# Physics 3204 Course Clarifications

This document contains detailed marking schemes for items that are typically asked by teachers or items that students often have difficulty with. Common student errors or misconceptions are highlighted and some teaching suggestions are provided. This document will be reviewed by teachers every year and any recommended additions or corrections will be made at that time. Please contact me with any comments regarding this document.(reneeboyce@gov.nl.ca)

General Notes:

1. $g = 9.80\dfrac{m}{s^2}$ for the problems outlined.

2.   The method for expressing direction is S30°E. Answers may also be expressed as 30° E of S.

3.   Two sign conventions are acceptable for uniform circular motion questions. We can consider toward the center or upward as being positive.

4.   In projectile motion questions where objects are projected at an angle, the angle should be expressed as above or below the horizontal (not as north, south, east or west). For example,
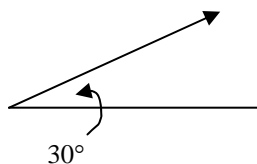
The angle shown should be expressed as 30° above the horizontal, not E30°N or 30° N of E.

30°

Unit 1: Force, Motion and Energy
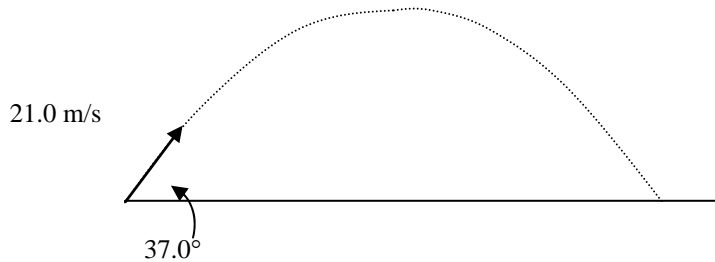
ITEM #1.1
Concept: Projectile Motion
Issue: Separating motion into horizontal and vertical components.

A football is kicked with a speed of 21.0 m/s at an angle of 37.0° above the horizontal.
  a) How much later does it hit the ground? **(3 marks)**
  b) What is the range? **(1 mark)**

Solution:

First find the initial velocity components:

$$v_{1x} = v_1 \cos 37.0°$$

$$v_{1x} = (21.0 \frac{m}{s}) \cos 37.0°$$

$$v_{1x} = 16.771 \frac{m}{s} \quad \textbf{(0.5)}$$

$$v_{1y} = v_1 \sin 37.0°$$

$$v_{1y} = (21.0 \frac{m}{s}) \sin 37.0°$$

$$v_{1y} = 12.638 \frac{m}{s} \quad \textbf{(0.5)}$$

Then find the time using information from vertical direction:

$$\Delta \vec{d}_y = \vec{v}_{1y} \Delta t + \frac{1}{2} \vec{a}_y \Delta t^2$$

$$0 = (12.638 \frac{m}{s}) \Delta t + \frac{1}{2} (-9.80 \frac{m}{s^2}) \Delta t^2 \quad \textbf{(1)}$$

$$0 = 12.638 \frac{m}{s} \Delta t - 4.90 \frac{m}{s^2} \Delta t^2$$

$$0 = \Delta t (12.638 \frac{m}{s} - 4.90 \frac{m}{s^2} \Delta t)$$

$$\Delta t = 0s \quad \text{or} \quad \Delta t = \frac{12.638 \frac{m}{s}}{4.90 \frac{m}{s^2}} \quad \textbf{(1)}$$

$$\Delta t = 2.58s$$

Thus, the football hits the ground 2.58 s later.

Alternate Solution for a):
Students may break the motion into two sections (i.e. to the highest point and from the highest point back to the ground)

In this case students will still calculate the initial velocity components as in the previous solution:

$$v_{1x} = 16.771\frac{m}{s} \qquad \textbf{(0.5)} \qquad\qquad v_{1y} = 12.638\frac{m}{s} \qquad \textbf{(0.5)}$$

To the highest point we know that $v_{2y} = 0\frac{m}{s}$

Thus,

$$\vec{v}_{2y} = \vec{v}_{1y} + \vec{a}_y \Delta t \qquad \textbf{(0.5)}$$

$$0 = 12.638\frac{m}{s} + -9.80\frac{m}{s^2}\Delta t$$

$$\frac{-12.638\frac{m}{s}}{-9.80\frac{m}{s^2}} = \Delta t \qquad \textbf{(0.5)}$$

$$\Delta t = 1.29 s$$

Therefore the total time up and down is $2 x 1.29 s = 2.58 s$ $\qquad$ **(1)**
Thus the football strikes the ground 2.58 s later.

b) $\Delta d_x = v_{1x}\Delta t = (16.771\frac{m}{s})(2.58s)$

$\Delta d_x = 43.3m$ $\qquad\qquad\qquad\qquad\qquad$ **(1)**

Thus the range of the football is 43.3 m.

Common Errors and Misconceptions:

1. not separating the x and y components of the motion (eg. $\Delta \vec{d}_y = \vec{v}_{1x}\Delta t + \frac{1}{2}\vec{a}_y\Delta t^2$)

2. failing to realize that v_x is constant throughout the motion

3. failing to realize that $\vec{a}_y = -9.80\frac{m}{s^2}$ throughout the motion

4. getting the vector components for v_1 mixed up

NOTE: The range formula for objects which start and finish at the same elevation,

$R = \frac{v_1^2 \sin 2\theta}{g}$, can be used but it is not required in the Physics 3204curriculum.

ITEM #1.2
Concept: Projectile Motion (Horizontal Projection)
Issue: Use of the quadratic equation as the simplest solution method.

A driver on a motorcycle speeds horizontally off a 50.0 m high cliff. If the cycle left the cliff at a speed of 28.2 m/s, how far from the base of the cliff did the motorcycle land?
(3 marks)

28.2 m/s

50.0
m
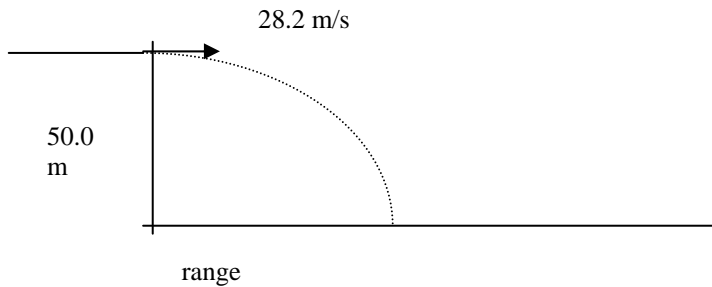
range

Solution:
Students should realize that,

$$v_{1x} = v_{2x} = 28.2 \frac{m}{s}$$

$$v_{1y} = 0 \frac{m}{s}$$

$$a_y = -9.80 \frac{m}{s^2}$$

$$\Delta d_y = -50.0m$$

Then we use,

$$\Delta \vec{d}_y = \vec{v}_{1y} \Delta t + \frac{1}{2} \vec{a}_y \Delta t^2$$

$$-50.0m = 0 + \frac{1}{2}(-9.80 \frac{m}{s^2})\Delta t^2 \qquad \textbf{(1)}$$

$$\Delta t^2 = \frac{2(-50.0m)}{-9.80 \frac{m}{s^2}}$$

$$\Delta t = 3.194s \qquad \textbf{(1)}$$

Then we use the time to find the range.

$$\Delta d_x = v_{1x} \Delta t = (28.2 \frac{m}{s})(3.194s)$$

$$\Delta d_x = 90.1m \qquad \textbf{(1)}$$

So the motorcycle lands 90.1 m from the base of the cliff.

Alternate Solution:

Find time first.

$$\vec{v}_{2y}^{\ 2} = \vec{v}_{1y}^{\ 2} + 2\vec{a}_y \Delta \vec{d}_y$$

$$v_{2y}^{\ 2} = 0 + 2(-9.80\frac{m}{s^2})(-50.0m)$$

$$v_{2y} = -31.30\frac{m}{s} \qquad \textbf{(1)}$$

Then,

$$\vec{a}_y = \frac{\vec{v}_{2y} - \vec{v}_{1y}}{\Delta t}$$

$$\Delta t = \frac{v_{2y} - v_{1y}}{a_y}$$

$$\Delta t = \frac{-31.30\frac{m}{s} - 0\frac{m}{s}}{-9.80\frac{m}{s^2}}$$

$$\Delta t = 3.19s \qquad \textbf{(1)}$$

And then find range as in first solution.   **(1)**

Note that to get the most accurate answer for time, you must carry the whole string of numbers (or at least extra significant figures) in intermediate calculations.

Common Errors and Misconceptions:
1.   realizing that the quantity being asked for is the range
2.   realizing that the displacement is –50.0 m
3.   knowing that v_{1y} is 0 m/s since there is no initial velocity in the vertical direction
4.   realizing that v_x is constant the whole time
5.   understanding that the object being projected horizontally will hit the ground in the same time as an object dropped vertically
6.   following a sequence of steps – knowing that you must find time first in order to get the range

ITEM #1.3
Concept: Newton's 2nd law in two dimensions.
Issue: Separating forces into horizontal and vertical components; representing forces in a free body diagram.
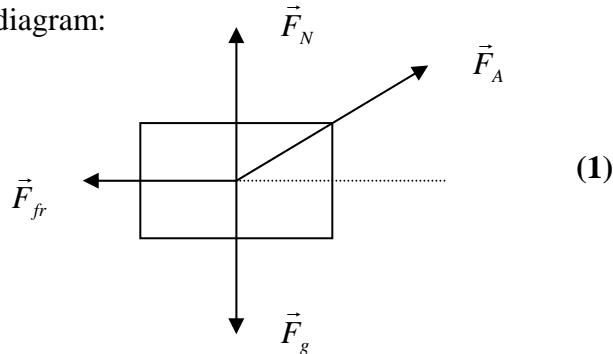
A 10.0 kg package is pulled along the floor with a force of 42 N. The force is applied at an angle of 30.0°. The coefficient of kinetic friction is 0.20.
   a) Sketch a free body diagram for the package. (**1 mark**)
   b) What is the acceleration of the package? (**3 marks**)

42 N

30.0°

Solution:
a) Free body diagram:

$\vec{F}_N$

$\vec{F}_A$

$\vec{F}_{fr}$

$\vec{F}_g$

(**1**)
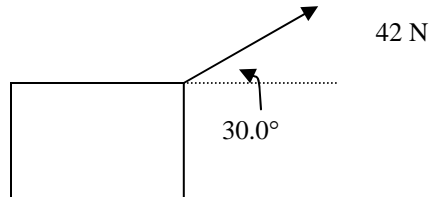
b) To find the acceleration first find the frictional force:
    In the y-direction,

$$\vec{F}_{net} = m\vec{a}_y$$

$$\vec{F}_N + \vec{F}_g + \vec{F}_A \sin\theta = 0$$

$$F_N - F_g + F_A \sin\theta = 0$$

$$F_N = mg - F_A \sin\theta \quad (\textbf{0.5})$$

$$F_N = (10.0kg)(9.80\frac{m}{s^2}) - (42N)(\sin 30.0°)$$

$$F_N = 77N \quad\quad (\textbf{0.5})$$

Then,

$$F_{fr} = \mu_k F_N$$

$$F_{fr} = (0.20)(77N)$$

$$F_{fr} = 15.4N \quad\quad (\textbf{0.5})$$

Then calculate acceleration.
In the x-direction,

$$\vec{F}_{net} = m\vec{a}_x$$

$$F_A \cos\theta + \vec{F}_{fr} = m\vec{a}_x \quad \textbf{(0.5)}$$

$$a_x = \frac{F_A \cos\theta - F_{fr}}{m}$$

$$a_x = \frac{42N \cos 30.0° - 15.4N}{10.0kg} \quad \textbf{(0.5)}$$

$$a_x = \frac{36.4N - 15.4N}{10.0kg}$$

$$a_x = 2.1\frac{m}{s^2} \quad \textbf{(0.5)}$$

Common Errors and Misconceptions:
1. not using vector components for the applied force
2. not finding the change in the normal force due to the applied force at angle θ (i.e. $F_N \neq mg$)
3. failing to keep the horizontal and vertical direction information separate when finding acceleration and normal force

ITEM #1.4
Concept: Newton's 2nd law in two dimensions.
**Issue: Separating forces into horizontal and vertical components; proper use of the x and y directions, and the positioning of angles in the diagram.**

What is the acceleration of the system shown if the coefficient of kinetic friction between the incline and the block on the incline is 0.15? **(4 marks)**
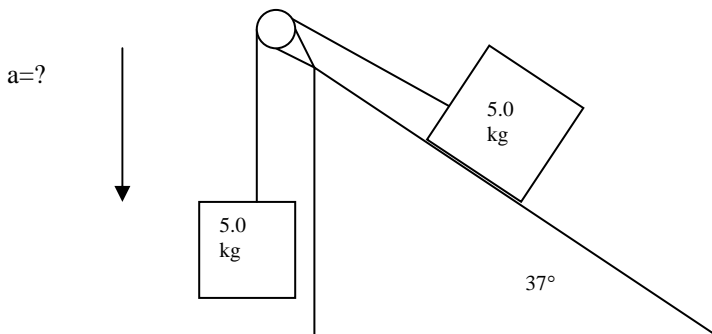
Solution:

Refer to the box on the incline as A and the hanging box as B. Consider the forces acting on the system as shown.
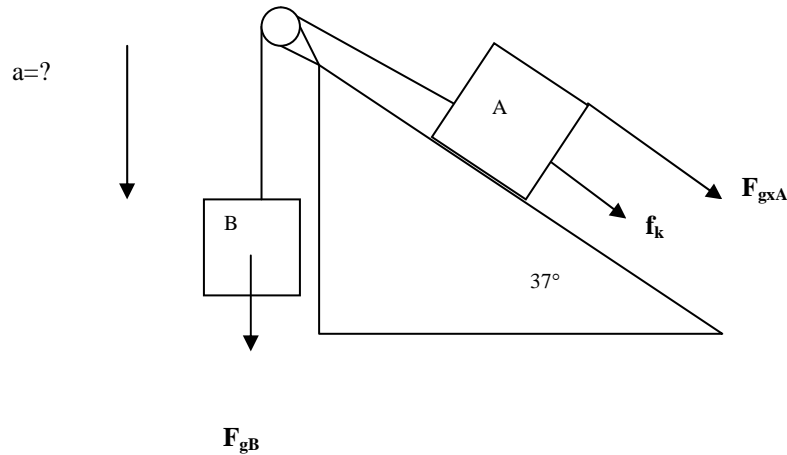
We can see from the diagram that,

$$F_{net} = F_{gB} - F_{gxA} - f_k \qquad \textbf{(1)}$$

where,

$$F_{gB} = m_B g$$

$$F_{gxA} = m_A g \sin 37°$$

$$f_k = \mu_k F_N = \mu_k F_{gyA} = \mu_k m_A g \cos 37°$$

Therefore,

$$F_{net} = (5.0kg)(9.80\frac{m}{s^2}) - (5.0kg)(9.80\frac{m}{s^2})\sin 37° - (0.15)(5.0kg)(9.80\frac{m}{s^2})\cos 37° \quad \textbf{(1.5)}$$

$$F_{net} = 13.6N \qquad \textbf{(0.5)}$$

And,

$$a = \frac{F_{net}}{m_{total}}$$

$$a = \frac{13.6N}{10.0kg}$$

$$a = 1.4\frac{m}{s^2} \qquad \textbf{(1)}$$

Common Errors and Misconceptions:
1. direction errors in realizing that friction opposes motion and must be opposite to the direction the system is moving in
2. mixing up x and y components when calculating F_{gx} and F_{gy} for block A

3.   realizing that the normal force for block A is equivalent to $m_A g \cos 37°$
4.   remembering that for inclined plane problems, we rotate the x and y coordinate grid

ITEM #1.5
Concept: Centripetal Force and Vertical Circles
Issue: In vertical circles, $\vec{F}_{centripetal} = \vec{F}_{gravitational} + \vec{F}_{normal}$. At minimum speed $\vec{F}_{normal} = 0N$ since there is no tension in the rope (or the force of the bottom of the bucket on the rope is zero).

A student whirls a bucket of water in a vertical circle fast enough so that the water does not fall out. If the student's arm is 0.75 m long, what is the minimum speed at which the bucket must be swung? **(3 marks)**

Solution:
At the minimum speed,
$$\vec{F}_{centripetal} = \vec{F}_{gravitational}$$ since the normal force is zero.   **(1)**
Thus,
$$\frac{mv^2}{r} = mg$$
$$\frac{v^2}{r} = g$$
$$v^2 = rg$$
$$v = \sqrt{rg} \qquad \textbf{(1)}$$
$$v = \sqrt{(0.75m)(9.80\frac{m}{s^2})}$$
$$v = 2.7\frac{m}{s} \qquad \textbf{(1)}$$
Thus the bucket must be swung at a minimum speed of 2.7 m/s.

Common Errors and Misconceptions:
1.   Accelerating downward does not mean falling straight downward, but changing one's velocity in the downward direction (i.e. at the top of circular motion).
2.   realizing that mass is not needed to solve the problem (i.e. speed is independent of mass)
3.   knowing the conditions required for minimum speed (i.e. normal force (or tension) is equal to zero)

ITEM #1.6
Concept: Uniform Circular Motion
Issue: Definition of net force as centripetal force; the choice of direction system.

A ball on the end of a string is revolving at a uniform rate in a vertical circle of radius 96.5 cm as shown. If its speed is 3.15 m/s and its mass is 0.335 kg, what is the tension in the string when the ball is,

        a) at the top of its path? **(2 marks)**
        b) at the bottom of its path? **(2 marks)**
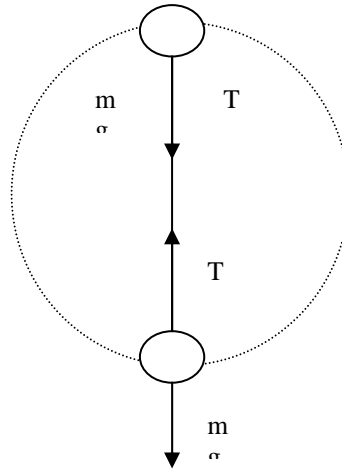
Solution:
This solution assumes that towards the center of the circle is a positive direction.

a) $\vec{T} + \vec{F}_g = \vec{F}_c$

      $T = F_c - F_g$ **(1)**

      $T = \dfrac{mv^2}{r} - mg$

      $T = \dfrac{(0.335kg)(3.15\frac{m}{s^2})^2}{0.965m} - (0.335kg)(9.80\frac{m}{s^2})$ **(0.5)**

      $T = 0.162N$ **(0.5)**

b) $\vec{T} + \vec{F}_g = \vec{F}_c$

      $T - F_g = F_c$

      $T = F_c + F_g$ **(1)**

      $T = \dfrac{mv^2}{r} + mg$

      $T = \dfrac{(0.335kg)(3.15\frac{m}{s^2})^2}{0.965m} + (0.335kg)(9.80\frac{m}{s^2})$ **(0.5)**

      $T = 6.73N$ **(0.5)**

Alternate Solution:
This solution assumes upward to be positive and downward to be negative.

a) $\vec{T} + \vec{F}_g = \vec{F}_c$

$$T + -mg = \frac{-mv^2}{r} \quad \textbf{(1)}$$

$$T = mg - \frac{mv^2}{r}$$

$$T = (0.335kg)(9.80\frac{m}{s^2}) - \frac{(0.335kg)(3.15\frac{m}{s^2})^2}{0.965m} \quad \textbf{(0.5)}$$

$$T = -0.162N \quad \textbf{(0.5)}$$

The tension in the line pulls the ball downward with a force of 0.162 N (tension is 0.162 N in both directions).

b) $\vec{T} + \vec{F}_g = \vec{F}_c$

$$T + -mg = \frac{mv^2}{r}$$

$$T = mg + \frac{mv^2}{r} \quad \textbf{(1)}$$

$$T = (0.335kg)(9.80\frac{m}{s^2}) + \frac{(0.335kg)(3.15\frac{m}{s^2})^2}{0.965m} \quad \textbf{(0.5)}$$

$$T = 6.73N \quad \textbf{(0.5)}$$

The tension pulls up on the ball with 6.73 N of force (tension is 6.73 N in both directions).

Common Errors and Misconceptions:
1. failing to be consistent with direction system
2. failing to realize that the net force is the centripetal force
3. understanding that the object is indeed accelerating even though the speed is constant

ITEM #1.7
Concept: Torque
Issue: Using either $\tau = rF_\perp$ or $\tau = r_\perp F$.

A 20.0 kg sign hangs from a 5.00 kg uniform rod (2.14 m long), as shown below. What tension must the guy wire provide to prevent the sign from rotating around the hinge if the center of mass of the sign is 1.56 m from the hinge? **(3 marks)**
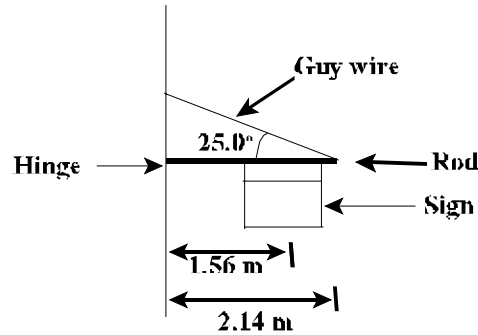
Solution:
Place the pivot at the point where the wall meets the rod.
$$\vec{\tau}_{net} = 0$$
$$\tau_{cw} = \tau_{ccw}$$

$$\tau_{rod} + \tau_{sign} = \tau_{wire} \qquad \textbf{(1)}$$
$$F_{rod}r_{rod} + F_{sign}r_{sign} = F_{wire}r_{wire}$$
$$(5.00kg)(9.80\frac{m}{s^2})(1.07m) + (20.0kg)(9.80\frac{m}{s^2})(1.56m) = F_{wire}\sin 25°(2.14m) \qquad \textbf{(1)}$$
$$52.43N \cdot m + 305.76N \cdot m = 0.904F_{wire}$$
$$F_{wire} = 396N \qquad \textbf{(1)}$$

Alternate Solution:
$$\vec{\tau}_{net} = 0$$
$$\vec{\tau}_{rod} + \vec{\tau}_{sign} + \vec{\tau}_{wire} = 0 \text{ where a clockwise torque is considered positive.}$$

Common Errors and Misconceptions:
1. ignoring the direction of the torque
2. not using the perpendicular component of the force or radius
3. initially specifying a pivot point from which all radii are measured
4. using center of mass to identify r

ITEM #1.8
Concept: Uniform Circular Motion (Horizontal Plane)
Issue: Determining the tension in a line holding a body rotating at a constant speed.

The diagram below shows a ball moving at a constant speed in a circular path on a flat table. What is the tension in the string which is attached to a 0.150 kg ball in order to keep the ball revolving at a radius of 0.600 m, given that the ball makes 2.00 revolutions each second? **(3 marks)**
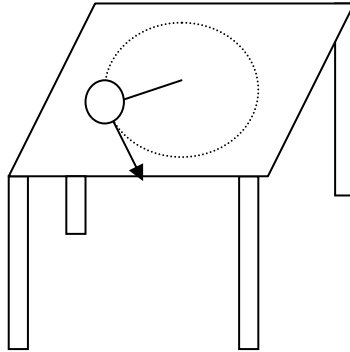
Solution:

$$\vec{T} = \vec{F}_{centripetal} \qquad \textbf{(0.5)}$$

$$v = \frac{2\pi r}{T} \; where \, T = \frac{\# \sec onds}{\# revolutions} = \frac{1.00s}{2.00} = 0.500s \quad \textbf{(0.5)}$$

$$v = \frac{2\pi(0.600m)}{0.500s}$$

$$v = 7.54\frac{m}{s} \qquad \textbf{(1)}$$

Then,

$$\vec{T} = F_{centripetal} = \frac{mv^2}{r}$$

$$\vec{T} = \frac{(0.150kg)(7.54\frac{m}{s})^2}{0.600m}$$

$$\vec{T} = 14.2N \qquad \textbf{(1)}$$

Common Errors and Misconceptions:

1.   confusing frequency and period (expressing $T = 2.0 \; \frac{cycles}{\sec ond}$ instead of $T = 0.500s$)
2.   not realizing that the tension in the line provides the centripetal force (hence $\vec{T} = \vec{F}_{centripetal}$)
3.   forgetting to square v in the centripetal force equation
4.   confusing $\vec{T}$ for tension with T for period

Unit II: Fields
ITEM #2.1
Concept: Charging by Induction
**Issue: Knowing how electrons move in charge distribution on an electroscope.**
Describe how a positive residual charge on a metal leaf electroscope could be produced by induction. Explain using a series of diagrams. **(3 marks)**
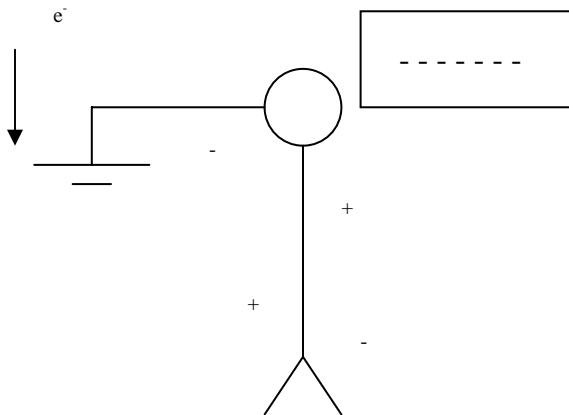Solution:

Step 1: The electroscope is neutral.

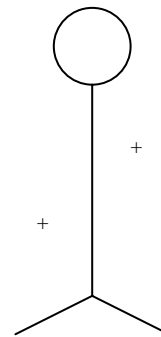Step 2: When a negatively charged rod is brought near, electrons in the electroscope are repelled away from the rod. The electroscope leaves repel. **(1)**
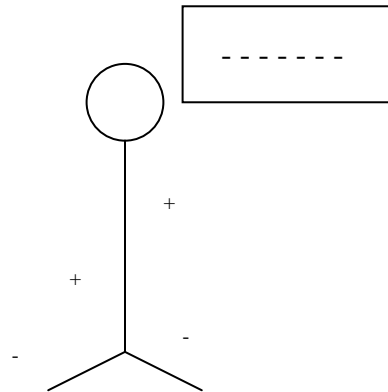
Step 3: When grounded, electrons run off to the ground. Leaves collapse somewhat. **(1)**

Step 4: The electroscope is left with a positive charge. Leaves repel. **(1)**

Common Errors and Misconceptions:
1.   showing when the leaves diverge and collapse
2.   knowing that only electrons move
3.   understanding the redistribution of charge when the grounding is removed

ITEM #2.2
Concept: Coulomb's Law
Issue: This is a common examination problem. Directional system in drawing a free body diagram for object B is important.

Using the diagram below, what is the net force on B due to the presence of A and C?
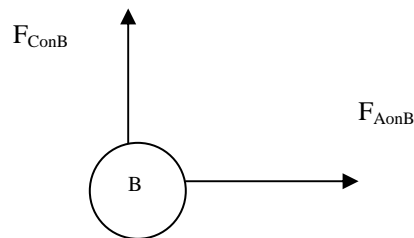**(4 marks)**
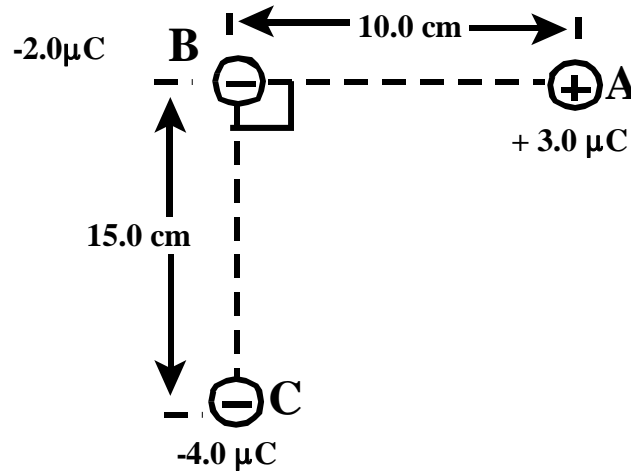
Solution:
First calculate the force of C on B and then of A on B.

$$\vec{F}_{ConB} = \frac{kQ_C Q_B}{r_{CB}^2} = \frac{(9.0x10^9 \frac{N \cdot m^2}{C^2})(-4.0x10^{-6}C)(-2.0x10^{-6}C)}{(0.150m)^2} = 3.2N \quad \textbf{(1)}$$

$$\vec{F}_{AonB} = \frac{kQ_A Q_B}{r_{AB}^2} = \frac{(9.0x10^9 \frac{N \cdot m^2}{C^2})(3.0x10^{-6}C)(-2.0x10^{-6}C)}{(0.100m)^2} = -5.4N \quad \textbf{(1)}$$

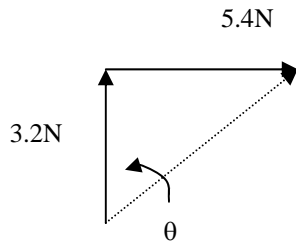To get the magnitude and direction of the net force on B, draw a vector diagram.

Then,

$$\vec{F}_{net}^2 = \vec{F}_{ConB}^2 + \vec{F}_{AonB}^2$$

$$F_{net}^2 = (3.2N)^2 + (5.4N)^2$$

$$F_{net} = 6.3N \quad \textbf{(1)}$$

Then find the angle,

$$\tan \theta = \frac{5.4N}{3.2N} = 59° \, EofN \, or \, N59° \, E \quad \textbf{(1)}$$

Common Errors and Misconceptions:
1.   finding the direction of force vectors for F_{ConB} and F_{AonB}
2.   forgetting to square the distance in the Coulomb's Law formula
3.   remembering to convert distances to meters and microcoulombs to Coulombs
4.   understanding the concept of perpendicular vectors (i.e. vector addition)
5.   using negative values from force calculations when finding the net force – students only need to use the magnitude of F_{ConB} and F_{AonB} when finding F_{net} (direction is taken care of in the vector diagram)

ITEM #2.3
Concept: Electric Field Strength
Issue: This is a common exam problem for electric field strength.

Two point charges $Q_1 = 3.6x10^{-6} C$ and $Q_2 = -2.7x10^{-6} C$ are arranged as shown.
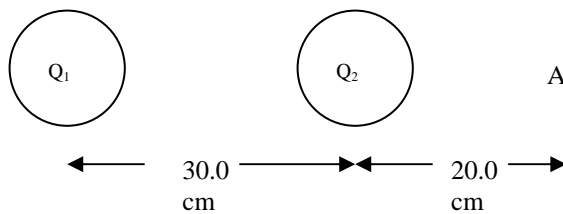
a)   What is the net electric field strength (magnitude and direction) at point A due to the combined electric fields of both charges. **(3 marks)**
b)   What force is exerted on a charge of $4.5x10^{-6} C$ placed at point A? **(1 mark)**

Solution:
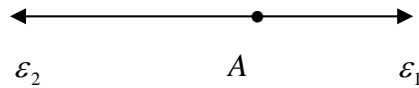a) Find the magnitude of the electric field from each charge at A.

$$\vec{\varepsilon}_1 = \frac{kQ_1}{r^2} = \frac{(9.0x10^9 \frac{N \cdot m^2}{C^2})(3.6x10^{-6}C)}{(0.500m)^2} = 1.296x10^5 \frac{N}{C} \quad \textbf{(1)}$$

$$\vec{\varepsilon}_2 = \frac{kQ_2}{r^2} = \frac{(9.0x10^9 \frac{N \cdot m^2}{C^2})(-2.7x10^{-6}C)}{(0.200m)^2} = -6.075x10^5 \frac{N}{C} \quad \textbf{(1)}$$

Then calculate the net electric field using the vector diagram resulting if there were a small positive test charge placed at point A.

$$\vec{\varepsilon}_{net} = \vec{\varepsilon}_1 + \vec{\varepsilon}_2$$

$$\vec{\varepsilon}_{net} = 1.296x10^5 \frac{N}{C} + -6.075x10^5 \frac{N}{C} = -4.8x10^5 \frac{N}{C} = 4.8x10^5 \frac{N}{C}(left) \quad \textbf{(1)}$$

b) $\vec{F}_e = q\vec{\varepsilon}$

$$\vec{F}_e = (4.5x10^{-6}C)(-4.8x10^5 \frac{N}{C}) = -2.2N = 2.2N(left) \quad \textbf{(1)}$$

Common Errors and Misconceptions:
1. knowing that to calculate $\vec{\varepsilon}_{net}$ students need to use a positive test charge at A (by convention)
2. remembering to square the distance
3. confusing the positive test charge in a) and the negative charge used in part b)
4. forgetting to get total distance away from A for Q_1

ITEM #2.4
Concept: Relationship between gravitational and electric force.
Issue: Expressing the relationship between topics covered in different units.

Compare the electric and gravitational forces with respect to relative size, direction and effect of separation distance. **(3 marks)**

Solution:
❖ The gravitational force is quite weak for ordinary sized masses whereas the electric force is noticeable for small charges (μC). **(1)**
❖ The gravitational force is solely an attractive force whereas electrical forces may be attractive or repulsive. **(1)**
❖ Both gravitational and electric forces vary inversely with the square of their separation distances. **(1)**

Common Errors and Misconceptions:
1.   finding difficulty comparing two fundamentally different forces

ITEM #2.5
Concept: Circuit Analysis
Issue: Being able to draw a circuit and then solve for different variables.

Two devices, one with a resistance of 12 Ω and the other with a resistance of 25Ω are wired in parallel. This combination is connected in series to a third device of resistance 8.0 Ω and then to a switch and a 12V battery.
a) Draw a labeled diagram for this circuit, using proper symbols for resistors, battery and switch. **(1 mark)**
b) Determine the total current drawn from the battery when the switch is closed. **(2 marks)**

Solution:
a)   **(1)**
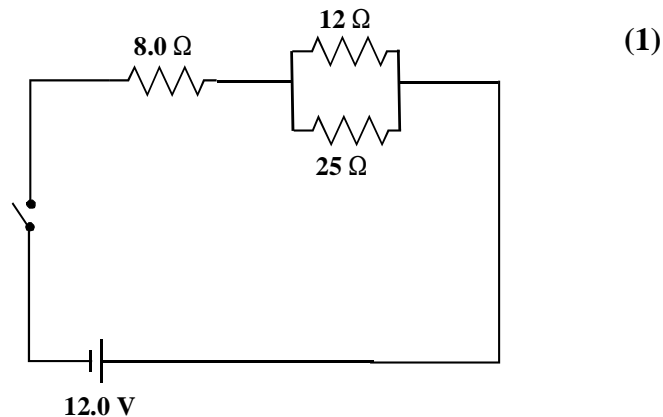
b)   To find I_T, we must first find the equivalent resistance for the parallel combination and the whole circuit.

$$\frac{1}{R_P} = \frac{1}{12\Omega} + \frac{1}{25\Omega}$$
$R_P = 8.11\Omega$ **(0.5)**
Therefore,
$R_T = 8.0\Omega + 8.11\Omega$
$R_T = 16.11\Omega$ **(0.5)**

Then using Ohm's Law,
$$I_T = \frac{V_T}{R_T} = \frac{12V}{16.11\Omega} = 0.74A$$ **(1)**

Common Errors and Misconceptions:
1.   drawing the schematic diagram
2.   knowing the rules for parallel and series components of combination circuits
3.   realizing that to find I_T, equivalent resistance must be found first

ITEM #2.6
Concept: Circuits.
Issue: Applying Ohm's Law and Kirchoff's Laws to solve circuit problems.

What is the voltage drop across R_1 and R_2 in the circuit diagram below? **(4marks)**
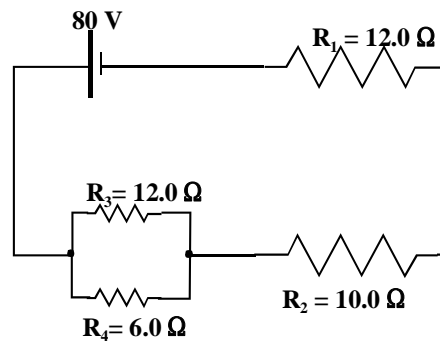
Solution:
First find R_T for the circuit.
$$\frac{1}{R_P} = \frac{1}{12.0\Omega} + \frac{1}{6.0\Omega}$$
$R_P = 4.0\Omega$ **(0.5)**
Then for the series circuit remaining,
$R_T = 12.0\Omega + 10.0\Omega + 4.0\Omega$
$R_T = 26.0\Omega$ **(0.5)**

Next find the total current for the circuit.

$$I_T = \frac{V_T}{R_T} = \frac{80V}{26.0\Omega} = 3.07A = 3.1A \quad \textbf{(0.5)}$$

Since current in a series circuit is the same,

$$I_1 = 3.1A$$

Thus,

$$V_1 = I_1 R_1 = (3.1A)(12.0\Omega) = 37V \quad \textbf{(1)}$$

Then,

$$V_P = I_P R_P = (3.1A)(4.0\Omega) = 12V \quad \textbf{(0.5)}$$

Since voltage is the same in a parallel combination,

$$V_3 = 12V \quad \textbf{(1)}$$

Common Errors and Misconceptions:
1. not using series and parallel rules to find the total resistance
2. using Ohm's Law with the wrong values
3. failing to recognize the series and parallel components of the combination circuit
4. redrawing the circuit is important for keeping series and parallel rules separate

Item #2.7
Concept: Power and Circuits
Issue: Practical application of circuit analysis.

A 75 W light bulb, a $1.8x10^3$ W electric heater, a $3.5x10^2$ W stereo receiver and a $1.2x10^3$ W hair dryer will draw current at the same time. The power company is supplying $1.2x10^2$ V of potential difference and a $2.0x10^1$ A fuse is protecting the circuit.
a) What is the total current drawn by the appliances? **(2 marks)**
b) Will the $2.0x10^1$ A fuse blow? Explain. **(1 mark)**

Solution:
a) Since all the appliances draw current at the same time, the total power drawn is,

$$P_{TOTAL} = 75W + 1.8x10^3 W + 3.5x10^2 W + 1.2x10^3 W = 3425W \quad \textbf{(1)}$$

$$I_T = \frac{P_T}{V_T} = \frac{3425W}{1.2x10^2 V} = 29A \quad \textbf{(1)}$$

b) Yes the fuse will blow. The total current is greater than the maximum current permitted by the fuse. **(1)**

Common Errors and Misconceptions:
1. Knowing that this is a home circuit and we have a parallel connection where $V = V_T = 1.2x10^2 V$.
2. Must use the sum of the power and $P = IV$.

Item #2.8
Concept: Cost of electricity.
Issue: This is a practical application of electricity and a common exam question.

Calculate the cost of operating an oven for 3.00h if it draws 25.0A from a 2.40×10^2 V supply at a rate of 8.49 cents per kilowatt hour. **(2 marks)**

Solution:
$$P = IV = (25.0A)(2.40x10^2 V) = 6000W = 6.00kW \quad \textbf{(0.5)}$$
$$E = Pt = (6.00kW)(3.00h) = 18.0kw \cdot h \quad\quad\quad \textbf{(0.5)}$$
Then,
$$\cos t = energy x rate$$

$$\cos t = (18.0kW \cdot h)(8.49 \frac{cents}{kW \cdot h}) = 153cents = \$1.53 \quad \textbf{(1)}$$

Common Errors and Misconceptions:
1.   Significant figures must be noted when setting these questions.
2.   Power must be changed from watts to kilowatts.

Item #2.9
Concept: Magnetic Field about a current carrying wire.
Issue: Extension of set magnetic field formula. This is a novel application since it is a problem with a second wire where we must add the effect of the second wire's field.

Two current carrying vertical wires are placed 20.0 cm apart as shown. Each wire carries a DC current of 25A.
a) Determine the magnitude and direction of the magnetic field at point X, resulting only from wire A. **(2 marks)**
b) What would be the net magnetic field at X resulting from both wires? **(1 mark)**
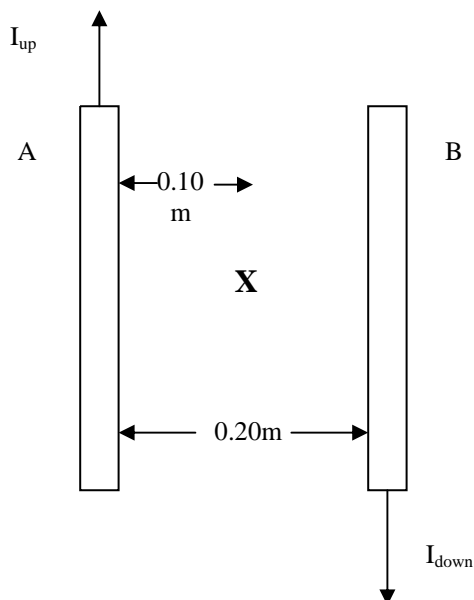
Solution:

a) $$B = \frac{\mu I}{2\pi r} = \frac{(4\pi x 10^{-7}\, \frac{T \cdot m}{A})(25A)}{2\pi(0.100m)} \quad \textbf{(1)}$$

$$B = 5.0 x 10^{-5} T (out\ of\ page) \quad \textbf{(1)}$$

(The direction is determined using the left hand rule where the fingers point out).

b) Since wire B carries the same current at the same distance, the magnitude of the magnetic field from B equals that of A. Using the left hand rule, the field from B is also out of the page. Both fields from A and B will reinforce in order to produce a field of, $B = 2(5.0 x 10^{-5} T) = 1.0 x 10^{-4} T (out\ of\ the\ page)$ **(1)**
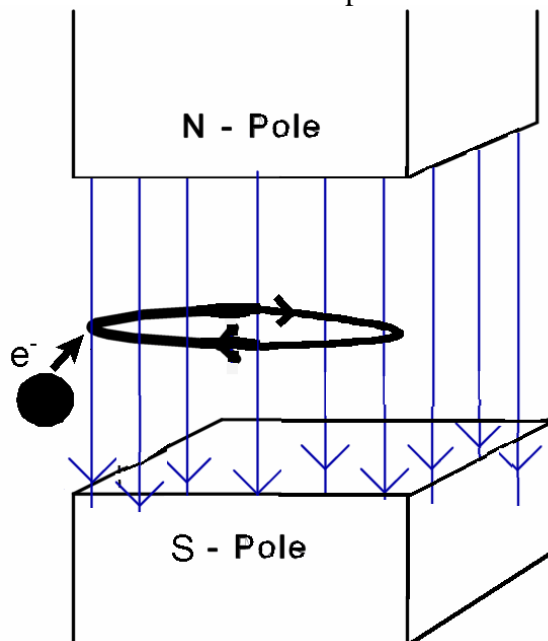
Common Errors and Misconceptions:
1. Students often use the general rule that likes repel and unlikes attract. In this case, when the current flows in opposite or unlike directions the fields reinforce between the wires and the wires would be pushed apart.

Item #2.10
Concept: Moving charge in magnetic fields and circular motion.
Issue: Difficulty in relating two different concepts within the same problem (synthesis).

An electron is shot perpendicularly into a magnetic field of strength $5.7 x 10^{-5}$ T with a velocity of $2.0 x 10^{6}$ m/s. What is the radius of the electron's path inside the magnetic field? **(4 marks)**

Solution:

$$\vec{F}_{magnetic} = \vec{F}_{centripetal} \quad \textbf{(1)}$$

$$Bqv\sin\theta = \frac{mv^2}{r} \quad \textbf{(1)}$$

Since $\theta = 90°\ and\ \sin 90° = 1$, we can write,

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

$$R = \frac{mv}{Bq} \quad \textbf{(1)}$$

$$R = \frac{(9.11x10^{-31}kg)(2.0x10^6\ \frac{m}{s})}{(5.7x10^{-5}T)(1.6x10^{-19}C)} = 0.20m \quad \textbf{(1)}$$

Common Errors and Misconceptions:
1.   Recognizing that the net force acting on the charge to keep it in its circular path is the magnetic force.
2.   Miscalculation of scientific notation.

Item #2.11
Concept: Lenz's Law
Issue: A magnetic field passing through conductors can induce a voltage and produce a current. The direction of the current must obey Lenz's law.

Two identical magnets are dropped simultaneously through the hollow tubes as shown below.
A student observes that both magnets fall at different rates.
Which magnet should fall faster? Using your knowledge of physics principles, how could this observation be explained? (**2 marks**)
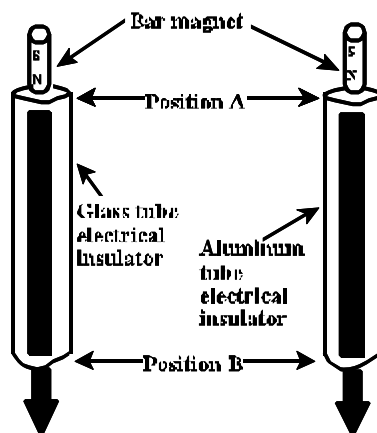
Solution:
- ❖ The faster speed of fall would occur in the glass rod. **(1)**
- ❖ An induced current would be produced around the metal tube as each pole of the magnet moves through it. The direction of these currents will be such to produce a magnetic force to oppose the motion that produced it in accordance with Lenz's Law, thereby making it more difficult to fall down through the metal tube. No such current is induced in the glass as charges do not easily move through insulators.
  (1 mark – mentioning Lenz's Law producing field to oppose motion)
  (1 mark – full description)

Common Errors and Misconceptions:
1.   Confusion between induced voltage and induced current (if electrons are held and are unable to easily move as in an insulator, no current will flow despite the energy given them).
2.   Confusion in treating the wire as a series of loops.
3.   Relative movement between the wire and the magnet – usually the wire is repelled, not the magnets. This may cause some confusion.

Unit III
Matter-Energy Interface

Item #3.1
Concept: Photon momentum
Issue: Common problem on calculating photon momentum.

What is the frequency of electromagnetic radiation whose photons have a momentum of
$2.80x10^{-27} \dfrac{kg \cdot m}{s}$? **(3 marks)**

Solution:
$$p = \frac{h}{\lambda} \text{ and } \lambda = \frac{c}{f}$$
Thus,
$$p = \frac{h}{\dfrac{c}{f}} = \frac{hf}{c} \quad \textbf{(1)}$$
and,
$$f = \frac{pc}{h} \quad \textbf{(1)}$$

$$f = \frac{(2.80x10^{-27} \dfrac{kg \cdot m}{s})(3.00x10^{8} \dfrac{m}{s})}{6.626x10^{-34} J \cdot s} = 1.27x10^{15} \, Hz \quad \textbf{(1)}$$

Common Errors and Misconceptions:
1.   Failing to integrate separate formulae.
2.   Knowing the information that is not specifically given in the question.

Item #3.2
Concept: Work Function
Issue: This is a common problem on calculating work function and photon energy.

A material with a work function of 5.15 eV is shone with incident light that has a wavelength of 632 nm.
a) Determine whether this light will cause the metal to exhibit the photoelectric effect. Show workings. **(3marks)**
b) If the emitting metal is changed, the threshold wavelength in the photoelectric effect increases. Explain how the work function value will change. **(1 mark)**

Solution:
a) If $E_{photon}>W_o$ then the material will exhibit the photoelectric effect. Thus we will calculate the energy of the photon. **(1)**

$$E_{photon} = \frac{hc}{\lambda} = \frac{(6.626x10^{-34} J \cdot s)(3.00x10^8 \frac{m}{s})}{632x10^{-9}m} = 3.15x10^{-19}J \qquad \textbf{(1)}$$

$$E_{photon} = \frac{3.15x10^{-19}J}{1.60x10^{-19}\frac{J}{eV}} = 1.97eV \qquad \textbf{(0.5)}$$

Since 1.97eV<5.15eV, the $E_{photon}<W_o$ and this material will not exhibit the photoelectric effect. **(0.5)**

b) If λ increases, then frequency decreases. **(0.5)**
    If frequency decreases, since $W_o = hf_o$, then W_o would decrease also.   **(0.5)**

Common Errors and Misconceptions:
1.   Understanding of the "nano" prefix.
2.   Remembering to convert the photon energy from Joules into electron volts.
3.   Understanding proportionality relationships for part b).
4.   Realizing that $E_{photon}>W_o$ in order to start the problem.

Question #3.3
Concept: Hydrogen spectra
Issue: Common problem.

Determine the wavelength of the light given off when an electron in hydrogen moves from the n=4 to the n=2 orbit. **(6 marks)**

Solution:

$$E_4 = \frac{13.6eV}{n^2} = \frac{13.6eV}{4^2} = 0.85eV \qquad \textbf{(0.5)}$$

$$E_2 = \frac{13.6eV}{n^2} = \frac{13.6eV}{2^2} = 3.4eV \qquad \textbf{(0.5)}$$

Then,
$$hf = E_2 - E_4$$
$$hf = 3.4eV - 0.85eV = 2.55eV \qquad \textbf{(0.5)}$$

Then,
$$\lambda = \frac{c}{f} = \frac{hc}{\Delta E} \qquad \textbf{(0.5)}$$

$$\lambda = \frac{(6.626x10^{-34}\,J \cdot s)(3.00x10^8\,\frac{m}{s})}{2.55eV}$$

$$\lambda = \frac{(6.626x10^{-34}\,J \cdot s)(3.00x10^8\,\frac{m}{s})}{4.08x10^{-19}\,J} \qquad \textbf{(0.5)}$$

$$\lambda = 4.88x10^{-7}\,m \qquad \textbf{(0.5)}$$

Alternate Solution:

$$\frac{1}{\lambda} = \frac{2\pi^2 Z^2 e^4 mk^2}{h^3 c}(\frac{1}{n_l^2} - \frac{1}{n_u^2}) \qquad \textbf{(1)}$$

Where,
$$\frac{2\pi^2 Z^2 e^4 mk^2}{h^3 c}$$

is the Rydberg constant ($R = 1.0974x10^7\,m^{-1}$)

So,
$$\frac{1}{\lambda} = 1.0974x10^7\,m^{-1}(\frac{1}{2^2} - \frac{1}{4^2}) = 2057625 m^{-1} \qquad \textbf{(1)}$$

$$\lambda = 4.86x10^{-7}\,m \qquad \textbf{(1)}$$

Common Errors and Misconceptions:
1. Note that in alternate solutions answers are identical to 2 significant figures, but not to 3. This is due to rounding in the original formulae constants. Either answer is acceptable.
2. The first solution is probably the method that will be used by most students.
3. Common error is forgetting to convert electron volts to Joules.

Item #3.4
Concept: Half-life
Issue: Relating rate of decay, number of nuclei present and half-life (solving for unknown).

The number of radioactive nuclei in a particular sample decreases over 15 days to $\frac{1}{16}^{th}$ of the original number. What is the half-life of these nuclei? **(2 marks)**

Solution:

$$\frac{A}{A_o} = \frac{N}{N_o} = \left(\frac{1}{2}\right)^{\frac{t}{T_{\frac{1}{2}}}} \quad \textbf{(1)}$$

$$\frac{1}{16} = \left(\frac{1}{2}\right)^{\frac{15}{T_{\frac{1}{2}}}}$$

$$\left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^{\frac{15}{T_{\frac{1}{2}}}}$$

$$4 = \frac{15}{T_{\frac{1}{2}}}$$

$$T_{\frac{1}{2}} = \frac{15}{4}$$

$$T_{\frac{1}{2}} = 3.75 = 3.8\,days \quad \textbf{(1)}$$

Common Errors and Misconceptions:
1. Students may not realize that the ratio of the activity rates equals the ratio of the number of nuclei present in the sample.
2. Possible calculation error in exponent laws (i.e. if $x^a = x^b$ then a=b).

Item #3.5
Concept: Matter-energy
Issue: Energy produced is a result of a loss in mass ($\Delta E = \Delta mc^2$)

Use the data in the table below to answer the following questions.

Particle	Mass (kg)
^2H	3.3444×10^{-27}
^3H	5.0082×10^{-27}
^4He	6.6463×10^{-27}
neutron	1.6749×10^{-27}

a) How much energy is produced in the fusion reaction below? **(2 marks)**

$$_1^2H + _1^3H \rightarrow _2^4He + _0^1n + \gamma$$
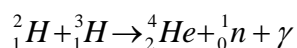
b) How much energy will a rocket that contains 1.000 kg of $_1^2H$ gain from the fusion reaction?
   (1 mark)

Solution:
a) $\Delta m = m_{before} - m_{after}$ **(0.5)**

   $\Delta m = (3.3444x10^{-27} kg + 5.0082x10^{-27} kg) - (6.6463x10^{-27} kg + 1.6749x10^{-27} kg)$

   $\Delta m = 3.14x10^{-29} kg$ **(0.5)**

Then,
$\Delta E = \Delta mc^2$ **(0.5)**

$\Delta E = (3.14x10^{-29} kg)(3.00x10^8 \frac{m}{s})^2$

$\Delta E = 2.83x10^{-12} J$
          (0.5)

b) $\frac{E}{m} = \frac{2.83x10^{-12} J}{3.3444x10^{-27} kg} = 8.46x10^{14} \frac{J}{kg}$ **(1)**

Common Errors and Misconceptions:
1.   Improper rounding made before subtracting mass causes large error in the energy
       calculated.
2.   Problems with units.
3.   Forgetting to square "c".

Item #3.6
Concept: Nuclear physics.
Issue: Common problem – nuclear equations.

Complete the following nuclear equations:

a) $\quad ^{236}_{93}Np \rightarrow ^{-}_{-}\_\_ + ^{236}_{94}Pu$ **(2marks)**

b) $\quad ^{53}_{26}Fe \rightarrow ^{0}_{1}\beta + ^{-}_{-}Co + \gamma$ **(2marks)**

c) $\quad ^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{-}_{-}He + \gamma$ **(2marks)**

Solution:

a) $\quad$ Atomic # = -1
$\qquad$ Mass # = 0 $\qquad\qquad$ Particle must be $\beta^- or ^0_{-1}e$

b) $\quad$ Atomic # = 25 (26-1)
$\qquad$ Mass # = 53 $\qquad\qquad$ Answer is $^{53}_{25}Co$

c) $\quad$ Atomic # = 2 (88-86)
$\qquad$ Mass # = 4 (226-222) $\qquad$ Answer is ^4_2He

1 pt for each particle (0.5 for atomic # and 0.5 for mass #)

Common Errors and Misconceptions:
1. $\quad$ Confusing mass # with atomic #.