

# UNIVERSITY OF SASKATCHEWAN

Department of Physics and Engineering Physics

Physics 115.3 – Physics and the Universe

## FINAL EXAMINATION

December 19, 2015

Time: 3 hours

NAME: \_\_\_\_\_ SOLUTIONS \_\_\_\_\_ STUDENT NO.: \_\_\_\_\_  
(Last) **Please Print** (Given)

LECTURE SECTION (please check):


- 01 Dr. M. Ghezelbash
- 02 Dr. D. Janzen
- 03 B. Zulkoskey
- 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 12 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	<input checked="" type="checkbox"/>	25	
B1	<input type="checkbox"/>	10	
B2	<input type="checkbox"/>	10	
B3	<input type="checkbox"/>	10	
B4	<input type="checkbox"/>	10	
B5	<input type="checkbox"/>	10	
B6	<input type="checkbox"/>	10	
TOTAL		75	

continued on page 2...

**PART A**

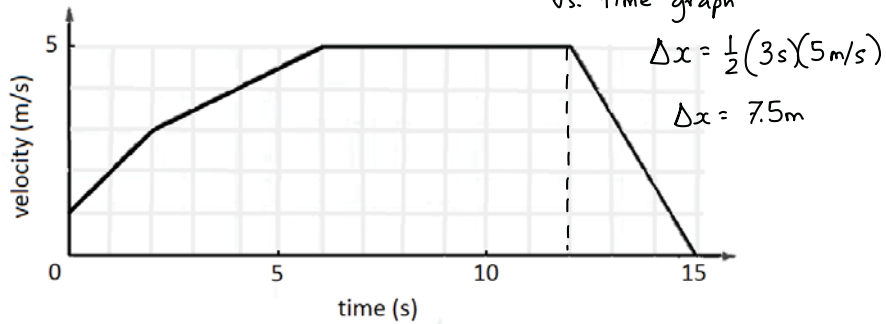
FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

- A1. Which one of the following relationships is dimensionally consistent with an expression yielding a value for magnitude of acceleration? In these equations,  $x$  represents the magnitude of displacement,  $t$  represents time, and  $v$  represents speed.

(A)  $\frac{v^2}{x}$   $\frac{m^2/s^2}{m}$   $\frac{m^2/s^2}{m/s^2}$  (B)  $\frac{v}{t^2}$   $\frac{m/s}{s^2}$   $\frac{m/s}{m/s^3}$  (C)  $\frac{v}{x^2}$   $\frac{m/s}{m^2}$   $\frac{m/s}{1/m \cdot s}$  (D)  $\frac{v^2}{t}$   $\frac{m^2/s^2}{s}$   $\frac{m^2/s^2}{m^2/s^3}$  (E)  $\frac{x}{t}$   $\frac{m}{s}$

- A2. The graph below represents the motion of an object moving in one dimension. How far did the object travel between  $t = 12$  s and  $t = 15$  s?

A



- (A) 7.5 m (B) 15 m (C) 30 m (D) 6.0 m (E) 36 m

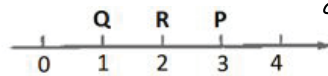
- A3. An arrow is shot straight up in the air at an initial speed of 15.0 m/s. After how much time is the arrow heading downward at a speed of 8.00 m/s?

D

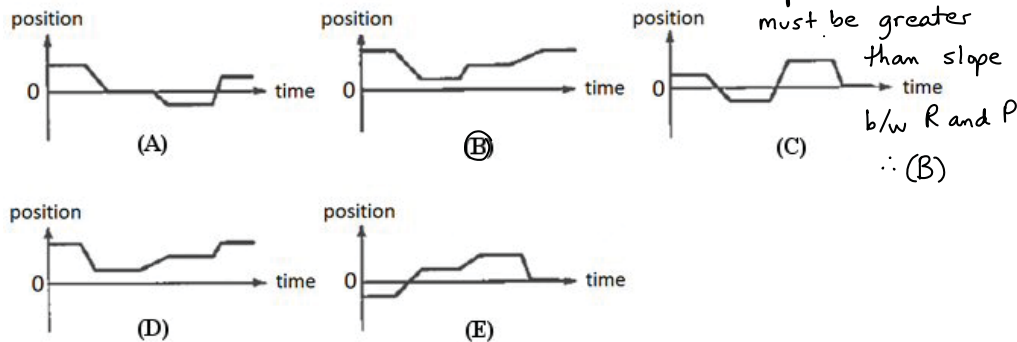
(A) 3.22 s (B) 0.714 s (C) 1.24 s (D) 2.35 s (E) 1.87 s  
 $v = v_0 + at \Rightarrow t = \frac{v - v_0}{a}$   
 $t = \frac{-8.00 \text{ m/s} - 15.0 \text{ m/s}}{-9.80 \text{ m/s}^2}$

- A4. A person moves between positions P, Q, R, and P, as illustrated on the number line axis below. The person is initially at point P, and she then moves along the axis to Q and stays there a moment. She then runs quickly to R, pauses, and then strolls slowly back to P. Which one of the position vs. time graphs below correctly represents this motion?

B



her position is always positive, so only possibilities are (B) and (D). She runs quickly to R but strolls slowly back to P.  $\therefore$  slope b/w Q and R must be greater than slope b/w R and P.  $\therefore$  (B)



- A5. A constant horizontal force is exerted for a short time interval on a cart that is initially at rest on a horizontal frictionless air track. The force gives the cart a certain final speed,  $v_{\text{light}}$ . The same force is then exerted for the same period of time on another cart, also initially at rest, that has twice the mass of the first one. If the final speed of the heavier cart is  $v_{\text{heavy}}$ , which one of the following statements is correct?

B

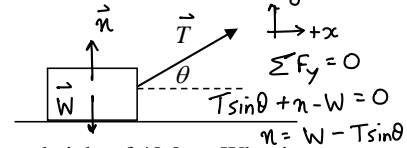
(A)  $v_{\text{heavy}} = \frac{1}{4} v_{\text{light}}$  (B)  $v_{\text{heavy}} = \frac{1}{2} v_{\text{light}}$  (C)  $v_{\text{heavy}} = v_{\text{light}}$  (D)  $v_{\text{heavy}} = 2 v_{\text{light}}$  (E)  $v_{\text{heavy}} = 4 v_{\text{light}}$   
 $v = v_0 + at$  and  $\sum F = ma$   
 $v_{\text{light}} = 0 + \frac{F}{m_{\text{light}}} t = \frac{F}{m_{\text{light}}} t$   
 $v_{\text{heavy}} = \frac{F}{m_{\text{heavy}}} t$  and  $m_{\text{heavy}} = 2m_{\text{light}}$   
 $\therefore v_{\text{heavy}} = \frac{F}{2m_{\text{light}}} t = \frac{1}{2} v_{\text{light}}$

continued on page 3...

**A6.** A girl is using a rope to pull a box that has a weight of magnitude  $W$  across a level, horizontal surface. The rope makes an angle of  $\theta$  above the horizontal, and the magnitude of the tension in the rope is  $T$ . Which one of the following is the correct expression for the magnitude of the  $y$  normal force of the floor on the box?

B

- (A)  $W - T$       (B)  $W - T(\sin\theta)$       (C)  $W + T$   
(D)  $W + T(\cos\theta)$       (E)  $W - T(\cos\theta)$



**A7.** Old Faithful geyser in Yellowstone Park shoots water vertically to a height of 40.0 m. What is the velocity of the water as it leaves the ground?  $E_i = E_f \Rightarrow \frac{1}{2}mv_i^2 = mgh \Rightarrow v_i = \sqrt{2gh}$

B

- (A) 20.0 m/s      (B) 28.0 m/s      (C) 7.00 m/s      (D) 14.0 m/s      (E) 10.0 m/s       $v_i = 28.0 \text{ m/s}$

**A8.** If the momentum of an object is tripled, by what factor does its kinetic energy change? (You may assume that the mass of the object does not change.)  $KE = \frac{1}{2}mv^2 = \frac{1}{2} \frac{m^2v^2}{m} = \frac{p^2}{2m}$

A

- (A)  $KE_f = 9 KE_i$       (B)  $KE_f = 3 KE_i$       (C)  $KE_f = KE_i$   
(D)  $KE_f = (1/3)KE_i$       (E)  $KE_f = (1/9)KE_i$        $KE_i = \frac{p_i^2}{2m}$ ;  $KE_f = \frac{p_f^2}{2m} = \frac{(3p_i)^2}{2m} = 9 \frac{p_i^2}{2m} = 9 KE_i$

**A9.** An object on a rotating disk is held in place at a distance  $r$  from the disk's centre. Which one of the following statements is **FALSE** concerning this object?

E

- (A) If the disk has an angular acceleration, the object has both a centripetal and a tangential acceleration. TRUE  
(B) The object always has a centripetal acceleration. TRUE  
(C) The object has a tangential acceleration only if the disk has an angular acceleration. TRUE  
(D) If the angular speed is constant, the object must have constant tangential speed. TRUE  
(E) If the angular speed is constant, the object does not have an acceleration. FALSE,  $a_c = r\omega^2$

**A10.** 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. T  
(C) The speed of the satellite depends on the radius of the orbit. T  
(D) The speed of the satellite depends on the universal gravitational constant. T  
(E) The speed of the satellite depends on the acceleration due to gravity at its location. T  
 $F_{\text{grav}} = ma_c = mg_{\text{eff}}$   
 $\frac{GM_E m}{r^2} = \frac{mv^2}{r} = mg_{\text{eff}}$   
 $v = \sqrt{\frac{GM_E}{r}}$   
 $v = \sqrt{g_{\text{eff}} r}$

**A11.** A satellite is orbiting at a distance of one Earth radius above the Earth's surface. At this altitude, the acceleration due to gravity is what factor times the value of  $g$  at the Earth's surface?

B

- (A) zero      (B)  $\frac{1}{4}$       (C)  $\frac{1}{2}$       (D) 2      (E) 4  
 $g = F_{\text{grav}}/m = \frac{GM_E m}{(R_E + r)^2} = \frac{GM_E}{(2R_E)^2} = \frac{GM_E}{4R_E^2} = \frac{1}{4}g$

**A12.** A merry-go-round driven by a motor rotates with constant angular speed regardless of the number of the riders or their locations. As a rider moves from the rim of the merry-go-round toward the centre, what happens to the magnitude of the centripetal force that must be exerted on him?

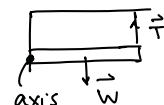
B

- (A) It increases.  
(B) It decreases.  $F_c = ma_c = mr\omega^2$ ;  $m$  and  $\omega$  are constant  $\therefore F_c \propto r$ , so  $F_c \downarrow$  as  $r$  decreases  
(C) It remains the same.  
(D) It increases or decreases, depending on the direction of rotation.  
(E) The centripetal force is always zero because the rider moves on the merry-go-round.

**A13.** A uniform beam is attached to a wall by a frictionless hinge. The beam is held horizontally by a vertical cable that attaches the far end of the beam to the ceiling. Which one of the following is the correct relationship between the magnitude of the tension,  $T$ , in the cable and the magnitude of the weight,  $W$ , of the beam?  $\sum \tau = 0 \Rightarrow LT - \frac{1}{2}LW = 0 \Rightarrow T = \frac{1}{2}W$

D

- (A)  $T = W$       (B)  $T = 2W$       (C)  $T = 4W$       (D)  $T = \frac{1}{2}W$       (E)  $T = \frac{1}{4}W$



**A14.** Two forces are acting on an object. Which one of the following statements is correct?

D

- (A) The object is in equilibrium if the forces are equal in magnitude and opposite in direction.  
(B) The object is in equilibrium if the net torque on the object is zero.  
(C) The object is in equilibrium if the forces act at the same point on the object.  
(D) The object is in equilibrium if the net force and the net torque on the object are zero.  
(E) The object cannot be in equilibrium because more than one force acts on it.

- 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, and  $I \downarrow$  when arms pulled in.  $\therefore$  Since  $L = I\omega$  is constant,  $\omega \uparrow$  when  $I \downarrow$*

- A16.** Consider two wheels of the same radius and the same mass. One wheel has most of its mass at its rim, with spokes connecting the rim to the central hub (think of a bicycle wheel). The other wheel is a uniform solid disk. The wheels are free to rotate about a fixed axis that is perpendicular to the plane of the wheel and passing through its centre. If the same net torque is applied to each wheel at the same time, which one (spoked or solid) will be spinning faster after two seconds?
- B**
- (A) The spoked wheel will be spinning faster because it has a greater moment of inertia.  
**(B)** The solid disk will be spinning faster.  
 (C) Neither, they will be spinning at the same rate because their radii are equal.  
 (D) Neither, they will be spinning at the same rate because their masses are equal.  
 (E) It is impossible to answer this question because it is possible that the wheels will not rotate when the net torque is applied.
- $\sum \tau = I\alpha$  and  $\omega = \omega_0 + \alpha t$ ;  $\alpha = \frac{\sum \tau}{I}$ ; wheel with smaller  $I$  will have larger  $\alpha$  and  $\therefore$  larger  $\omega$  at any time.*

- A17.** A solid disk and a hoop are simultaneously released from rest at the top of an incline and roll down without slipping. Which object reaches the bottom first?
- C**
- (A) The one that has the larger mass arrives first.  
 (B) The one that has the larger radius arrives first.  
**(C)** The disk arrives first.  
 (D) The hoop arrives first.  
 (E) The hoop and the disk arrive at the same time.
- $Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$   
 $\omega = v/R$   
 $Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\frac{v^2}{R^2}$   
 Hoop:  $Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}Mv^2 \Rightarrow v = \sqrt{gh}$   
 Disk:  $Mgh = \frac{1}{2}Mv^2 + \frac{1}{4}Mv^2 \Rightarrow v = \sqrt{\frac{4}{3}gh}$*

- A18.** Three charged particles are arranged on the corners of a square as shown in the figure below, with charge  $-Q$  on both the particle at the upper left corner and the particle at the lower right corner, and charge  $+Q$  on the particle at the lower left corner. What is the direction of the electric field at the upper right corner, which is a point in empty space?
- D**
- (A) upward and to the right (as shown by (a))  
 (B) to the right (as shown by (b))  
 (C) downward (as shown by (c))  
**(D)** downward and to the left (as shown by (d))  
 (E) The field is exactly zero at that point.
- 
- $r_2^2 = 2d^2$   
 $E_2 = \frac{k_e |Q|}{2d^2} = \frac{k_e Q}{2d^2}$   
 $E_1 = E_3 = \frac{k_e |-Q|}{d^2}$   
 $E_{1+3} = \sqrt{E_1^2 + E_3^2} = \frac{k_e Q}{d^2} \cdot \sqrt{2}$*
- magnitude of  $\vec{E}_1 + \vec{E}_3$  (in the direction of (d)) is greater than magnitude of  $\vec{E}_2$  (in the direction of (a)).  
 $\therefore \vec{E}_{tot}$  is in the direction indicated by (d).  
 $\therefore$  (D)*

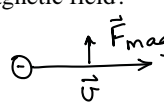
- A19.** An electron is accelerated from rest through a potential difference of 20 V. After passing through the potential difference, the kinetic energy of the electron is...
- A**
- (A) 20 eV. (B) 20 J. (C)  $3.2 \times 10^{-18}$  eV. (D)  $1.6 \times 10^{-19}$  eV. (E) 10 J.
- $|\Delta KE| = |\Delta PE| = |q\Delta V| = |(-e)(20V)| = 20eV$*

- A20.** Consider two positive point charges, separated by a distance  $d$ . The magnitude of the electrostatic force of one charge on the other is  $F_i$ . If the distance between the charges is doubled, the magnitude of the electrostatic force of one charge on the other, in terms of  $F_i$ , is now...
- E**
- (A)  $4 F_i$  (B)  $2 F_i$  (C)  $F_i$  (D)  $\frac{1}{2} F_i$  **(E)**  $\frac{1}{4} F_i$

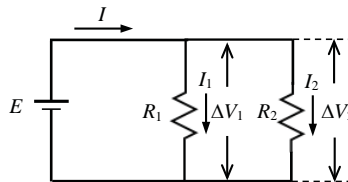
$F_i = \frac{k_e q_1 q_2}{d^2}$ ;  $F_{new} = \frac{k_e q_1 q_2}{(2d)^2} = \frac{1}{4} \frac{k_e q_1 q_2}{d^2} = \frac{1}{4} F_i$  continued on page 5...

- A21.** An electron is released from rest in a region where the electric field is uniform and directed to the right. Which one of the following statements is correct?  $\vec{F} = q\vec{E}$ ;  $\vec{F} = -e\vec{E}$ ;  $\vec{F}$  and  $\vec{a}$  are opposite to  $\vec{E}$
- D**
- (A) The electron will accelerate to the right, moving in the direction in which the electric potential energy is increasing.
- (B) The electron will accelerate to the right, moving in the direction in which the electric potential energy is decreasing.
- (C) The electron will accelerate to the left, moving in the direction in which the electric potential energy is increasing.
- (D)** The electron will accelerate to the left, moving in the direction in which the electric potential energy is decreasing. *The electron will gain KE and lose PE.*
- (E) The electron will remain motionless because if the electric field is uniform there is no net electric force on the electron.

- A22.** A piece of conducting wire has a resistance  $R$ . Another piece of wire of the same material is twice as long and has half the radius. The resistance of the second piece of wire is  $R = \frac{\rho l}{A}$ ;  $A \propto r^2$ ;  $R = \frac{\rho l}{\pi r^2}$ ;  $R' = \frac{\rho(2l)}{\pi(r/2)^2} = 8 \frac{\rho l}{\pi r^2} = 8R$
- E**
- (A)  $R/8$       (B)  $\frac{1}{2}R$       (C)  $R$       (D)  $2R$       **(E)  $8R$**

- A23.** An electron is released such that its initial velocity is from left to right across this page. The electron's path, however, is deflected toward the top edge of the page due to the presence of a uniform magnetic field. What is the direction of this magnetic field?
- E**
- (A) from bottom edge to top edge of the page
- (B) from right to left across the page
- (C) from left to right across the page
- (D) into the page
- (E)** out of the page
- From RHR:  $q\vec{v}$  to left,  $\vec{F}_{mag}$  up,  $\therefore \vec{B}$  out of page*
- 

- A24.** Two resistors are connected in parallel as shown in the circuit diagram below. An ideal voltage source is connected to this parallel combination of resistors. Which one of the following statements is correct?
- A**



*Kirchhoff's Voltage Law:*

$$E = \Delta V_1 = \Delta V_2$$

*Kirchhoff's Current Law:*

$$I = I_1 + I_2$$

- (A)**  $I = I_1 + I_2$  and  $E = \Delta V_1 = \Delta V_2$       (B)  $I = I_1 = I_2$  and  $E = \Delta V_1 + \Delta V_2$
- (C)  $I = I_1 + I_2$  and  $E = \Delta V_1 - \Delta V_2$       (D)  $I = I_1 = I_2$  and  $E = \Delta V_1 = \Delta V_2$
- (E)  $I = I_1 + I_2$  and  $E = \Delta V_1 + \Delta V_2$

- A25.** A copper wire of length  $\ell$  and radius  $r$  connects two points in an electric circuit that differ in electric potential by  $\Delta V$ . The current through the wire is  $I$ . You want to replace the copper wire with an aluminum wire of the same length, and you want the current through the wire to remain the same. The resistivity of aluminum is greater than the resistivity of copper. Which one of the following statements is correct? *Need the resistance of the aluminum wire to be the same as the resistance of the copper wire.*
- A**
- (A)** The radius of the aluminum wire must be greater than  $r$ .  $R_{Al} = R_{Cu} \Rightarrow \frac{\rho_{Al} \ell}{A_{Al}} = \frac{\rho_{Cu} \ell}{A_{Cu}}$
- (B) The radius of the aluminum wire must be less than  $r$ .
- (C) Electric current does not depend on the composition of the wire, so any radius of aluminum wire can be used.  $\rho_{Al} > \rho_{Cu} \Rightarrow A_{Al} > A_{Cu}, \therefore r_{Al} > r_{Cu}$
- (D) Electric current does not depend on the composition of the wire, so the radius of the aluminum wire must be  $r$ .
- (E) It is impossible for an aluminum wire to carry the same current as a copper wire, regardless of the dimensions of the aluminum wire.

**PART B**

**ANSWER FIVE OF THE PART B QUESTIONS ON THE FOLLOWING PAGES AND INDICATE YOUR CHOICES ON THE COVER PAGE.**

**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.**

**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 cliff diver runs horizontally off a cliff that is 35.0 m above the water, but he must clear rocky outcrops at water level that extend out into the water 5.00 m from the base of the cliff directly under the edge of the cliff (see diagram at right).

x	y
$v_{0x} = v_0$	$v_{0y} = 0$
$a_x = 0$	$a_y = -g$
$v_x = v_0$	$v_y = ?$
$\Delta x = +5.00\text{m}$	$\Delta y = -35.0\text{m}$
$t = ?$	

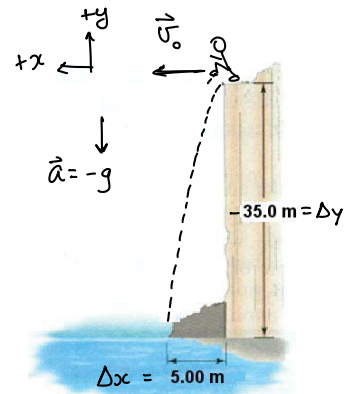


image credit: Giancoli, 6<sup>th</sup> ed.

- (a) Calculate the minimum speed with which the diver must leave the cliff in order to miss the rocks at water level. (5 marks)

$$\Delta x = v_{0x} t \Rightarrow v_{0x} = \frac{\Delta x}{t}$$

1.87 m/s

Calculate t from y information

$$\Delta y = v_{0y} t + \frac{1}{2} a_y t^2 = 0 + \frac{1}{2} a_y t^2 \Rightarrow t = \sqrt{\frac{2\Delta y}{a_y}}$$

$$t = \sqrt{\frac{2(-35.0\text{m})}{-9.80\text{m/s}^2}} = 2.673\text{s}$$

$$v_{0x_{\min}} = \frac{5.00\text{m}}{2.673\text{s}} = \textcircled{1.87\text{m/s}}$$

- (b) Assuming the diver leaves the cliff with the minimum speed described in (a), calculate the diver's speed when he reaches the water. If you did not obtain an answer for (a), use a value of 1.85 m/s. (5 marks)

$$v_x = v_{0x} = 1.87\text{m/s}$$

26.3 m/s

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

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

$$v_y = 0 + (-9.80\text{m/s}^2)(2.673\text{s})$$

$$v_y = -\sqrt{2a_y \Delta y}$$

$$v_y = -26.2\text{m/s}$$

$$v_y = -\sqrt{2(-9.80\text{m/s}^2)(-35.0\text{m})}$$

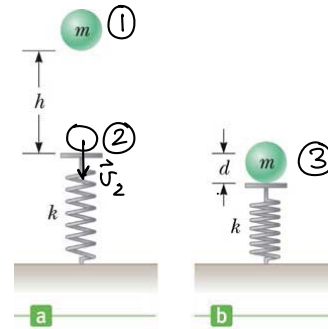
$$v_y = -26.2\text{m/s}$$

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(1.87\text{m/s})^2 + (-26.2\text{m/s})^2}$$

v = 26.3 m/s

- B2.** A ball of mass  $m = 1.80 \text{ kg}$  is released from rest at a height  $h = 65.0 \text{ cm}$  above a light vertical spring of force constant  $k$ . The ball strikes the top of the spring and compresses it a distance  $d = 9.00 \text{ cm}$  as it comes to rest. Neglect any energy losses during the collision of the ball with the spring.

Mechanical Energy is conserved.  
 $E_1 = E_2 = E_3$   
 $mgh = \frac{1}{2}mv_2^2 = -mgd + \frac{1}{2}kx^2$



- (a) Calculate the speed of the ball when it initially makes contact with the spring. (4 marks)

Mechanical Energy is conserved.

$$E_1 = E_2$$

$$mgh = \frac{1}{2}mv_2^2$$

$$v_2 = \sqrt{2gh} = \sqrt{2(9.80 \text{ m/s}^2)(0.650 \text{ m})}$$

$$v_2 = 3.57 \text{ m/s}$$

$$3.57 \text{ m/s}$$

- (b) Calculate  $k$ , the force constant of the spring. (6 marks)

Mechanical Energy is conserved.

$$E_1 = E_3$$

$$mgh = mg(-d) + \frac{1}{2}kd^2$$

$$mg(h+d) = \frac{1}{2}kd^2$$

$$\frac{2mg(h+d)}{d^2} = k$$

$$k = \frac{2(1.80 \text{ kg})(9.80 \text{ m/s}^2)(0.650 \text{ m} + 0.0900 \text{ m})}{(0.0900 \text{ m})^2}$$

$$k = 3.22 \times 10^3 \text{ N/m}$$

$$3.22 \times 10^3 \text{ N/m}$$



**B3.** A digital audio compact disc (CD) carries data along a continuous spiral track from the inner circumference of the disk to the outside edge. A CD player turns the disc so that the track moves counter-clockwise above a lens at a constant tangential speed of 1.30 m/s.

- (a) Calculate the required angular speed of the disc at the beginning of the recording, where the spiral track has a radius of 2.30 cm. (2 marks)

$$v_t = r\omega$$

$$\omega_1 = \frac{v_t}{r_1} = \frac{1.30 \text{ m/s}}{0.0230 \text{ m}} = 56.5 \text{ rad/s}$$

$$56.5 \text{ rad/s}$$

- (b) Calculate the required angular speed of the disc at the end of the recording, where the spiral track has a radius of 5.80 cm. (2 marks)

$$v_t = r\omega$$

$$\omega_2 = \frac{v_t}{r_2} = \frac{1.30 \text{ m/s}}{0.0580 \text{ m}} = 22.4 \text{ rad/s}$$

$$22.4 \text{ rad/s}$$

- (c) Calculate the average angular acceleration of the disc if the full-length recording lasts for 74 minutes and 33 seconds. (3 marks)

$$\bar{\alpha} = \frac{\Delta\omega}{\Delta t} = \frac{\omega_2 - \omega_1}{t}$$

$$-7.62 \times 10^{-3} \text{ rad/s}^2$$

$$\bar{\alpha} = \frac{22.4 \text{ rad/s} - 56.5 \text{ rad/s}}{(74 \text{ min} \times \frac{60 \text{ s}}{\text{min}}) + 33 \text{ s}} = -7.62 \times 10^{-3} \text{ rad/s}^2$$

$$t = (74 \text{ min} \times \frac{60 \text{ s}}{\text{min}}) + 33 \text{ s} = 4,473 \text{ s}$$

- (d) Assuming the angular acceleration is constant; calculate the total angular displacement of the disc as it plays the full-length recording from start to finish. If you did not obtain answers for (a), (b), and (c), use values of 56.0 rad/s, 22.0 rad/s, and  $-0.00750 \text{ rad/s}^2$ , respectively. (3 marks)

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

$$1.76 \times 10^5 \text{ rad}$$

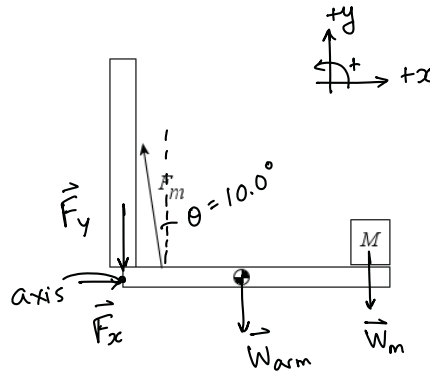
$$\Delta\theta = (56.5 \text{ rad/s})(4,473 \text{ s}) + \frac{1}{2}(-7.62 \times 10^{-3} \text{ rad/s}^2)(4,473 \text{ s})^2$$

$$\Delta\theta = 1.76 \times 10^5 \text{ rad}$$

$$\text{or } \Delta\theta = \frac{1}{2}(\omega_0 + \omega)t = \frac{1}{2}(56.5 \text{ rad/s} + 22.4 \text{ rad/s})(4,473 \text{ s})$$

$$\Delta\theta = 1.76 \times 10^5 \text{ rad}$$

- B4.** The diagram below is a partial free-body diagram of a horizontal forearm holding a block. The biceps muscle exerts a force  $F_m$  on the forearm at an angle of  $10.0^\circ$  from the vertical. The biceps muscle attaches to the forearm at a distance of 2.15 cm from the elbow joint. The mass of the forearm is 2.35 kg and its centre of mass is a distance of 20.0 cm from the elbow joint. The forearm is horizontal and a mass  $M$  of 6.95 kg is being held stationary at a distance of 44.5 cm from the elbow joint.



- (a) Calculate the magnitude of the force exerted on the forearm by the biceps muscle. (4 marks)

Forearm is in static equilibrium

$$\therefore \sum \vec{F} = 0 \text{ and } \sum \tau = 0$$

$$1.65 \times 10^3 \text{ N}$$

Calculate torque around the elbow joint

$$\sum \tau = 0 \Rightarrow r_m F_m \sin(90.0^\circ - 10.0^\circ) - r_{\text{arm}} m_{\text{arm}} g - r_M M g = 0$$

$$F_m = \frac{r_{\text{arm}} m_{\text{arm}} g + r_M M g}{r_m \sin(80.0^\circ)} = \frac{(20.0 \text{ cm})(2.35 \text{ kg})(9.80 \text{ m/s}^2) + (44.5 \text{ cm})(6.95 \text{ kg})(9.80 \text{ m/s}^2)}{(2.15 \text{ cm}) \sin 80.0^\circ}$$

$$F_m = 1.65 \times 10^3 \text{ N}$$

- (b) Calculate the horizontal and vertical components of the force exerted by the upper arm on the elbow joint. If you did not obtain an answer for (a), use a value of  $1.60 \times 10^3 \text{ N}$ . (6 marks)

$$\sum F_x = 0 \Rightarrow F_x - F_m \sin(10.0^\circ) = 0 \quad \text{horizontal:}$$

$$287 \text{ N}$$

$$F_x = F_m \sin(10.0^\circ)$$

vertical:

$$1.53 \times 10^3 \text{ N}$$

$$F_x = (1.65 \times 10^3 \text{ N}) \sin(10.0^\circ) = 287 \text{ N}$$

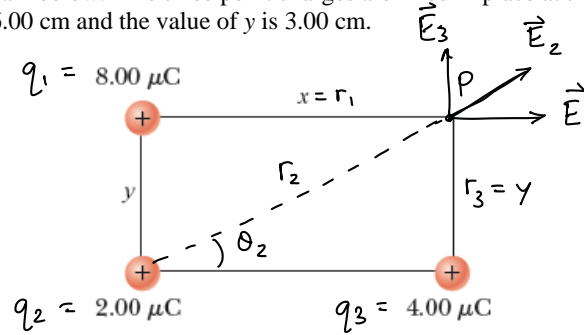
$$\sum F_y = 0 \Rightarrow -F_y + F_m \cos(10.0^\circ) - m_{\text{arm}} g - M g = 0$$

$$F_y = F_m \cos(10.0^\circ) - m_{\text{arm}} g - M g$$

$$F_y = (1.65 \times 10^3 \text{ N}) \cos(10.0^\circ) - (2.35 \text{ kg})(9.80 \text{ m/s}^2) - (6.95 \text{ kg})(9.80 \text{ m/s}^2)$$

$$F_y = 1.53 \times 10^3 \text{ N}$$

- B5.** Consider the diagram below. The three point charges are fixed in place at the positions shown. The value of  $x$  is 6.00 cm and the value of  $y$  is 3.00 cm.



- (a) Assuming that the electric potential at infinite distance is zero, calculate the electric potential at the upper right corner (the corner without a charge) of the rectangle in the above diagram. (3 marks)

$$r_2 = \sqrt{x^2 + y^2} = \sqrt{(6.00 \text{ cm})^2 + (3.00 \text{ cm})^2} = 6.71 \text{ cm} \quad \boxed{2.67 \times 10^6 \text{ V}}$$

$$V_p = V_1 + V_2 + V_3 = \frac{k_e q_1}{r_1} + \frac{k_e q_2}{r_2} + \frac{k_e q_3}{r_3}$$

$$V_p = \left( 8.99 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2} \right) \left[ \frac{+8.00 \times 10^{-6} \text{ C}}{0.0600 \text{ m}} + \frac{+2.00 \times 10^{-6} \text{ C}}{0.0671 \text{ m}} + \frac{+4.00 \times 10^{-6} \text{ C}}{0.0300 \text{ m}} \right]$$

$$V_p = 2.67 \times 10^6 \text{ N} \cdot \text{m} / \text{C} = \boxed{2.67 \times 10^6 \text{ V}}$$

- (b) Calculate the magnitude of the electric field at the upper right corner. (5 marks)

From the diagram,  $\tan \theta_2 = \frac{y}{x}$

$$\theta_2 = \text{invtan} \left( \frac{3.00 \text{ cm}}{6.00 \text{ cm}} \right) = 26.6^\circ$$

$$E = \frac{k_e |q|}{r^2} \Rightarrow \vec{E}_1 = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2) (8.00 \times 10^{-6} \text{ C})}{(0.0600 \text{ m})^2} \text{ in } +x\text{-dir in}$$

$$\vec{E}_1 = 2.00 \times 10^7 \text{ N/C in } +x\text{-dir in}; \vec{E}_2 = 3.99 \times 10^6 \text{ N/C @ } \theta_2 \text{ with } x\text{-axis}$$

$$\vec{E}_3 = 4.00 \times 10^7 \text{ N/C in } +y\text{-dir in}$$

$$\left. \begin{aligned} E_{y_{\text{tot}}} &= E_3 + E_2 \sin \theta_2 = 4.18 \times 10^7 \text{ N/C} \\ E_{x_{\text{tot}}} &= E_1 + E_2 \cos \theta_2 = 2.36 \times 10^7 \text{ N/C} \end{aligned} \right\} E_{\text{tot}} = \sqrt{E_x^2 + E_y^2} = \boxed{4.80 \times 10^7 \text{ N/C}}$$

- (c) If a  $-2.50 \mu\text{C}$  charge is placed at the upper right corner, calculate the magnitude of the electric force exerted on it. If you did not obtain an answer for (b), use a value of  $5.00 \times 10^7 \text{ N/C}$ . (2 marks)

$$\vec{F} = q\vec{E}$$

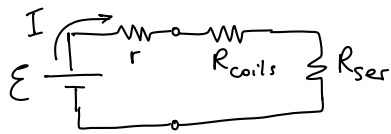
$$F = |q| |E| = (2.50 \times 10^{-6} \text{ C}) (4.80 \times 10^7 \text{ N/C})$$

$$\boxed{F = 1.20 \times 10^2 \text{ N}}$$

**B6.** A real voltage source has an open-circuit voltage of 12.0 V and an internal resistance of 0.500  $\Omega$ . The voltage source is used to supply current to a pair of coils that are used to produce a magnetic field and deflect an electron beam.

- (a) If the total resistance of the pair of coils is 1.25  $\Omega$ , calculate the additional resistance that must be added in series with the coils so that the coil current is 3.65 A. (2 marks)

$$1.54 \Omega$$



$$\mathcal{E} = IR_{\text{tot}} = I(r + R_{\text{coils}} + R_{\text{ser}})$$

$$R_{\text{ser}} = \frac{\mathcal{E}}{I} - r - R_{\text{coils}}$$

$$R_{\text{ser}} = \frac{12.0\text{V}}{3.65\text{A}} - 0.500\Omega - 1.25\Omega = 1.54\Omega$$

- (b) The electrons in the beam have a kinetic energy of 44.5 eV just as they enter the region of the magnetic field created by the coils. Calculate the speed of the electrons. (3 marks)

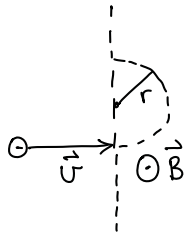
$$KE = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2(44.5\text{eV} \times 1.602 \times 10^{-19}\text{C/e})}{9.109 \times 10^{-31}\text{kg}}}$$

$$3.96 \times 10^6 \text{ m/s}$$

$$v = 3.96 \times 10^6 \text{ m/s}$$

- (c) Assuming that the electrons are moving in a direction perpendicular to the magnetic field created by the coils, calculate the magnitude of the magnetic field that is necessary for the electrons to move in a circle with a radius of 5.15 cm. If you did not obtain an answer for (b), use a value of  $4.00 \times 10^6$  m/s. (5 marks)



$$F_{\text{mag}} = |q|vB \sin\theta$$

$$\vec{v} \perp \vec{B} \Rightarrow \theta = 90^\circ$$

$$\therefore F_{\text{mag}} = |q|vB$$

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

$$4.37 \times 10^{-4} \text{ T}$$

$$\therefore F_{\text{mag}} = ma_c$$

$$|q|vB = \frac{mv^2}{r} \Rightarrow$$

$$B = \frac{mv}{|q|r} = \frac{(9.109 \times 10^{-31}\text{kg})(3.96 \times 10^6\text{m/s})}{(1.602 \times 10^{-19}\text{C})(0.0515\text{m})}$$

$$B = 4.37 \times 10^{-4} \text{ T}$$