Name: _____

Class: _____

Due Date: _____

A.0 Math

Understandings
- Fundamental and derived SI units
- Scientific notation and metric multipliers
- Significant figures
- Orders of magnitude
- Estimation
- Random and systematic errors
- Absolute, fractional, and percentage uncertainties
- Error bars
- Uncertainty of gradient and intercepts
- Vector and scalar quantities
- Combination and resolution of vectors

If you are interested in learning more about mathematical physics then please read the books *Mathematical Methods in the Physical Sciences* by Mary L. Boas and *div grad curl and all that* by H.M. Schey.

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Define the fundamental units

https://www.nist.gov/pml/weights-and-measures/metric-si/si-units

Quantity	Unit	Definition
/		

Memorize these two acronyms to memorize the SI fundamental units:

My **K**nuckles **G**row **S**tronger **A**nd **K**ill **M**ore **C**reatures

=

Meters **K**ilo**G**rams **S**econds **A**mperes **K**elvin **M**oles **C**andela

Part 2: Answer the following questions about fundamental units

https://physics.nist.gov/cuu/Units/units.html
https://www.nist.gov/pml/weights-and-measures/metric-si/si-units

1. What is the meaning and what are the fundamental units of *perimeter*?

2. What is the meaning, equation, and the fundamental units of *circumference*?

3. What is the meaning and what are the fundamental units of *area*?

4. What is the meaning and what are the fundamental units of *volume*?

5. Use the equation $\vec{v} = \frac{\Delta \vec{x}}{\Delta t}$ to solve for the fundamental units of *velocity*.

6. Use the equation $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ to solve for the fundamental units of *acceleration*.

7. Use the equation $\vec{j} = \frac{\Delta \vec{a}}{\Delta t}$ to solve for the fundamental units of *jerk*.

8. What are the units of *force*?

9. Use the equation $\sum \vec{F} = m\vec{a}$ to solve for the fundamental units of *force*.

10. What are the units of *energy*?

11. Use the equation $E_{\mathrm{k}} = \frac{1}{2}mv^2$ to solve for the fundamental units of *kinetic energy*.

12. Use the equation $E_{\mathrm{p}} = m\vec{g}\vec{h}$ to solve for the fundamental units of the *gravitational potential energy* near the surface of a planet.

13. What are the fundamental units of *energy*?

14. What are the units of *work*?

15. Use the equation $W = \vec{F}\vec{d}\cos\theta$ to solve for the fundamental units of *work W*.

16. What is the relationship between the fundamental units of *work* and *energy*?

17. What are the units of *power*?

18. Use the equation $P = \frac{\mathrm{Work}}{t}$ to solve for the fundamental units of *power P*.

19. Use the equation $\vec{p} = m\vec{v}$ to solve for the fundamental units of *momentum* $\vec{p}$.

20. What are the units of *pressure*?

21. Use the equation $P = \frac{F}{A}$ to solve for the fundamental units of *pressure P*.

22. Use the equation $PV = nRT$ to solve for the fundamental units of the *ideal gas constant R*.

23. What is the meaning and what are the fundamental units of *period T*?

24. What is the meaning and what are the fundamental units of *frequency f*?

25. What is the meaning and what are the fundamental units of *wavelength* λ?

26. Intensity is defined as power per unit area. What are the fundamental units of *intensity I*?

27. Use the equation $F_{\text{electric}} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$ to solve for the fundamental units of the *permittivity of free space* ε_0.

28. Use the equation $\vec{F}_{\text{e}} = q\vec{E}_{\text{ext}}$ to solve for the fundamental units of the *electric field E*.

29. What are the units of *current I*? Use the equation $I = \frac{\Delta q}{\Delta t}$ to solve for the fundamental units of *current I*.

30. Use the equation $I = \frac{\Delta q}{\Delta t}$ to solve for the fundamental units of *charge q*.

31. Use the equation $V = W/q$ to solve for the fundamental units of *voltage V*.

32. What are the units for the *resistance* in a resistor *R*?

33. Use the equation $V = IR$ to solve for the fundamental units of *resistance R*.

34. What are the units of *magnetic field* $\vec{B}$?

35. Use the equation $\vec{F}_B = q\vec{v}\vec{B}_{\text{ext}}$ to solve for the fundamental units of the *magnetic field* $\vec{B}$.

36. Use the equation $F_{\text{gravity}} = \frac{Gm_1m_2}{r^2}$ to solve for the fundamental units of the *gravitational constant G*.

37. Use the equation $E = hf$ to solve for the fundamental units of *Planck's constant h*.

38. Use the equation $P = e\sigma AT^4$ to solve for the fundamental units of the *Stefan-Boltzmann constant* σ. The variable *e* is unitless.

Part 3: Determine the number of significant figures

1. 1,000	21.0.00020	41.100.00
2. 1,000.	22.0.0205	42.300.0000
3. 1,000.00	23.0.2	43.301
4. 1,020	24.8,000	44.301.001
5. 1020.	25.8,070	45.301.0010000
6. 1,020.0	26.8.0	46.8,670
7. 1,000.001	27.8.007	47.80,600
8. 1,200	28.800,700	48.8,670.00
9. 1,200.	29.800,700.00	49.1,000,000
10.1,200.00	30.4	50.1,200,000
11.1,200.03	31.4.0	51.1,205,000
12.1,200.0300	32.4.000	52.4,000
13.100200	33.1.2	53.4,300
14.100200.	34.1.25	54.4,300.
15.100200.00	35.1.250000	55.4,030
16.4,500	36.10	56.4003
17.4,050	37.10.	57.4,003.
18.405	38.100	
19.0.0000405	39.101	
20.0.0002	40.100.	

Part 4: Unit conversions

1. A man has a mass of 80 kg. What is the mass of the man in pounds? Show all your work and place a box around your answer.

2. How many seconds are in 80 years? Show all your work and place a box around your answer.

3. In 2009 Usain Bolt ran 100 m in a record time of 9.58 s. If he continues to run at this constant rate then how many meters will he run in one day? Show all your work and place a box around your answer.

4. In 2018 Eliud Kipchoge ran a marathon (42.195 km) in a record time of 2:01:39. If he continues to run at this constant rate then how many meters will he run in one day? Show all your work and place a box around your answer.

5. The circumference of the Earth is about 40,075.017 km from the Equator. What is the circumference of the Earth in inches? Show all your work and place a box around your answer.

6. The surface area of Earth is about 510,064,472 square kilometers. What is the surface area of the Earth in square inches? Show all your work and place a box around your answer.

7. The volume of Earth is about 1,083,206,916,846 cubic kilometers. What is the volume of Earth in cubic inches? Show all your work and place a box around your answer.

8. The speed of light is 299,792,458 m/s. What is the distance, in kilometers, light travels in one year? Show all your work and place a box around your answer.

9. The density of gold is 19.32 grams per cubic centimeters. What is the density of gold in kilograms per cubic meters? Show all your work and place a box around your answer.

10. The density of gold is 19.32 grams per cubic centimeters. What is the density of gold in pounds per cubic feet? Show all your work and place a box around your answer.

11. A man drinks 60 liters of water in a 30 day month. On average how many cubic meters of water does he drink per hour? Show all your work and place a box around your answer.

Part 5: Answer the following questions

1. Define *random error* and give two examples.

2. Define *systematic error* and give two examples.

3. Define *accuracy* and give an example of high accuracy and low accuracy.

4. Define *precision* and give an example of high precision and low precision.

5. List some rules with regards to uncertainties in measurements.

6. State the equation and give the meaning of *standard deviation* σ.

7. Calculate the *absolute uncertainty*, *fractional uncertainty*, and *percent uncertainty* for a measured length of 87.65 ± 0.43 m.

8. **Use a pencil and ruler!** Draw a simple but neat graph of a *displacement vs. time* graph with measurement points and a best-fit line.

Part 6: Learn how to add, subtract, multiply, and divide uncertainties

1. 3.14 ± 0.15
   $+ \quad 9.26 \pm 0.53$

2. 6.26 ± 0.43
   $+ \quad 3.8 \ \pm 0.27$

3. 1.69 ± 0.39
   $+ \quad 9.37 \pm 0.51$

4. $\begin{array}{rl} & 5.89 \pm 0.79 \\ - & 3.23 \pm 0.84 \end{array}$

5. $\begin{array}{rl} & 9.50 \pm 0.28 \\ - & 8.4 \ \pm 0.97 \end{array}$

6. $\begin{array}{rl} & 5.82 \pm 0.09 \\ - & 4.94 \pm 0.45 \end{array}$

7. 3.14 ± 0.15
$\times \quad 9.26 \pm 0.53$

8. 6.26 ± 0.43
$\times \quad 3.8 \ \pm 0.27$

9. 1.69 ± 0.39
$\times \quad 9.37 \pm 0.51$

10. $\begin{array}{rl} & 5.89 \pm 0.79 \\ \div & 3.23 \pm 0.84 \end{array}$

11. $\begin{array}{rl} & 9.50 \pm 0.28 \\ \div & 8.4 \ \pm 0.97 \end{array}$

12. $\begin{array}{rl} & 5.82 \pm 0.09 \\ \div & 4.94 \pm 0.45 \end{array}$

13. $(3.14 \pm 0.15)^2$

14. $(9.26 \pm 0.53)^3$

15. $(6.26 \pm 0.43)^4$

16. $\sqrt{(3.14 \pm 0.15)}$

17. $\sqrt[3]{(9.26 \pm 0.53)}$

18. $\sqrt[4]{(6.26 \pm 0.43)}$

19. What is the percent uncertainty of the perimeter of a rectangle if has a length of 2.45 ± 0.3 m and a width of 3.56 ± 0.4 m?

20. What is the percent uncertainty of the area of a rectangle if its length is uncertain by 3% and its width is uncertain by 4%?

21. What is the percent uncertainty of the volume of a box if its length is uncertain by 3%, its width is uncertain by 4%, and its height is uncertain by 5%?

22. What is the percent uncertainty of the perimeter/circumference of a circle if its radius is uncertain by 7%?

23. What is the percent uncertainty of the area of a circle if its radius is uncertain by 7%?

24. What is the percent uncertainty of the volume of a sphere if its radius is uncertain by 7%?

25. Mustafa has a height of (172 ± 0.2) cm. Nour has a height of (167 ± 0.35) cm. How much taller, including uncertainty, is Mustafa taller than Nour?

26. Twelve identical square tiles each have a length of 45.62 cm with an uncertainty of 0.2 cm. What is the total length, including uncertainty, of the 12 tiles if they are each placed side-by-side?

27. What is the perimeter, including uncertainty, of a rectangle with a length of (3.14 ± 0.15) cm and a width of (9.26 ± 0.53) cm?

28. What is the area, including uncertainty, of a rectangle with a length of (3.14 ± 0.15) cm and a width of (9.26 ± 0.53) cm?

29. What is the volume, including uncertainty, of a box with a length of (3.14 ± 0.15) cm, a width of (9.26 ± 0.53) cm, and a height of (6.26 ± 0.43) cm?

30. What is the perimeter/circumference, including uncertainty, of a circle with a radius of (3.83 ± 0.27) cm?

31. What is the area, including uncertainty, of a circle with radius of (3.83 ± 0.27) cm?

32. What is the volume, including uncertainty, of a sphere with radius of (3.83 ± 0.27) cm?

33. What is the speed, including uncertainty, of a boat which travels (31.41 ± 0.59) m in (2.65 ± 0.35) s?

Part 7: Define the following terms

1. magnitude

2. scalar

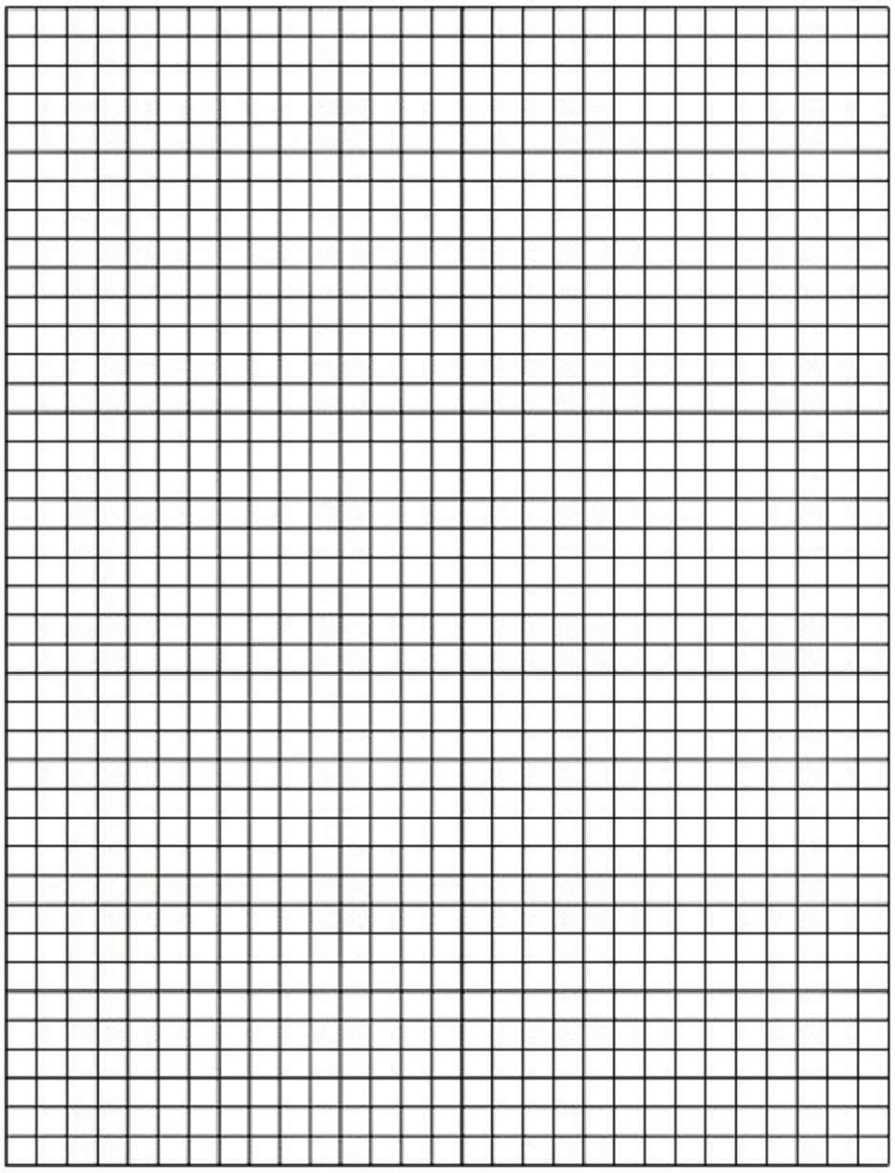
3. vector (What is the symbol for a vector?)

Part 8: Determine if the following quantities are *scalars* or *vectors*.

1. Money	23. Impulse
2. Perimeter	24. Pressure
3. Circumference	25. Moles
4. Area	26. Temperature
5. Volume	27. Wavelength
6. Angle	28. Period
7. Time	29. Frequency
8. Length	30. Charge
9. Distance	31. Current
10. Displacement	32. Voltage
11. Speed	33. Gravitational field strength
12. Velocity	34. Energy density
13. Acceleration	35. Specific energy
14. Jerk	36. Angular speed
15. Force	37. Angular acceleration
16. Work	38. Electric Potential
17. Calories	39. Electric field
18. Energy	40. Magnetic field
19. Kinetic energy	41. Electromotive force
20. Potential energy	42. Moment of inertia
21. Power	43. Entropy
22. Momentum	44. Reynold's number

Part 9: Drawing vectors. Use a pencil and ruler!

1. Let the vectors $\vec{A} = (x_1, y_1) = (3, -2)$ and $\vec{B} = (x_2, y_2) = (-1,4)$
   a. Draw a horizontal and vertical axis on the graph on the next page. Label the horizontal axis x and the vertical axis y.
   b. Draw $\vec{A}$ on the graph below.
   c. What is the magnitude of the horizontal component of $\vec{A}$?
   d. What is the magnitude of the vertical component of $\vec{A}$?
   e. What is the magnitude of $\vec{A}$?
   f. Draw $\vec{B}$ on the graph below.
   g. What is $\vec{A} + \vec{B}$? Draw it on the graph below.
   h. What is the magnitude of the horizontal component of $\vec{A} + \vec{B}$?
   i. What is the magnitude of the vertical component of $\vec{A} + \vec{B}$?
   j. What is the magnitude of $\vec{A} + \vec{B}$?
   k. What is $\vec{B} + \vec{A}$? Draw it on the graph below.
   l. What is $\vec{A} - \vec{B}$? Draw it on the graph below.
   m. What is $\vec{B} - \vec{A}$? Draw it on the graph below.
   n. What is $-\vec{A} - \vec{B}$? Draw it on the graph below.
   o. What is $-\vec{B} - \vec{A}$? Draw it on the graph below.



Part 10: The Classic "Boat Crossing a River" Problem

1. Adam is on a boat. It is moving from south to north on a river at a speed of 9 m/s. The water in the river is moving from east to west with a speed of 4 m/s. The river is 81 m wide.
   a. Draw a figure.
   b. How long will it take for the boat to reach the other side?
   c. How many meters will the boat have traveled westward?
   d. What will be the total displacement of the boat?