full marks you must explain the reasoning behind your answer. (*3 marks*)

Mechanical energy is conserved throughout the rider's motion. i.e. The speed at D depends only on the initial speed and the initial height.

$E_A = E_D \Rightarrow \cancel{m}gh_A = \tfrac{1}{2}\cancel{m}v_D^2 \Rightarrow v_D = \sqrt{2gh_A}$, independent of whether $h_C = 15.0\text{ m}$ or 10.0 m

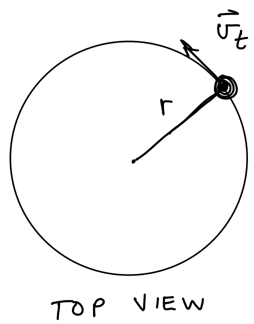
v_D remains the same

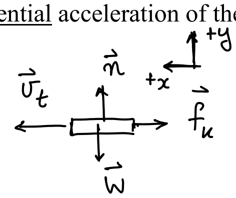
continued on page 8...

Student No.: ______________________

B3. An object of mass 367 g, moving on a horizontal surface, is tethered to a post by a wire and undergoing circular motion with a radius of 22.5 cm. The coefficient of kinetic friction between the object and the surface is 0.0128.

(a) Calculate the magnitude of the <u>tangential</u> acceleration of the object. (*4 marks*)





$\boxed{0.125\ m/s^2}$

$\Sigma F_x = ma_t$ $\quad \Sigma F_y = 0$

$-f_k = ma_t$ $\quad n - mg = 0$

$n = mg$

$-\mu_k n = ma_t$

$-\mu_k mg = ma_t$

$a_t = -\mu_k g$

$a_t = -(0.0128)(9.80\ m/s^2) = -0.125\ m/s^2$

$|a_t| = 0.125\ m/s^2$

(b) At time $t = 0.00$ s the object is moving with an angular speed of 3.25 rad/s. Calculate the angular speed of the object at $t = 1.42$ s. If you did not obtain an answer for (a), use a value of 0.130 m/s^2. (*3 marks*)

Rotational kinematics : $\omega = \omega_0 + \alpha t$

$\boxed{2.46\ rad/s}$

$\alpha = \frac{a_t}{r} = \frac{-0.125\ m/s^2}{0.225\ m} = -0.556\ rad/s^2$

$\omega = 3.25\ rad/s + (-0.556\ rad/s^2)(1.42s) = 2.46\ rad/s$

(c) Calculate the tension in the wire at $t = 1.42$. If you did not obtain an answer for (b), use a value of 2.50 rad/s. (*3 marks*)

The tension in the wire is the radial force causing the object to have a centripetal acceleration.

$\boxed{0.500N}$

$\Sigma F_r = ma_c \Rightarrow T = mr\omega^2$

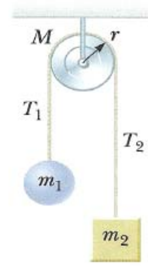
$T = (0.367\ kg)(0.225\ m)(2.46\ rad/s)^2$

$T = 0.500N$

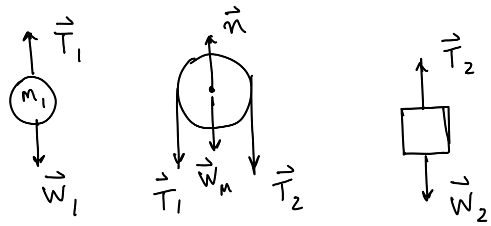
continued on page 9...

 Student No.: ______________________

B4. An Atwood's machine consists of blocks of masses m_1 = 10.0 kg and m_2 = 20.0 kg attached by a cord running over a pulley. The pulley is a solid cylinder of mass M = 8.00 kg and radius r = 0.200 m. The block of mass m_2 is allowed to drop and the cord turns the pulley without slipping.



(a) Draw the free body diagram for each object. (*2 marks*)



(b) Calculate the magnitude of the acceleration of the masses. (*4 marks*)

For each object, choose the +ve direction to be the direction of the acceleration

$\boxed{2.88 \text{ m/s}^2}$

mass 1:

$T_1 - m_1 g = m_1 a$

$T_1 = m_1(a+g)$

Pulley:

$\Sigma \tau = I\alpha$

$T_2 r - T_1 r = I\frac{a}{r}$

mass 2:

$m_2 g - T_2 = m_2 a$

$T_2 = m_2(g-a)$

$(m_2 g - m_2 a)\cancel{r} - (m_1 a + m_1 g)\cancel{r} = \frac{1}{2} M r^{\cancel{2}} \frac{a}{\cancel{r}}$

$m_2 g - m_2 a - m_1 a - m_1 g = \frac{1}{2} M a$

$m_2 g - m_1 g = \frac{1}{2} M a + m_2 a + m_1 a$

$$a = \frac{(m_2 - m_1) g}{\frac{1}{2} M + m_2 + m_1} = \frac{(20.0\text{ kg} - 10.0\text{ kg})(9.80\text{ m/s}^2)}{\frac{1}{2}(8.00\text{ kg}) + 20.0\text{ kg} + 10.0\text{ kg}} = 2.88\text{ m/s}^2$$

(c) Calculate the magnitude of the tension T_1. If you did not obtain an answer for (b), use a value of 3.00 m/s². (*2 marks*)

$\boxed{127 \text{ N}}$

$\Sigma \vec{F}_1 = m_1 \vec{a}$

$T_1 - m_1 g = m_1 a$

$T_1 = m_1(a+g) = (10.0\text{ kg})(2.88\text{ m/s}^2 + 9.80\text{ m/s}^2)$

$T_1 = 127\text{ N}$

(d) Calculate the magnitude of the tension T_2. If you did not obtain an answer for (b), use a value of 3.00 m/s². (*2 marks*)

$\boxed{138 \text{ N}}$

$\Sigma \vec{F}_2 = m_2 \vec{a}$

$m_2 g - T_2 = m_2 a$

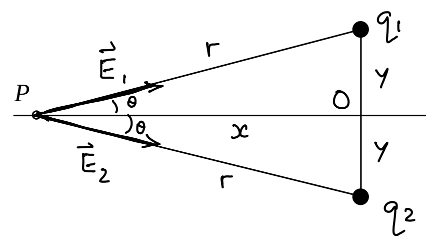
$T_2 = m_2(g-a) = (20.0\text{ kg})(9.80\text{ m/s}^2 - 2.88\text{ m/s}^2)$

$T_2 = 138\text{ N}$

continued on page 10...

Student No.: ______________________

B5. A charge of -4.55 nC is fixed in place at $x = 0$, $y = +2.00$ cm and an identical charge of -4.55 nC is fixed in place at $x = 0$, $y = -2.00$ cm.



$\theta = \text{invtan}\left|\left(\frac{y}{x}\right)\right|$

$\theta = \text{invtan}\left(\frac{2.00\text{ cm}}{8.00\text{ cm}}\right)$

$\theta = 14.0°$

$q_1 = q_2 = q = -4.55 \times 10^{-9}\text{ C}$

(a) Calculate the electric field (magnitude and direction) at a point *P* that is located at $x = -8.00$ cm, $y = 0$. (4 marks)

$E_1 = E_2 = \frac{k_e|q|}{r^2}$; $r = \sqrt{x^2+y^2}$

magnitude: $\boxed{1.17 \times 10^4\text{ N/C}}$

$E_1 = E_2 = \frac{(8.99 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2})(4.55 \times 10^{-9}\text{ C})}{(0.0800\text{ m})^2 + (0.0200\text{ m})^2}$

direction: $\boxed{+x}$

$E_1 = E_2 = 6.015 \times 10^3\text{ N/C}$; $\vec{E}_p = \vec{E}_1 + \vec{E}_2 \Rightarrow$

$E_{px} = E_{1x} + E_{2x}$

$E_{py} = E_{1y} + E_{2y}$

$E_{px} = E_1 \cos\theta + E_2 \cos\theta$

$E_{py} = E_1 \sin\theta - E_2 \sin\theta = 0$

$E_{px} = 1.167 \times 10^4\text{ N/C}$

$E_p = E_{px} = 1.17 \times 10^4\text{ N/C}$, $+x$-direction

(b) Calculate the electric potential at *P*. (3 marks)

$V_p = V_1 + V_2 = \frac{k_e q_1}{r} + \frac{k_e q_2}{r}$

$\boxed{-992\text{ V}}$

$V_p = \frac{(8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(-4.55 \times 10^{-9}\text{ C})}{\sqrt{(0.0800\text{ m})^2 + (0.0200\text{ m})^2}} \cdot 2 = -992\text{ V}$

(c) A proton is released from rest at *P*. Calculate the kinetic energy of the proton, in eV, as it passes through the origin ($x = 0$, $y = 0$). (3 marks)

Only the conservative electric force is acting on the proton $\Rightarrow \Delta KE + \Delta PE_{el} = 0$

$\boxed{3.10 \times 10^3\text{ eV}}$

$\Delta KE = -\Delta PE_{el} = -q\Delta V \Rightarrow KE_f - 0 = -(+e)(V_0 - V_p)$

$V_0 = \frac{k_e q_1}{y} + \frac{k_e q_2}{y} = 2\frac{k_e q}{y} = \frac{2(8.99 \times 10^9\text{ N}\cdot\text{m}^2/\text{C}^2)(-4.55 \times 10^{-9}\text{ C})}{0.0200\text{ m}}$

$V_0 = -4.09 \times 10^3\text{ V}$

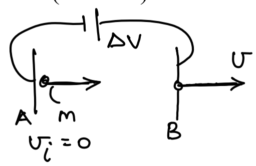
$\therefore KE_f = -(+e)\left(-4.09 \times 10^3\text{ V} - (-992\text{ V})\right) = 3.10 \times 10^3\text{ eV}$

$= 3.10\text{ keV}$

continued on page 11...

B6. An electron (mass *m*, charge −*e*) is accelerated from rest through a potential difference Δ*V*, after which it enters a region where there is a uniform magnetic field *B* that is directed perpendicular to the electron's velocity.

(a) Derive an expression for the speed, υ, of the electron when it enters the magnetic field. Your answer may contain the symbols *m*, *e*, and Δ*V*, and numbers and constants as appropriate. (*3 marks*)



Electric force is conservative:

$$\Delta KE + \Delta PE = 0$$

$$\Delta KE_{AB} = -\Delta PE_{AB}$$

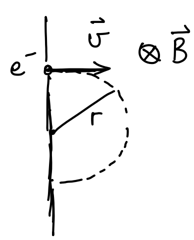
$$\frac{1}{2}mv^2 - 0 = -(-e)\Delta V$$

$$\boxed{v = \sqrt{\frac{2e\Delta V}{m}}}$$

$$\frac{1}{2}mv^2 = e\Delta V$$

$$v = \sqrt{\frac{2e\Delta V}{m}}$$

(b) Derive an expression for the radius, *r*, of the circular path followed by the electron while it is in the magnetic field. Your answer may contain the symbols *m*, *e*, υ, and *B*, and numbers and constants as appropriate. (*3 marks*)



$\vec{F} \perp \vec{v} \Rightarrow$ uniform circular motion

$$\boxed{r = \frac{mv}{eB}}$$

$$\Sigma F_r = ma_c$$

$$F_{mag} = \frac{mv^2}{r}$$

$$e\cancel{v}B\sin 90° = \frac{mv^{\cancel{2}}}{r}$$

$$r = \frac{mv}{eB}$$

(c) Suppose the experiment were repeated using a proton instead of an electron. In terms of the electron's mass, *m*, the proton mass is 1.84 × 10³ *m*. Calculate the numerical value of the ratio r_p / r where r_p and *r* are the radii of the circular paths taken by the proton and electron, respectively, in the magnetic field. (*4 marks*)

proton and electron have same magnitude of electric charge, e.

$$\boxed{42.9}$$

$$\frac{r_p}{r} = \frac{m_p v_p / eB}{mv/eB} = \frac{m_p v_p}{mv} = \frac{m_p}{m} \cdot \frac{\sqrt{\frac{2e\Delta V}{m_p}}}{\sqrt{\frac{2e\Delta V}{m}}} = \frac{m_p}{m} \cdot \sqrt{\frac{m}{m_p}} = \sqrt{\frac{m_p}{m}}$$

$$\frac{r_p}{r} = \sqrt{\frac{1.84 \times 10^3 m}{m}} = 42.9$$

END OF EXAMINATION