UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3 – Physics and the Universe

FINAL EXAMINATION

December 21, 2016 Time: 3 hours

NAME: Solutions STUDENT NO.: ________________

(Last) **Please Print** (Given)

LECTURE SECTION (please check):

- ❑ 01 A. Zulkoskey
- ❑ 02 Dr. D. Janzen
- ❑ 03 B. Zulkoskey
- ❑ 04 Dr. S. Litt
- ❑ 97 Dr. A. Farahani
- ❑ C15 Dr. A. Farahani

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	

PART A

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

A1. Use the significant figures rules to properly express the answer to the following addition problem: 21.4 + 15 + 4.003 + 17.17 = least # of dec. plcs. ⇒ units place ⇒ 58

D

(A) 57.573 (B) 57.57 (C) 57.6 (D) 58 (E) 60

A2. In lab M36, you studied the perfectly inelastic collision between a ball and a pendulum cage. Suppose that the mass of the ball was measured to be 65.6 ± 0.3 g and its speed before colliding was determined to be 4.22 ± 0.25 m/s. Which one of the following expressions is correct for the momentum of the ball before the collision? $p = mv \Rightarrow \delta p = \left(\frac{\delta m}{m} + \frac{\delta v}{v}\right)p$

B

(A) 0.58 ± 0.55 kg.m/s (B) 0.277 ± 0.018 kg.m/s (C) 0.584 ± 0.072 kg.m/s

(D) 0.277 ± 0.075 kg.m/s (E) 0.584 ± 0.036 kg.m/s

Choose DOWN +ve:

$\Delta y_1 = \frac{1}{2}gt^2$; $\Delta y_2 = \frac{1}{2}g(t-1s)^2$

A3. Two objects are released from rest from the same height at the edge of the top of a building. Object 1 is released first, and one second later object 2 is released. Which one of the following statements is correct? (You may ignore any effects due to air resistance.) $\Delta y_1 - \Delta y_2 = \frac{1}{2}g(t^2 - (t-1s)^2)$

C

(A) Once both objects have been released, the distance between them remains the same as they fall, regardless of their masses. $\Delta y_1 - \Delta y_2 = \frac{1}{2}g(t^2 - t^2 + (2s)t - (1s)^2)$

(B) Once both objects have been released, the distance between them decreases as they fall, regardless of their masses. $\Delta y_1 - \Delta y_2 = \frac{1}{2}g((2s)t - (1s)^2)$

(C) Once both objects have been released, the distance between them increases as they fall, regardless of their masses. ∴ $\Delta y_1 - \Delta y_2$ increases as t increases

(D) If object 2 is more massive, then once both objects have been released the distance between them decreases as they fall.

(E) If both objects have the same mass, then once both objects have been released the distance between them remains the same as they fall.

A4. A wagon starts from rest and undergoes a constant acceleration for 6 seconds during trial 1. In trial 2, the wagon starts from rest and undergoes the same constant acceleration for 2 seconds. How does the displacement during trial 2 compare with the displacement during trial 1? The trial 2 displacement is… $\Delta x_1 = \frac{1}{2}a(6s)^2 = 18a(s)^2$; $\Delta x_2 = \frac{1}{2}a(2s)^2 = 2a(s)^2$

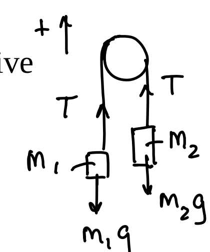
A

(A) one-ninth as large. (B) one-third as large (C) three times as large.

(D) nine times as large. (E) $1/\sqrt{3}$ times as large. $\Delta x_2 = \frac{2}{18}\Delta x_1 = \frac{1}{9}\Delta x_1$

A5. Two objects, of different masses, $m_1 < m_2$, are connected by a string that passes over a frictionless pulley where a_1 and a_2 are the magnitudes of the accelerations of the respective masses. Which one of the following mathematical statements accurately describes the magnitude of the acceleration a_2? $a_2 = a_1$; $T - m_1 g = m_1 a_1 = m_1 a_2$

A



(A) $a_2 < g$ (B) $a_2 > g$ (C) $a_2 = g$ (D) $a_2 < a_1$ (E) $a_2 > a_1$

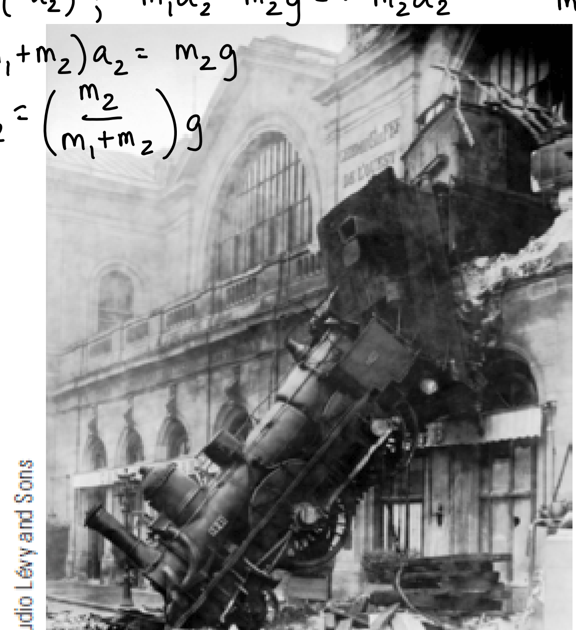
$T - m_2 g = m_2(-a_2)$; $m_1 a_2 - m_2 g = -m_2 a_2$

$(m_1 + m_2)a_2 = m_2 g$

$a_2 = \left(\frac{m_2}{m_1 + m_2}\right)g$

A6. In the photo, a locomotive has broken through the wall of a train station. During the collision, what can be said about the force exerted by the locomotive on the wall?

B



(A) The force exerted by the locomotive on the wall was less than the force exerted by the wall on the locomotive.

(B) The force exerted by the locomotive on the wall was the same in magnitude as the force exerted by the wall on the locomotive.

(C) The force exerted by the locomotive on the wall was larger than the force exerted by the wall on the locomotive.

(D) The wall cannot be said to "exert" a force; after all, it broke.

(E) More information – e.g. about the train's momentum and the structural integrity of the wall – is needed to answer this question.

NEWTON III – the two forces are an action/reaction pair.

A7. A car of mass m travelling at speed υ crashes into the rear of a truck of mass $2m$ that is at rest and in neutral at an intersection. If the collision is perfectly inelastic, what is the speed of the car after the collision?

C

Conservation of Momentum : $m\upsilon = (m+2m)V_f$; $V_f = \left(\frac{m}{3m}\right)\upsilon$

$V_f = \frac{1}{3}\upsilon$

(A) υ (B) $\frac{1}{2}\upsilon$ (C) $\frac{1}{3}\upsilon$ (D) 2υ (E) zero

A8. Mark and David are loading identical cement blocks onto David's pickup truck. Mark lifts his block straight up from the ground to the truck, whereas David slides his block up a ramp on massless, frictionless rollers. Which one of the following statements is true?

C

No friction, so required external work $= \Delta PE_{grav} = mg\Delta h$ = same for both

(A) Mark does more work than David.
(B) David does more work than Mark.
(C) Mark and David do the same amount of work.
(D) None of these statements is necessarily true because the angle of the incline is unknown.
(E) None of these statements is necessarily true because the mass of one block is not given.

A9. The gravitational force exerted on an astronaut on Earth's surface is 650 N down. When she is in the International Space Station, which one of the following statements is true?

A

$F_{grav} = \frac{GM_E m}{r^2}$; $F_{grav} \downarrow$ as $r \uparrow$

(A) The gravitational force on her is smaller.
(B) The gravitational force is exactly the same.
(C) The gravitational force on her is larger.
(D) The gravitational force on her is indeterminate: it depends on the space station's orbital and rotational speeds, which are not given.
(E) The gravitational force is exactly zero.

A10. A satellite moves in a circular orbit at a constant speed around Earth. Which one of the following statements is true?

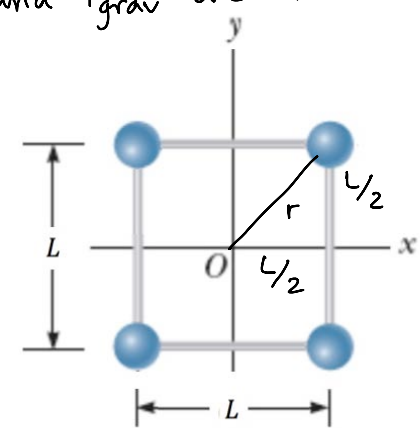
B

uniform circular motion $\Rightarrow a_c = \frac{\upsilon^2}{r}$, directed radially inward

(A) The satellite moves at constant speed and therefore has no acceleration.
(B) The satellite has an acceleration directed toward Earth.
(C) The satellite has an acceleration directed away from Earth.
(D) No force acts on the satellite.
(E) Work is done on the satellite by the force of gravity. – No, because displacement and F_{grav} are $\perp$.

A11. The model shown to the right consists of four solid spheres, each of mass M and radius R, connected by rods of length L and negligible mass. This model is rotating about the axis perpendicular to the page through point O. What is the moment of inertia of the model? You may assume that $R << L$.

C



(A) ½ ML^2
(B) ML^2
(C) $2ML^2$
(D) $4ML^2$
(E) $8ML^2$

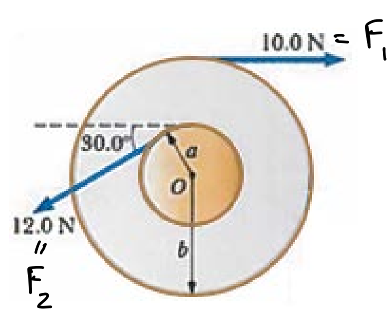
$r^2 = \left(\frac{L}{2}\right)^2 + \left(\frac{L}{2}\right)^2 = \frac{L^2}{2}$

$I = 4(Mr^2)$

$I = 4\left(M\left(\frac{L^2}{2}\right)\right) = 2ML^2$

A12. Calculate the magnitude of the net torque on the wheel in the figure to the right about the axle through O perpendicular to the page, taking a = 7.00 cm and b = 16.0 cm.

A



(A) 0.760 N·m
(B) 0.873 N·m
(C) 1.18 N·m
(D) 2.02 N·m
(E) 2.44 N·m

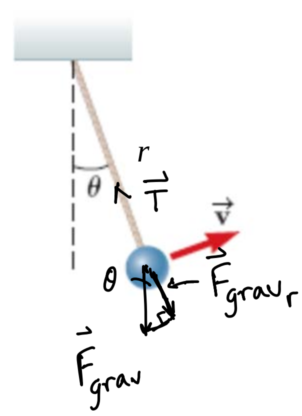
$\tau_{net} = \tau_1 + \tau_2$

$\tau_{net} = -bF_1 \sin 90° + aF_2 \sin 90°$

$\tau_{net} = -0.760$ N·m $\Rightarrow |\tau_{net}| = 0.760$ N·m

A13. One end of a cord is fixed and a small object with a mass m is attached to the other end, where it swings in a section of a vertical circle of radius r, as shown in the figure. At this instant, what is the tension in the string?

B



(A) $mg + \frac{m\upsilon^2}{r}$ (B) $mg\cos\theta + \frac{m\upsilon^2}{r}$ (C) $mg\cos\theta - \frac{m\upsilon^2}{r}$

(D) $mg\sin\theta + \frac{m\upsilon^2}{r}$ (E) $mg\sin\theta - \frac{m\upsilon^2}{r}$

$F_{grav_r} = F_{grav}\cos\theta$

$F_{grav_r} = mg\cos\theta$

$\Sigma F_r = ma_c$

$T - F_{grav_r} = \frac{m\upsilon^2}{r} \Rightarrow T = mg\cos\theta + \frac{m\upsilon^2}{r}$

A14. A box slides down a frictionless incline, and a hoop rolls down another incline. Both inclines have the same height, and both the box and the hoop have the same mass. If both objects start from rest, upon reaching the bottom of the incline which one will have the greater kinetic energy and which one will have the greater speed?

C

$\Delta PE = mg\Delta h =$ same for both $\Rightarrow$ ΔKE same for both

(A) The box will have the greater kinetic energy and the greater speed.
(B) The hoop will have the greater kinetic energy and the greater speed.
(C) Both will have the same kinetic energy, but the box will have the greater speed.
(D) Both will have the same kinetic energy, but the hoop will have the greater speed.
(E) The box will have greater kinetic energy, but the hoop will have the greater speed.

$KE_i = 0 \Rightarrow KE_f$ same for both.

$KE_{f_{box}} = \frac{1}{2}mv_{box}^2$

$KE_{f_{hoop}} = \frac{1}{2}mv_h^2 + \frac{1}{2}I\omega_h^2 = \frac{1}{2}mv_h^2 + \frac{1}{2}(mR^2)\left(\frac{v_h}{R}\right)^2 = mv_h^2$

$\cancel{m}v_h^2 = \frac{1}{2}\cancel{m}v_{box}^2 \Rightarrow v_{box} > v_{hoop}$

A15. A physics instructor, initially spinning on a stool with arms outstretched, pulls his arms in so that they are close to his body. Which one of the following statements correctly describes what happens when he pulls his arms toward his body?

D

(A) His angular momentum increases and he spins faster.
(B) His angular momentum decreases and he spins faster.
(C) His moment of inertia increases and he spins faster.
(D) His moment of inertia decreases and he spins faster.
(E) His moment of inertia remains constant and he spins faster.

Angular momentum is conserved.
$I\downarrow \Rightarrow \omega\uparrow$

A16. A wheel has a radius of 30.0 cm. How far (path length) does a point on the circumference travel if the wheel is rotated 4.50 revolutions.

E

$s = r\theta = (0.300\,\text{m})(4.50\,\text{rev})(2\pi\,\text{rad/rev}) = 8.48\,\text{m}$

(A) 1.35 m (B) 1.41 m (C) 2.83 m (D) 4.24 m (E) 8.48 m

A17. What is the angular speed, due to Earth's daily rotation, of a person living in Saskatoon (52.1°N latitude)?

E

$\omega = \frac{2\pi\,\text{rad}}{\text{day}} \times \frac{1\,\text{day}}{24\,\text{h}} \times \frac{1\,\text{h}}{3600\,\text{s}} = 7.27\times10^{-5}\,\text{rad/s}$

(A) 1.05×10^{-5} rad/s (B) 2.10×10^{-5} rad/s (C) 3.64×10^{-5} rad/s
(D) 4.47×10^{-5} rad/s (E) 7.27×10^{-5} rad/s

A18. What happens when a charged insulator is placed near an uncharged metallic object?

B

(A) They repel each other.
(B) They attract each other.
(C) They may attract or repel 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.

Polarization of the metallic object results in electrostatic attraction.

A19. A test charge of –*q* (a negative test charge) is used to measure an electric field at a point *P*. The field is found to have a magnitude of 2 N/C. When the test charge is removed, the electric field at point *P*…

A

(A) will be the same magnitude and direction as originally measured.
(B) will change in magnitude but not direction.
(C) will reverse in direction with same magnitude.
(D) will change both magnitude and direction.
(E) will be zero.

$\vec{E}$ is a property of the location in space, independent of how it was measured.

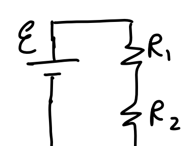
A20. At a distance of *r* from a certain positive point charge, the electric field created by the charge has a magnitude of E_A and the electric potential due to the charge is V_A. Which one of the following options is correct for the magnitude of the electric field, E_B, and the electric potential, V_B, at a distance of *r*/2 from the charge?

D

$E \propto \frac{1}{r^2}$; $\frac{1}{(\frac{1}{2})^2} = 4$

(A) $E_B = ¼\,E_A$; $V_B = ¼\,V_A$ (B) $E_B = ¼\,E_A$; $V_B = ½\,V_A$ (C) $E_B = 4E_A$; $V_B = 4V_A$
(D) $E_B = 4E_A$; $V_B = 2V_A$ (E) $E_B = 2E_A$; $V_B = 4V_A$

$V \propto \frac{1}{r}$; $\frac{1}{(\frac{1}{2})} = 2$



A21. An ideal, 12.0-V source is connected across the series combination of two resistors, R_1 and R_2. $R_1 = 4.0\ \Omega$ and $R_2 = 8.0\ \Omega$. The current through R_1 is…

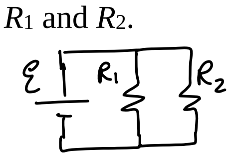
C

$I = \frac{V}{R_{tot}} = \frac{12.0\,\text{V}}{12.0\,\Omega} = 1.0\,\text{A}$

(A) 3.0 A (B) 1.5 A (C) 1.0 A (D) 32 A (E) 4.5 A

A22. An ideal, 12.0-V source is connected across the parallel combination of two resistors, R_1 and R_2. $R_1 = 4.0\ \Omega$ and $R_2 = 8.0\ \Omega$. The current through R_1 is…

A



(A) 3.0 A (B) 1.5 A (C) 1.0 A (D) 32 A (E) 4.5 A

$I_1 = \frac{\mathcal{E}}{R_1} = \frac{12.0\,\text{V}}{4.0\,\Omega} = 3.0\,\text{A}$

A23. You wish to use a negatively-charged rod to cause an isolated metal ball to acquire a net positive charge. Which one of the following procedures will work? Charging by induction

D

(A) It is not possible to use a negatively-charged rod to cause an object to acquire a positive charge.
(B) Connect the metal ball to ground, touch the rod to the ball, then remove the rod, and then disconnect the ball from ground.
(C) Connect the metal ball to ground, touch the rod to the ball, then disconnect the ball from ground, and then remove the rod.
(D) Connect the metal ball to ground, bring the rod close to the ball but do not touch it, then disconnect the ball from ground, and then remove the rod.
(E) Touch the rod to the metal ball for a few seconds, then remove it.

A24. Car batteries are often rated in ampere-hours. This rating pertains to the amount of a certain physical quantity that the battery can supply. The physical quantity corresponding to the ampere-hour rating is…

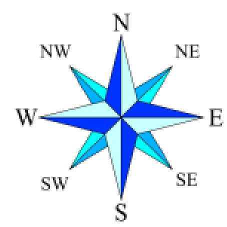
D

$A \cdot h \Rightarrow \frac{\text{charge}}{\text{time}} \cdot \text{time} = \text{charge}$

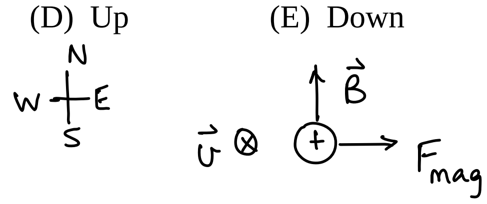
(A) current (B) power (C) energy (D) charge (E) potential

A25. A ball with a positive charge is dropped at the equator (where the Earth's magnetic field is horizontal and directed North). Immediately after it is released, what is the direction of the magnetic force acting on the ball? (image attribution: http://cliparts.co/clipart/3775881)

A



(A) East (B) West (C) North
(D) Up (E) Down



$\vec{F}_{mag} = q\vec{v} \times \vec{B}$; RHR

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.

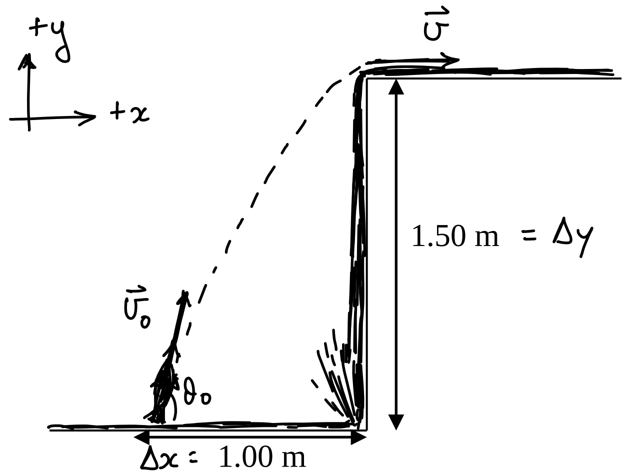
<u>SHOW AND EXPLAIN YOUR WORK</u> – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY.

EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

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

B1. A fish is attempting to jump to the top of a waterfall that is 1.50 m high. The fish begins the jump (leaves the water) a horizontal distance of 1.00 m from the base of the waterfall. The fish jumps such that it just reaches the top of the waterfall, that is, it is moving horizontally when it reaches the top of the waterfall.

(a) Draw a diagram, showing the trajectory of the fish from when it leaves the water until it reaches the top of the waterfall, and your choice of coordinate system. (*2 marks*)



(b) Calculate the vertical component of the initial velocity of the fish such that it just reaches the height of the waterfall. (*2 marks*)

$v_{0y} = ?$; $v_y = 0$, $\Delta y = 1.50\text{m}$, $a_y = -g$

$v_y^2 = v_{0y}^2 + 2a_y \Delta y$

$0 = v_{0y}^2 + 2(-g)\Delta y$

$v_{0y} = \sqrt{-2(-g)(\Delta y)} = \sqrt{2(9.80\text{m/s}^2)(1.50\text{m})} = 5.422 \text{ m/s}$

$\boxed{5.42 \text{ m/s}}$

(c) Calculate the time that it takes the fish to reach the top of the waterfall. If you did not obtain an answer for (a), use a value of 5.50 m/s. (*2 marks*)

$v_y = v_{0y} + a_y t$

$t = \frac{0 - v_{0y}}{-g}$

$t = \frac{-5.422\text{m/s}}{-9.80\text{ m/s}^2}$

$t = 0.5533\text{s}$

$\Delta y = \frac{1}{2}(v_{0y} + v_y)t$

$t = \frac{2\Delta y}{v_{0y} + v_y}$; $v_y = 0$

$t = \frac{2(1.50\text{m})}{5.422\text{m/s}} = 0.5533\text{s}$

$\boxed{0.553\text{s}}$

(d) Calculate the angle of the initial velocity of the fish such that it just reaches the top of the waterfall. If you did not obtain an answer for (c), use a value of 0.550 s. (*4 marks*)

$\theta_0 = \text{invtan}\left(\frac{v_{0y}}{v_{0x}}\right)$; $v_{0y} = 5.422\text{ m/s}$

$\Delta x = v_{0x}t + \frac{1}{2}a_x t^2 = v_{0x}t$ since $a_x = 0$.

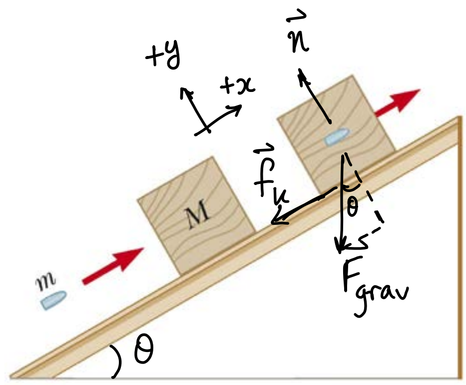
$v_{0x} = \frac{\Delta x}{t} = \frac{1.00\text{m}}{0.5533\text{s}} = 1.807\text{ m/s}$

$\theta_0 = \text{invtan}\left(\frac{5.422\text{ m/s}}{1.807\text{ m/s}}\right) = 71.6°$

$\boxed{71.6°}$

B2. A bullet of mass m = 4.20 g is fired parallel to an inclined table, into a wooden block of mass M = 255 g that initially sits at rest. The bullet remains in the block after the collision. The coefficient of kinetic friction between the block and the table is 0.333, the angle of incline of the table is 30.0°, and the bullet and block slide a distance of 0.425 m up the table before stopping.

(a) On the diagram to the right, draw the forces acting on the bullet/block combination after the collision (while the combination is still moving up the incline). Include your coordinate system. (*2 marks*)



(b) Calculate the work done by gravity in bringing the bullet/block combination to rest. (*2 marks*)

$W_{grav} = F_{grav}\cos(\theta + 90°)\,d = M_{tot}\,g(\cos 120°)\,d$

$W_{grav} = (0.25920\text{ kg})(9.80\text{ m/s}^2)(\cos 120°)(0.425\text{ m})$

$W_{grav} = -0.5398\text{ J}$

$\boxed{-0.540\text{ J}}$

ALT: $W_{grav} = -\Delta PE_{grav} = -M_{tot}\,g\,h = -M_{tot}\,g\,d\sin\theta$

$W_{grav} = -(0.25920\text{ kg})(9.80\text{ m/s}^2)(0.425\text{ m})(\sin 30.0°)$

$W_{grav} = -0.5398\text{ J}$

(c) Calculate the work done by friction in bringing the bullet/block combination to rest. (*2 marks*)

$W_{fr} = f_k(\cos 180°)\,d \;;\; f_k = \mu_k n$

$\boxed{-0.311\text{ J}}$

$\Sigma F_y = 0 \Rightarrow n - F_{grav_y} = 0 \Rightarrow n = M_{tot}\,g\cos\theta$

$W_{fr} = (\mu_k M_{tot}\,g\cos\theta)(\cos 180°)\,d$

$W_{fr} = (0.333)(0.25920\text{ kg})(9.80\text{ m/s}^2)(\cos 30.0°)(-1)(0.425\text{ m})$

$W_{fr} = -0.311\text{ J}$

(d) Calculate the speed of the bullet/block combination immediately after the bullet has embedded in the block. If you did not obtain answers for (b) and (c), use a value of −0.550 J for (b) and a value of −0.300 J for (c). (*2 marks*)

Use the Work-Energy Theorem:

$\boxed{2.56\text{ m/s}}$

$W_{net} = \Delta KE = KE_f - KE_i \Rightarrow W_{grav} + W_{fr} = 0 - \frac{1}{2}M_{tot}V^2$

$$V = \sqrt{\frac{-2(W_{grav} + W_{fr})}{M_{tot}}} = \sqrt{\frac{-2(-0.540\text{ J} - 0.311\text{ J})}{0.25920\text{ kg}}} = 2.56\text{ m/s}$$

ALT: $\Sigma F_x = ma_x \Rightarrow -mg\sin\theta - f_k = ma_x \Rightarrow -mg\sin\theta - \mu_k n = ma_x$ (n determined from $\Sigma F_y = 0$ in (c))

$-mg\sin\theta - \mu_k mg\cos\theta = ma_x \Rightarrow a_x = -g(\sin\theta + \mu_k\cos\theta)$

$a_x = (-9.80\text{ m/s}^2)(\sin 30.0° + (0.333)\cos 30.0°) = -7.726\text{ m/s}^2$

$v_x^2 = v_{0x}^2 + 2a_x\Delta x \Rightarrow v_{0x} = \sqrt{-2a_x\Delta x} = \sqrt{-2(-7.726\text{ m/s}^2)(0.425\text{ m})} = 2.56\text{ m/s}$

(e) Calculate the initial speed of the bullet. If you did not obtain an answer for (d), use a value of 2.50 m/s. (*2 marks*)

Conservation of Momentum

$\boxed{158\text{ m/s}}$

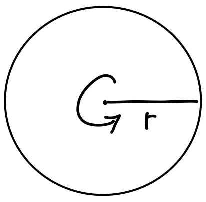
$P_{tot_i} = P_{tot_f}$

$$m_b v_b = M_{tot}V \Rightarrow v_b = \frac{M_{tot}V}{m_b} = \frac{(0.25920\text{ kg})(2.56\text{ m/s})}{0.00420\text{ kg}} = 158\text{ m/s}$$

B3. A circular disk of radius 16.0 cm is accelerated from rest to 1.26×10^3 rpm (revolutions per minute) in 3.00 s.

(a) Calculate the average angular acceleration of the disk. (*3 marks*)

$\boxed{44.0 \text{ rad/s}^2}$



$$\omega_0 = 0$$

$$\omega = 1.26\times10^3 \frac{\text{rev}}{\text{min}} \times \frac{1\text{ min}}{60\text{ s}} \times \frac{2\pi \text{ rad}}{\text{rev}} = 131.95 \text{ rad/s}$$

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega - \omega_0}{t} = \frac{131.95 \text{ rad/s}}{3.00\text{ s}} = 44.0 \text{ rad/s}^2$$

(b) Assuming constant angular acceleration, calculate the number of revolutions of the disk during the 3.00-s acceleration period. (*3 marks*)

$\boxed{31.5 \text{ rev}}$

$$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\Delta\theta = 0 + \frac{1}{2}(44.0 \text{ rad/s}^2)(3.00\text{ s})^2$$

$$\Delta\theta = 198 \text{ rad} \times \frac{1 \text{ rev}}{2\pi \text{ rad}} = 31.5 \text{ rev}$$

ALT: $\Delta\theta = \frac{1}{2}(\omega_0 + \omega)t = \frac{1}{2}(0 + 131.95 \text{ rad/s})(3.00\text{s}) = 198 \text{ rad}$
$= 31.5 \text{ rev}$

ALT 2: $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

$$\Delta\theta = \frac{\omega^2}{2\alpha} = \frac{(131.95 \text{ rad/s})^2}{2(44.0 \text{ rad/s}^2)} = 198 \text{ rad} = 31.5 \text{ rev}$$

(c) A sample of blood in a small vial is attached to the rim of the disk. The mass of a red blood cell is 3.00×10^{-16} kg and the magnitude of the centripetal force acting on it as it settles out of the blood plasma is desired to be 4.20×10^{-11} N. Calculate the new angular speed (in revolutions per minute) at which the disk should be rotated. (*4 marks*)

$\boxed{8.93\times10^3 \text{ rpm}}$

$$F_c = ma_c$$

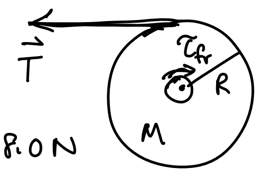
$$F_c = \frac{mv^2}{r} = mr\omega^2$$

$$\omega = \sqrt{\frac{F_c}{mr}} = \sqrt{\frac{4.20\times10^{-11}\text{ N}}{(3.00\times10^{-16}\text{ kg})(0.160\text{ m})}} = 935.4 \text{ rad/s}$$

$$935.4 \frac{\text{rad}}{\text{s}} \times \frac{60\text{ s}}{\text{min}} \times \frac{1 \text{ rev}}{2\pi \text{ rad}} = 8.93\times10^3 \text{ rev/min}$$

B4. A constant 18.0 N force is applied to a cord wrapped around a pulley of mass M = 6.00 kg and radius R = 45.0 cm. The pulley accelerates uniformly from rest to an angular speed of 10.0 rev/s in 4.50 s. There is a constant frictional torque of τ_{fr} = 1.60 N.m on the pulley due to friction at the axle of the pulley.

(a) Calculate the angular acceleration of the pulley. (*3 marks*)



$T = 18.0\,N$
$R = 0.450\,m$
$M = 6.00\,kg$
$t = 4.50\,s$

$\omega_0 = 0$

$\omega = 10.0\,rev/s \times \frac{2\pi\,rad}{rev} = 62.83\,rad/s$

$|\tau_{fr}| = 1.60\,N{\cdot}m$

$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{62.83\,rad/s - 0}{4.50\,s} = 13.96\,rad/s^2$

$\boxed{14.0\,rad/s^2}$

(b) Calculate the moment of inertia of the pulley. (The pulley is **not** a uniform solid disk.) If you did not obtain an answer for (a), use a value of 12.5 rad/s^2. (*4 marks*)

Newton II for Rotation: $\sum\tau = I\alpha$

$\therefore\ TR - \tau_{fr} = I\alpha$

$I = \frac{TR - \tau_{fr}}{\alpha} = \frac{(18.0\,N)(0.450\,m) - 1.60\,N{\cdot}m}{13.96\,rad/s^2} = 0.4656\,kg{\cdot}m^2$

$\boxed{0.466\,kg{\cdot}m^2}$

(c) The cord breaks at the instant that the pulley reaches an angular speed of 10.0 rev/s (at 4.50 s after it began accelerating). Calculate the time for the pulley to come to rest. If you did not obtain an answer for (b), use a value of 0.500 kg·m^2. (*3 marks*)

When the cord breaks, the only torque on the pulley is τ_{fr}.

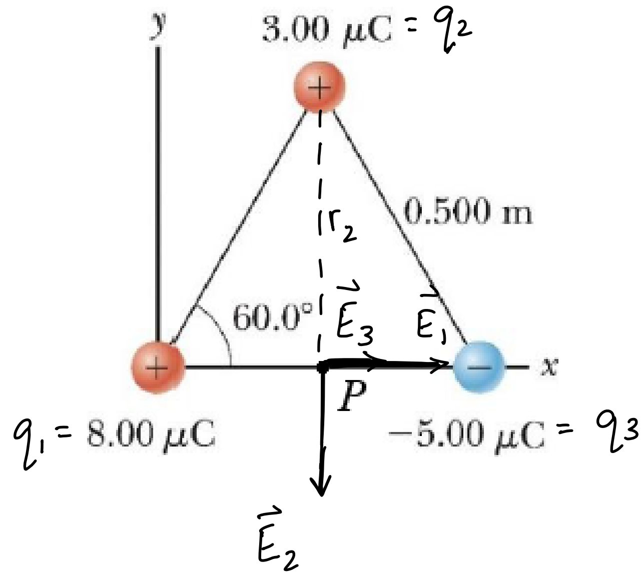
The new α is $\alpha = \frac{\tau_{fr}}{I} = \frac{-1.60\,N{\cdot}m}{0.4656\,kg{\cdot}m^2} = -3.436\,rad/s^2$

$\omega = \omega_0 + \alpha t$

$0 = \omega_0 + \alpha t \Rightarrow t = -\frac{\omega_0}{\alpha} = \frac{-62.83\,rad/s}{-3.436\,rad/s^2} = 18.3\,s$

$\boxed{18.3\,s}$

B5. Three charges are arranged at the corners of an equilateral triangle as shown in the figure. Consider a point *P* midway between the two charges on the *x*-axis.



(a) On the diagram above, draw the directions of each of the electric fields created at point *P* by the charges. (*3 marks*)

(b) Calculate the magnitude of the electric field at point *P* due to each charge. (*3 marks*)

$E = \frac{k_e|q|}{r^2}$; $r_1 = r_3 = 0.250\,m$

$r_2 = 0.500\,m \sin 60.0°$

$r_2 = 0.433\,m$

$E_1 = \frac{\left(8.99\times10^9 \frac{N\cdot m^2}{C^2}\right)\left|\left(8.00\times10^{-6}C\right)\right|}{(0.250\,m)^2}$

$E_1 = 1.151\times10^6\,N/C$; $E_2 = 1.439\times10^5\,N/C$; $E_3 = 7.192\times10^5\,N/C$

E (+8 μC): $\boxed{1.15\times10^6\,N/C}$ (+x)

E (+3 μC): $\boxed{1.44\times10^5\,N/C}$ (−y)

E (−5 μC): $\boxed{7.19\times10^5\,N/C}$ (+x)

(c) Calculate the magnitude of the net electric field at point *P*. If you did not obtain answers for (b), use the following values: *E* (+8 μC) = 1.00 × 10^6 N/C; *E* (+3 μC) = 1.40 × 10^5 N/C; *E* (−5 μC) = 7.00 × 10^5 N/C. (*2 marks*)

$E_p = \sqrt{E_{px}^2 + E_{py}^2}$

$E_p = \sqrt{\left(1.151\times10^6\,N/C + 7.192\times10^5\,N/C\right)^2 + \left(-1.439\times10^5\,N/C\right)^2}$

$E_p = 1.876\times10^6\,N/C$

$\boxed{1.88\times10^6\,N/C}$

(d) Calculate the direction of the net electric field at point *P*. Express your answer as an angle with respect to the positive *x*-axis. (*2 marks*)

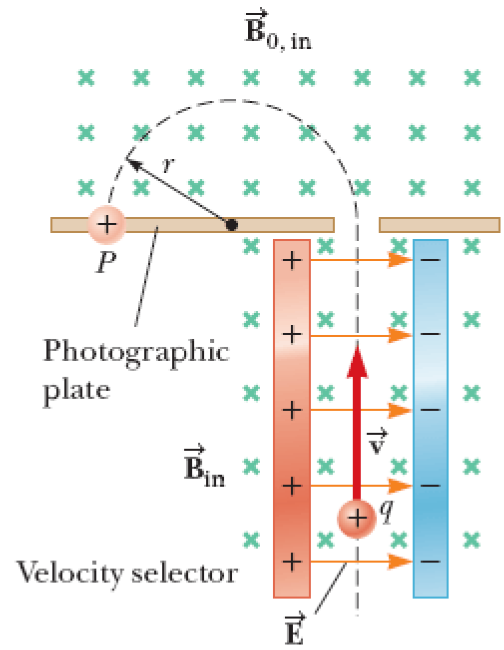
$\theta_{E_p} = \text{invtan}\left|\frac{E_{py}}{E_{px}}\right| = \text{invtan}\left|\frac{(-1.439\times10^5\,N/C)}{(+1.870\times10^6\,N/C)}\right|$

$\theta_{E_p} = 4.40°$; −ve y and +ve x ⇒ 4.40° CW from +x-axis

$\boxed{4.40° \text{ CW from } +x\text{-axis}}$

Student No.: ____________________

B6. Consider the mass spectrometer shown in the figure. The electric field between the plates in the velocity selector is 9.55×10^4 V/m, and the magnetic field in both the velocity selector and the deflection chamber is 0.950 T.



(a) Calculate the electric force on a singly-charged ion in the velocity selector. (*2 marks*)

$F_{el} = qE$

$\boxed{1.53 \times 10^{-14}\,\text{N}}$

$F_{el} = (1.60\times10^{-19}\,\text{C})(9.55\times10^{4}\,\text{N/C})$

$F_{el} = 1.528\times10^{-14}\,\text{N}$

$\frac{\text{N}}{\text{C}} = \frac{\text{V}}{\text{m}}$

(b) Calculate the required speed of a singly-charged ion in the velocity selector such that the magnetic force on it is equal and opposite to the electric force calculated in (a). If you did not obtain an answer for (a), use a value of 1.50×10^{-14} N. (*2 marks*)

$F_{mag} = |q| v B \sin\theta$; $\theta = 90°$ in this case

$\boxed{1.01\times10^{5}\,\text{m/s}}$

$$v = \frac{F_{mag}}{|q|B} = \frac{1.528\times10^{-14}\,\text{N}}{(1.60\times10^{-19}\,\text{C})(0.950\,\text{T})} = 1.005\times10^{5}\,\text{m/s}$$

(c) Before entering the velocity selector, the singly-charged ions must be accelerated from rest. If a singly-charged ion has a mass of 2.18×10^{-26} kg, calculate the potential difference through which it must be accelerated for it to acquire the speed calculated in (b). If you did not obtain an answer for (b), use a value of 1.10×10^5 m/s. (*3 marks*)

Conservation of Energy:

$\boxed{688\,\text{V}}$

$KE_i + PE_i = KE_f + PE_f$

$0 + PE_i - PE_f = KE_f \Rightarrow q(V_i - V_f) = \frac{1}{2}mv_f^2$

$$V_i - V_f = \frac{mv_f^2}{2q} = \frac{(2.18\times10^{-26}\,\text{kg})(1.005\times10^{5}\,\text{m/s})^2}{2(1.60\times10^{-19}\,\text{C})} = 688.4\,\text{V}$$

(d) Calculate the radius of the ion's path through the deflection chamber. (*3 marks*)

Since $\vec{F}_{mag}$ is $\perp$ to $\vec{v}$, the result is uniform circular motion.

$\boxed{1.44\,\text{cm}}$

$\Sigma F_r = ma_c$

$F_{mag} = \frac{mv^2}{r} \rightarrow r = \frac{mv^2}{F_{mag}} = \frac{(2.18\times10^{-26}\,\text{kg})(1.005\times10^{5}\,\text{m/s})^2}{1.528\times10^{-14}\,\text{N}}$

$r = 1.44\times10^{-2}\,\text{m}$

END OF EXAMINATION