IDX G9 Physics S+
Study Guide Issue Semester 1 Final
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Contents:

Chapter 4: Dynamics, Newton's Laws of Motion

4.1 Force

- **Force**: push or pull exerted by one object on another.
    - Vector
    - Interaction between 2 objects: **system** (to whom) and **agent** (by whom)
    - To cause deformation (change in dimension/shape)/change velocity
    - In Newtons (N); $1N=1kgm/s^2$; Measured using spring scale
    - Three factors:
        - **Magnitude**: the strength of the force vector.
        - **Direction**: in which direction the force vector acts.
        - **Point of application**: the location the force is exerted.
    - Drawing using arrow
        - Length is magnitude; tail is point of application, head is towards the force direction
        - Usually starts from central of mass of object or application

- **When drawing a free-body diagram, label all forces' directions from the center of the object**

- Four fundamental forces
  - Gravity, Strong force, Weak force, and Electromagnetic force

- **Contact force**
  - An object from the external world touches a system and thereby exerts a force on it
  - Eg: Friction, drag force (air resistance/fluid resistance), tension, normal force, spring force, applied force
- **Field force**
  - Exerted without contact
  - E.g. Gravitational force, Electric force, magnetic force
- **Gravitational Force**
  - **Weight** (W or Fg)
  - The force of Gravitational Force on an object at the surface of a planet.
  - $\mathbf{Fg = G\frac{m_1 m_2}{r^2}}$
- **Spring Force**
  - **Hooke's Law**:
  - The magnitude of the force is directly proportional to the amount of stretch/compression within the limit of a spring.
  - **Fsp=-kx**
  - Fsp: the force exerted by the spring on the attached object (N)
  - x: the displacement of the spring end from its equilibrium position. (cm)
  - k: spring constant (N/cm)
  - Elastic limit: A point beyond which the spring will no longer return to its original shape when the force is removed.
- **Friction**
  - **Sliding Friction**: the friction that occurs when two solid surfaces slide over each other.

- **Static friction** (Fsf): Caused by tendency of relative motion.
- No relative motion between 2 objects in touch
- $F_{f,static} = F_{cause}$
- **Kinetic friction** (Fkf) : Caused by the relative motion (relative motion between 2 objects in touch)
- Same objects: Ffk ≤Ffsmax
- **Ffk= μ kFN**
- μ k --coefficient of kinetic friction
- Ffk – kinetic friction
- Ffk does not change with the Fcause

- **Rolling Friction**: the friction that occurs
- When an object rolls over a surface. (smaller than sliding friction)

- **Fluid Friction**: the friction that occurs when an object move through a fluid.
- Eg.: air resistance/ friction in water, oil

- **Air resistance**
  - Depends on: Shape of the object
    - Streamline: reduce friction
  - Depends on: Size of an object
    - Surface area ↑ Fair ↑
  - Depends on: Speed of an object
    - Speed ↑ Fair ↑
  - Depends on: Fluid type: viscosity
    - More viscous Fair ↑

- **Balanced Forces**
  - Equilibrant and balanced force--> two forces are balanced.

        - When two difference forces acting on the same object (same point of application)
        - With the same magnitude, Opposite direction, Acts on the same line
    - Equilibrium (When objects experience balanced forces)
        - At rest
        - Uniform motion
        - Net force=0
    - Unbalanced forces: net force≠0 Motion is changed
        - Start moving
        - Stop moving
        - Change direction
        - Unbalanced forces will change the object’s motion.

4.2 Newton’s First Law

- Galileo did experiments: concludes that when zero resistance, horizontal motion never stops
    - Newton’s First law **(Law of Inertia)**
        - Every object continues in its state of rest or uniform velocity in straight line as long as no net force acts on it
        - Inertia: Tendency of object to resist change in state of motion
        - Mass: measure of inertia on object
        - if Mass increase, Inertia increases, Motion: harder

4.4 Newton’s Second Law

- The acceleration of an object is directly proportional to the net force acting on it, and is inversely proportional to the object’s mass.
- The direction of the acceleration is in the direction of the net force acting on the object
    - $\mathbf{a} = \frac{\mathbf{Fnet}}{\mathbf{m}}$ **or** $\mathbf{Fnet} = \mathbf{m} \times \mathbf{a}$
    - Fnet : net force, a: acceleration, m: object’s mass
    - Unit: N
        - 1N is 1kg/s^2

- Increasing acceleration
    - Increase net force; when mass is constant
    - Decrease mass; when net force is constant

4.5 Newton's Third Law

- If object A exerts a force on object B, then object B exerts an equal but opposite force on object A
    - Forces always come in pairs : Force (A on B) and Force (B on A)
    - **Opposite directions, equal magnitude, different systems, but Force of the same type**
    - Also called "**Action-Reaction pair of Forces**"
    - **When drawing the free-body diagram, remember to label the action and reaction pair of forces when needed!**
- **Balanced Forces**
    - **Same magnitude and Directions**
    - **Objects have the same system**; so they cancel each other
    - Doesn't always occur/change at the same time
    - **Not always the same type**
    - Doesn't change motion
- **Action-Reaction Forces**
    - **Same magnitude and Directions**
    - **Objects have the different systems**
    - Always occur/change at the same time
    - **Always the same type of force**
    - May change motion
- **Problem solving strategies**
    - Separate system(s) from external world
    - Draw a free body diagram and label the x,y-axis
    - **Connect the interaction pairs using dashed lines**
    - Use Newton's second or relate to acceleration/mass
    - Use the third law to balance the magnitudes of the forces

- Solve the problem

4.7 Solving Problems with Newton's Laws : Free-Body Diagrams&4.8 Problems Involving Friction, Inclines

- **Translational Equilibrium**
  - If the net force of an object is zero, then the object is in translational equilibrium
  - Object at rest
  - Object moving at constant velocity
  - Formula : **F=0 Fx=0 Fy=0**
- You can **modify the coordinate system** for convenience of calculation, **this way finding the force that needs to break down into x and y components will be easier**

<u>Chapter 1 Introduction, Measurement, Estimating</u>

1-4 Measurement and Uncertainty: Significant Figures

- **Measurement**: A comparison between an unknown quantity and a standard
- **Significant Figures**
  - The valid/ reliable digits in a measurement
  - Last digit in a measurement is called an estimated/uncertain digit
- **Rules for counting Significant Digits**:
  - All non-zero digits & any zeroes contained between non-zero digits count
    - Eg: 300042= 6 significant digits; 21009878= 8 significant digits
  - Exact numbers have infinite number of significant digits
    - **Eg**: 190 people=Infinite significant digits / pi has infinite significant figure, and also constants like the speed of light has infinite significant digits
  - Leading zeros don't count
    - Eg: 0.000908=3 significant digits
  - Trailing zeros count if there is a decimal point
    - Eg: 0.00090000=5 significant digits

- Trailing zeroes may/may not count if there is no decimal point
    - Eg: 1239840000=6 significant digits; but 1290000.=7 significant digits
- Scientific Notation is recommended

- Arithmetic with significant digits
    - The result can never be more precise than the least precise measurement

- **Addition and subtraction**
    - Round the results to **have as many decimal places (the number of the decimal places) as the measured number with the smallest number of decimal places**
        - Eg: 15.90+11.9 = 27.8
- **Multiplication and Division**
    - Round the results to **have as many significant fugures as the measured number with the smallest number of significant places**
    - Eg:409.2/11.4=35.9
- **Uncertainty (Error)**
    - **Systematic and Random Errors**
        - Note: No measurement made is ever exact
        - The accuracy and precision of a measurement are always limited
            - **Accuracy**: How close a measurement is to the 'true value" or accepted value
                - In other words, correctness
            - **Precision**: The repeatability of the measurement using a given instrument
                - In other words, the number of significant figures
    - Representing Experiment Results
        - **(Measured value ± uncertainty) unit= x±△x**
    - Two types of errors
        - **Random error**
            - The statistical fluctuations in the measured data due to the precision limitations of the measurement device

        - Can be reduced by averaging over large numbers of observation

    - **Systematic errors**
        - Are reducible inaccuracies that are consistently in the same direction
        - Can't be reduced or reduced by repeating measurements
    - **Instrument Limit of Error (ILE) and Least Count**
        - **Least Count**: the smallest division that is marked on the instrument
        - **ILE**: the precision to which a measuring device can be read, and is always equal to or smaller than the least count
            - For digital devices, the smallest division is the least count
            - Generally the ILE is the least count or 1/2 of the least count
        - **Deviation**: The difference between measurements and the average of the variety
        - **Written in (Measured value±Uncertainty)unit**

- **Relative and Absolute Errors**
    - Representing experiment result: (Measured value ± uncertainty) unit= $x \pm \triangle x$
    - **Absolute error/uncertainty: $\triangle x$**
    - **Relative uncertainty: $\frac{uncertainty}{measured\ value}=\frac{\triangle x}{x}$**
    - Precision is reported by using relative or fraction uncertainty or absolute value
        - keep 1-2 significant figures
    - **Relative Error: Relative Error=$\frac{measured\ value-expected\ value}{Expected\ value}$**
        - Accuracy is reported by using relative error
    - **Percentage Uncertainty= relative uncertainty*100%**
    - **Percentage Error=relative error*100%**
        - Keep 1-2 significant figures
- **Addition and Subtraction**
    - The absolute uncertainty of the final results= sum of absolute uncertainties
        - **Sum: $(A \pm \triangle A)+(B \pm \triangle B)=(A+B) \pm (\triangle A+\triangle B)$**

- **Subtraction: (A±△A)-(B±△B)=(A-B)±(△A+△B)**

- **Multiplication and Division**
  - The percent uncertainty of the final result=sum of percent uncertainties
    - **Multiplication:(A±△A)*(B±△B)=(A*B)±($\frac{\triangle A}{A}+\frac{\triangle B}{B}$)*(A*B)**
    - **Division:** $\frac{(A\pm\triangle A)}{(B\pm\triangle B)}=(\frac{A}{B})\pm(\frac{\triangle A}{A}+\frac{\triangle B}{B})*(\frac{A}{B})$
  - For multiplication by an exact number, multiply the uncertainty by the same exact number
- **Graphing**
  - Choose simple scales
    - Dependent Variable
      - factor that depends on the independent variable
      - On the Y axis
    - Independent Variable
      - the factor that is changed
      - On the X axis
  - Plot the points neatly
    - Do not use single bold dot
      - Use X or triangles with a dot
  - **Draw the best straight line through them if the points form one**
    - **Line of best fit**: drawn as close to all the data points as possible
  - Draw a free-hand curve of best fit if the points form a curve
  - Use apparatus to check the measurement again if a point is not on the line
    - Anomalous point: Point that is outside the range of the straight line

Chapter 1-5 Units, Standards, and the SI System

- **SI Base units**: the Système International d'Unités (SI) uses seven base quantities
  - **Length**: Meter (m)
  - **Mass**: Kilogram(kg)
  - **Time**: Second (s)

- **Temperature**: Kelvin (K)
- **Amount of substance**: Mole (mol)
- **Electric current**: ampere (A)
- **Luminous Intensity**: Candela (cd)

- Prefixes

TABLE 1–4
Metric (SI) Prefixes

Prefix	Abbreviation	Value
yotta	Y	10^{24}
zetta	Z	10^{21}
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro†	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

† μ is the Greek letter "mu."

- Converting Units
  - Conversion factor: multiplier equal to 1
- Order of Magnitude: Rapid Estimating
  - Using an approximate value for a quantity
    - Eg: Diameter of a galaxy: 10^21m
  - Rough Estimate: rounding off all number to one significant figure and its power of 10
  - Keep one significant figure in the power of 10

Chapter 8

8.1 Angular Quantities

- The circumference of a circle is **2πr**. Since a radian is based on an arc with length r, there are 2π radians in a full circle.
  - **To convert from degrees into radians, multiply by . 2π/360**

- **To convert from radians into degrees, multiply by 360/2π**

- **Angular position**: How far an object has rotated, respect to a reference line.
    - **Formula: d = l = 0r**
    - r = radius of circle in meters
    - l = the arc length subtended by the angle 0 in meters
    - 0 = in rad
    - Clockwise : -
    - Counterclockwise : +
- **Angular Displacement** : Change in angular position
    - **Formula : Delta 0 = 02 - 01**
    - Clockwise : -
    - Counterclockwise : +
- **Angular Velocity** : Angular Displacement divided by the time taken to make the displacement
    - Constant angular velocity: graph
    - Not constant ω : graph
    - Instantaneous angular velocity – equal to the slope of a graph of angular position

- 0-t graph is a straight line : constant ω
- 0-t graph is not a straight line : not constant ω
- Instantaneous ω is the tangent of the curve
    - **Formula : v = ωr**