First Name:_____   Last Name:_____

L09 – Worksheet – Parallel Plates and Conservation of Energy

Textbook Questions

Pg 573 #1: An alpha particle with a charge of +3.20 x 10^{-19} C and a mass of 6.65 x 10^{-27} kg is placed between two oppositely charged parallel plates with an electric potential difference of 4.00 x 10^4 V between them. The alpha particle is injected at the positive plate with an initial speed of zero, and it accelerates toward the negative plate. Determine the final speed of the alpha particle just before it strikes the negative plate.

$q = 3.20 \times 10^{-19} C$

$m = 6.65 \times 10^{-27} kg$

$\Delta V = 4.00 \times 10^4 V$

$V_i = 0 \, m/s$

$V_f = ?$

$\Delta V = \frac{\Delta E_p}{q} \rightarrow \Delta E_p = q\Delta V$ $E_k = \frac{1}{2}mv^2$

$E_p \longrightarrow E_k$

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

$(3.20 \times 10^{-19})(4.00 \times 10^4) = \frac{1}{2}(6.65 \times 10^{-27})v^2$

$v^2 = 3.85 \times 10^{12}$

$v = 1.962 \times 10^6 \, m/s$

Pg 573 #2: If a charge of -6.00 x 10^{-6} C gains 3.20 x 10^{-4} J of kinetic energy as it accelerates between two oppositely charged plates, what is the potential difference between the two parallel plates?

$q = -6.00 \times 10^{-6} C$

$\Delta E_k = 3.20 \times 10^{-4} J$

$E_p \rightarrow E_k$

$E_p \rightarrow 3.20 \times 10^{-4} J$

$E_p = 3.20 \times 10^{-4} J$

$\Delta V = \frac{\Delta E_p}{q} = \frac{3.20 \times 10^{-4} \, J}{6.00 \times 10^{-6} \, C}$

$\Delta V = 53.\overline{3} \, V$

Pg 575 #4: Calculate the speed of an electron and a proton after each has accelerated from rest through an electric potential of 220 V.

Electron

$E_p \rightarrow E_k$

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

$(1.60 \times 10^{-19})(220) = \frac{1}{2}(9.11 \times 10^{-31})v^2$

$v = 8.79 \times 10^6 \, m/s$

Proton

$E_p \rightarrow E_k$

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

$(1.60 \times 10^{-19})(220) = \frac{1}{2}(1.67 \times 10^{-27})v^2$

$v = 2.05 \times 10^5 \, m/s$

Pg 575 #5: Electrons n a TV picture tube are accelerated by a potential difference of 25 kV. Find the maximum speed the electrons would reach if relativistic effects are ignored.

$$\Delta V = \frac{\Delta E_p}{q}$$

$$\Downarrow$$

$$\Delta E_p = q \Delta V$$

$$E_p \rightarrow E_K$$
$$q \Delta V = \tfrac{1}{2} m v^2$$
$$(1.60 \times 10^{-19})(25,000) = \tfrac{1}{2}(9.11 \times 10^{-31})v^2$$
$$v = 9.37 \times 10^7 \, m/s$$

Pg 575 #6: A charge gains 1.92×10^{-14} J of electric potential energy when it moves through a potential difference of 3.20×10^4 V. What is the magnitude of the charge?

$$\Delta E_p = 1.92 \times 10^{-14} \, J$$
$$\Delta V = 3.20 \times 10^4 \, V$$
$$q = ?$$

$$\Delta V = \frac{\Delta E_p}{q}$$
$$3.20 \times 10^4 = \frac{1.92 \times 10^{-14}}{q}$$
$$q(3.20 \times 10^4) = 1.92 \times 10^{-14}$$
$$q = 6.0 \times 10^{-19} \, C$$

Pg 575 #7: How much work must be done to increase the electrical potential of a charge of 2.00×10^{-6} C by 120 V?

$$q = 2.00 \times 10^{-6} \, C$$
$$\Delta V = 120 \, V$$
$$\Delta E_p = W = ?$$

$$\Delta V = \frac{\Delta E_p}{q}$$
$$120 = \frac{\Delta E_p}{2.00 \times 10^{-6}}$$
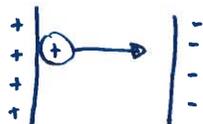$$\Delta E_p = 2.40 \times 10^{-4} \, J$$
$$W = \Delta E = 2.40 \times 10^{-4} \, J$$

Pg 575 #8: A deuterium ion (H^{1+}), a heavy isotope of hydrogen, has a charge of 1.60×10^{-19} C and a mass of 3.34×10^{-27} kg. It is placed between two oppositely charged plates with a voltage of 2.00×10^4 V. Find the final maximum speed of the ion if it is initially placed at rest

    a. At the positive plate.
    b. Midway between the two plates.

Ⓐ

Ⓑ Half distance = half voltage.
or half E_p.

$$1.60 \times 10^{-15} = \tfrac{1}{2}(3.34 \times 10^{-27})v^2$$
$$v = 9.788 \times 10^5 \, m/s$$

Half of
total E_p.

$$E_p \rightarrow E_K$$
$$q \Delta V = \tfrac{1}{2} m v^2$$
$$(1.60 \times 10^{-19})(2.00 \times 10^4) = \tfrac{1}{2}(3.34 \times 10^{-27})v^2$$
$$3.20 \times 10^{-15} = \tfrac{1}{2}(3.34 \times 10^{-27})v^2$$
$$v = 1.384 \times 10^6 \, m/s$$

E_p

Diploma Worksheet Questions – Conservation of Energy

Q210: The potential difference through which an electron must be accelerated to increase its speed from rest to 1.9 x 10^7 m/s is

a. 5.4 x 10^{-5} V
b. 1.1 x 10^{-4} V
c. 1.0 x 10^3 V
d. 2.1 x 10^3 V

$$E_p \rightarrow E_k$$
$$q\Delta V = \tfrac{1}{2}mv^2$$
$$(1.60\times10^{-19})\Delta V = \tfrac{1}{2}(9.11\times10^{-31})(1.9\times10^7)^2$$
$$\Delta V = 1027.72 V$$
$$\approx 1.0\times10^3 V$$

Q211: An average force of 6.00 x 10^{-3} N is required to move a 4.50 x 10^{-4} C charge from one point to another point that is 0.750 m away. The potential difference between the two points is

a. 2.03 V
b. 10.0 V
c. 13.0 V
d. 18.0 V

$$F = 6.00\times10^{-3} N$$
$$d = 0.750 m$$
$$q = 4.50\times10^{-4} C$$

OPTION #1
$$W = Fd$$
$$W = (6.00\times10^{-3})(0.750)$$
$$W = 0.0045 J$$
$$\Delta E_p = 0.0045 J$$
$$\Delta V = \frac{\Delta E_p}{q} = \frac{0.0045}{4.50\times10^{-4}} = 10 V$$

OPTION #2
$$|\vec{E}| = \frac{\vec{F}}{q}$$
$$|\vec{E}| = \frac{6.00\times10^{-3} N}{4.50\times10^{-4} C}$$
$$|\vec{E}| = 13.3 \text{ N/C}$$
$$|\vec{E}| = \frac{\Delta V}{\Delta d} =$$
$$13.\overline{3} = \frac{\Delta V}{0.75}$$
$$\Delta V = 9.\overline{9} V$$
$$\Delta V \approx 10 V$$

Q213: What will be the speed of an electron that accelerates from rest through a potential difference of 5.0 x 10^2 V?

a. 9.4 x 10^6 m/s
b. 1.3 x 10^7 m/s
c. 1.8 x 10^{14} m/s
d. 3.3 x 10^{16} m/s

$$E_p \rightarrow E_k$$
$$q\Delta V = \tfrac{1}{2}mv^2$$
$$(1.60\times10^{-19})(5.0\times10^2) = \tfrac{1}{2}(9.11\times10^{-31})v^2$$
$$v = 1.3\times10^7 \text{ m/s}$$

Use the following information to answer Q217 and Q218:

A particle with a mass of 3.60×10^{-18} kg acquires 3.00×10^5 eV of kinetic energy when it accelerates from rest through a potential difference of 1.00×10^4 V.

Q217: The charge on the particle is

a. 4.80×10^{-18} C
b. 3.33×10^{-2} C
c. 3.00×10^1 C
d. 2.08×10^{17} C

$$\frac{3.00 \times 10^5 \, eV}{1} \times \frac{1.60 \times 10^{-19} \, J}{1 \, eV} = 4.80 \times 10^{-14} \, J$$

$E_p \rightarrow E_K$

$q\Delta V \rightarrow E_K$

$q(1.00 \times 10^4) = 4.80 \times 10^{-14}$

$q = 4.80 \times 10^{-18}$ C

Q218: The speed that the particle acquires, expressed in scientific notation, is $b \times 10^w$ m/s. The value of b is _____.

*(Record your **three digit** answer in the Numerical Response boxes below)*

1	.	6	3

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

$4.8 \times 10^{-14} \, J = \frac{1}{2}(3.60 \times 10^{-18})v^2$

$v^2 = 26{,}666.\overline{6}$

$v = 163.299316186$ m/s

$v \approx 1.63 \times 10^2$ m/s

Diploma Worksheet Questions - Algebra

Use the following information to answer Q222 and Q223:

> An alpha particle, of mass m and charge q, undergoing an acceleration because of an external potential difference of V has a physical quantity S associated with it. The formula for S is
>
> $$S = \sqrt{2qVm}$$

Q222: When the potential difference is 7.62×10^4 V, the numerical value of S in SI units is

a. 3.2×10^{-40}

b. 1.8×10^{-20}

c. 4.5×10^{-11}

d. 4.4×10^{-7}

$S = \sqrt{2(3.20 \times 10^{-19})(7.62 \times 10^4)(6.65 \times 10^{-27})}$

$S = 1.80 \times 10^{-20}$

Q223: The appropriate SI unit for S is equivalent to the SI unit for

a. Force

b. Energy

c. Momentum

d. Magnetic field intensity

$S = \sqrt{2qVm}$

$S^2 = 2qVm$

$\dfrac{S^2}{2m} = qΔV$

So $\dfrac{S^2}{2m}$ is E_k

$\dfrac{S^2}{2m} = \frac{1}{2}mv^2$

$\cdot 2 \qquad \cdot 2$

$\dfrac{S^2}{m} = mv^2$

$\cdot m \qquad \cdot m$

$S^2 = m^2v^2$

$S = mv$, so $S = p$

Q224: An electron accelerates from rest across the gap between charged parallel plates and reaches a final speed of v. If the potential difference across the plates is tripled, the final speed of an electron accelerating from rest across the gap will be

a. $\dfrac{1}{3}v$

b. $\dfrac{1}{\sqrt{3}}v$

c. $\sqrt{3}v$

d. $9v$

$qΔV \rightarrow \frac{1}{2}mv^2$

$q(3ΔV) = \frac{1}{2}m(av)^2$

$3(qΔV) = \frac{1}{2}ma^2v^2$

$3(qΔV) = a^2(\frac{1}{2}mv^2)$

$3 = a^2$

$a = \sqrt{3}$

So increases by a factor of $\sqrt{3}$

Use the following information to answer Q227 – Q230:

Street Lamps

Some street lamps use vapour tubes. These tubes give off less heat than incandescent light bulbs and, therefore, use energy more efficiently. Two common types are sodium vapour tubes and mercury vapour tubes.

Common to Both Types of Vapour Tube

Both types of tube are constructed similarly and have a length of 20.0 cm. Inside the tube, electrons are accelerated across a potential difference, and some of them collide with the sodium or mercury atoms, thereby producing light.

Vapour Tubes At a Particular Instant

Sodium (Na) Vapour Tube

Mercury (Hg) Vapour Tube

At one particular instant in each tube, the electric potential difference between the electrodes is 110 V and electrode A is the cathode.

Q227: At the particular instant described, if an electron does not collide with any mercury atoms inside the tube, then the electron's maximum speed will be

a. 1.45×10^5 m/s
b. 4.40×10^6 m/s
c. 6.22×10^6 m/s
d. 3.86×10^{13} m/s

$E_p \rightarrow E_K$

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

$(1.60 \times 10^{-19})(110) = \frac{1}{2}(9.11 \times 10^{-31})v^2$

$v = 6,216,016.28034$ m/s

$v \approx 6.22 \times 10^6$ m/s

Q228: If an electron does not collide with any mercury atoms inside the tube, then the impulse given to the electron by the accelerating voltage, expressed in scientific notation, is _____ x 10^{-W} N*s.

*(Record your **three digit** answer in the Numerical Response boxes below)*

5	.	6	6

EASY

$F\Delta t = m\Delta V$
$= (9.11\times10^{-31})(6.216...\times10^{6})$
$= 5.66279... \times 10^{-24}$
$\approx 5.66\times10^{-W}$ Ns

$F\Delta t = (8.80\times10^{-17})(6.43...\times10^{-8})$
$F\Delta t = 5.66279\times10^{-24}$
$\approx 5.66\times10^{-W}$ Ns

HARD

$|\vec{E}| = \frac{\Delta V}{\Delta d} = \frac{110V}{20\times10^{-2}m} = 550$ N/C

$|\vec{E}| = \frac{F}{q}$ or $\vec{F} = q\vec{E} = (1.60\times10^{-19})(550)$
$= 8.80\times10^{-17}$ N

$a = \frac{F_{net}}{m} = \frac{8.80\times10^{-17}}{9.11\times10^{-31}} = 9.65971459934\times10^{13}$ m/s²

$d = v_i t + \frac{1}{2}at^2$
$20\times10^{-2} = \frac{1}{2}(9.6597...\times10^{13})t^2$
$t = 6.43498958112\times10^{-8}$ s

Q229: At the particular instant described, the magnitude of the electric field between the two electrodes is

$|\vec{E}| = \frac{\Delta V}{\Delta d} = \frac{110V}{20\times10^{-2}m} = 550$ N/C or V/m

a. **550 N/C** ⟵ (circled)
b. 550 J/C
c. 5.50 N/C
d. 5.50 J/C

Q230: At the particular instant described, the electrons in the vapor tube will accelerate

a. Toward the bottom of the tube
b. Toward electrode A
c. **Toward electrode B** (circled)
d. In all directions

Cathode is negative.

Electrons, originating from the cathode, were originally called "cathode rays".

This is actually a <u>Unit 4</u> question.

Cathode   Anode
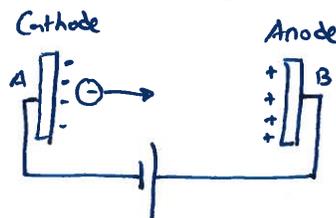
Challenge Questions

Use the following information to answer Q1:

Cyclotrons

A cyclotron is a type of particle accelerator invented by Ernest O. Lawrence in 1934 in which charged particles accelerate outwards from the center along a spiral path. The particles are held to a spiral trajectory by a static magnetic field and accelerated by a rapidly varying (radio frequency) electric field.

A proton leaves one of the "dees" travelling at 2.50×10^6 m/s, and is subject to an electric field created by a 2.00×10^4 V power supply, as diagrammed below.
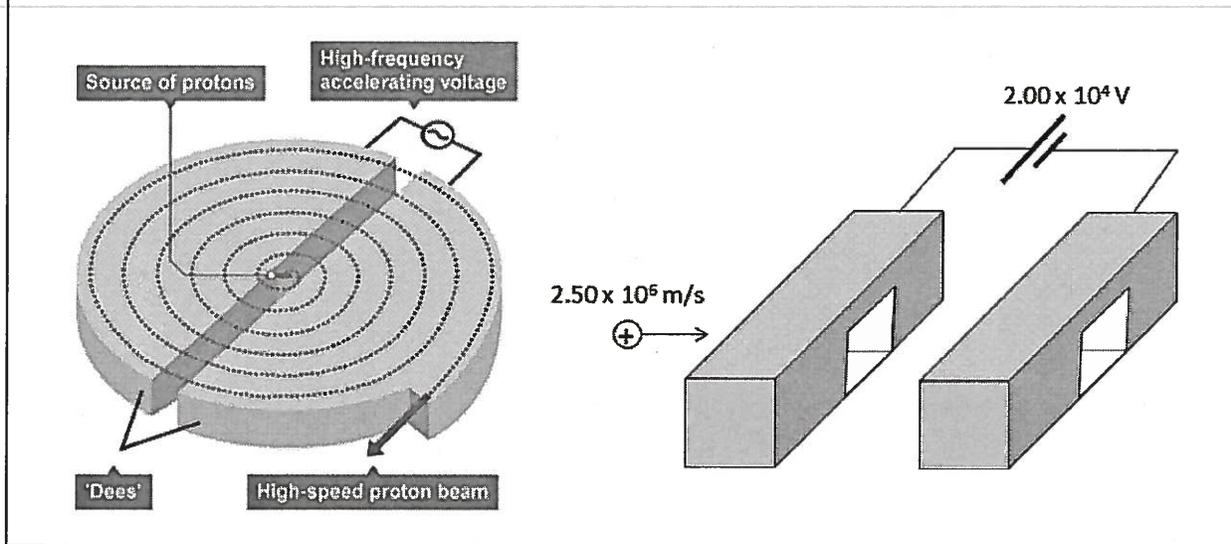
Q1: After being accelerated, the proton is now travelling at a speed of $a.bc \times 10^d$ m/s, where *a, b, c,* and *d* are ___, ___, ___, and ___.

*(Record your **three digit** answer in the Numerical Response boxes below)*

3	1	8	6

$$E_i \longrightarrow E_f$$

$$E_{ki} + E_{pi} \longrightarrow E_{kf}$$

$$\tfrac{1}{2}mv_i^2 + q\Delta V = \tfrac{1}{2}mv_f^2$$

$$\tfrac{1}{2}(1.67\times10^{-27})(2.50\times10^6)^2 + (1.60\times10^{-19})(2.00\times10^4) = \tfrac{1}{2}(1.67\times10^{-27})v_f^2$$

$$5.21875\times10^{-15} + 3.2\times10^{-15} = \tfrac{1}{2}(1.67\times10^{-27})v_f^2$$
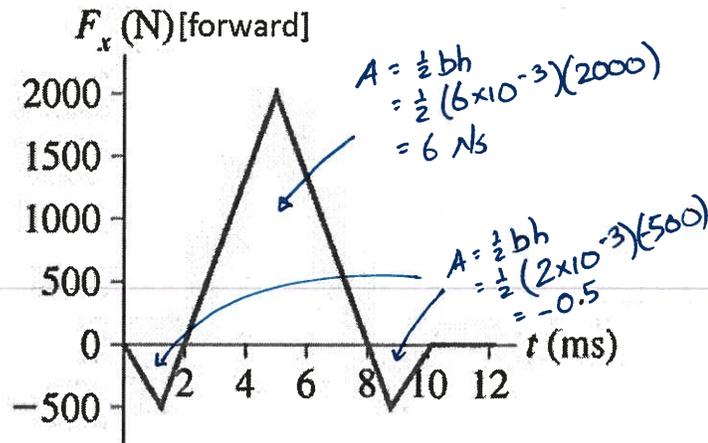
$$v_f = 3.175269...\times10^6 \text{ m/s}$$

$$v_f \approx 3.18 \times 10^6 \text{ m/s}$$

Cumulative Review from Previous Units

Use the following information to answer Q1:

A 2kg object is subject to the following impulse.

$$A = \tfrac{1}{2} bh$$
$$= \tfrac{1}{2}(6\times10^{-3})(2000)$$
$$= 6 \ Ns$$

$$A = \tfrac{1}{2} bh$$
$$= \tfrac{1}{2}(2\times10^{-3})(500)$$
$$= -0.5$$

Q1: If the object were originally travelling 2.5 m/s [backward], what is the final velocity of the object?

$$\text{Impulse} = (+6) + (-0.5) + (-0.5)$$
$$F_{\Delta}t = 5 \ Ns$$

$$F_{\Delta}t = m\Delta v$$
$$5 = (2)\Delta v$$
$$\Delta v = 2.5 \ m/s \ [f]$$

$$\Delta v = v_f - v_i$$
$$(+2.5) = v_f - (-2.5)$$
$$2.5 = v_f + 2.5$$
$$\vec{v}_f = 0 \ m/s \ [f]$$