PHYS 2211 Exam 3 - Spring 2018

Please circle your lab section and fill in your contact info below.

Section (K Curtis) and (M Fenton)		
Day	12-3pm	3-6pm
Monday	K01 M01	K02 M02
Tuesday	K03 M03	K04 M04
Wednesday	K05 M05	K06 M06
Thursday	K07 M07	K08 M08

"In accordance with the Georgia Tech Honor Code,
I have not given or received unauthorized aid on this test."

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Sign your name on the line above

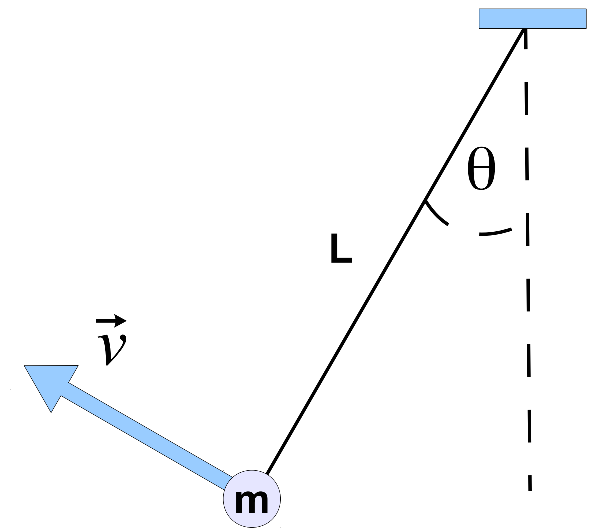
Instructions

- Please write with a pen or dark pencil to aid in electronic scanning.
- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization must be clear.
- Your solution should be worked out algebraically. Numerical solutions should only be evaluated at the last step. Incorrect solutions that are not solved algebraically will receive an 80 percent deduction.
- You must show all work, including correct vector notation.
- **Correct answers without adequate explanation will be counted wrong.**
- Incorrect work or explanations mixed in with correct work will be counted wrong. Cross out anything you do not want us to grade
- Make explanations correct but brief. You do not need to write a lot of prose.
- Include diagrams!
- **Show what goes into a calculation, not just the final number, e.g.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5 \times 10^4$
- Give standard SI units with your numeric results. Your symbolic answers should not have units.

Unless specifically asked to derive a result, you may start from the formulas given on the formula sheet, including equations corresponding to the fundamental concepts. If a formula you need is not given, you must derive it.

If you cannot do some portion of a problem, invent a symbol for the quantity you can not calculate (explain that you are doing this), and use it to do the rest of the problem.

Problem 1 [25 pts] Grader & Score: Key



A ball of mass m hangs motionless from a string. You pull the ball up and release it so that it swings down along a circular arc of radius L. When the string makes an angle θ from the vertical the ball is moving up and to the left with velocity $\vec{v}$ as shown in the diagram.

A. [10 pts] Determine the magnitude of the parallel component of the net force acting on the ball when the string is at angle θ and the ball has velocity $\vec{v}$ (the instant shown in the diagram).

Tension and gravity are the only forces acting on the ball. Since it's moving with circular motion, the tension only acts in the perpendicular direction. Thus, the parallel component of he net force is the same as the parallel component of gravity

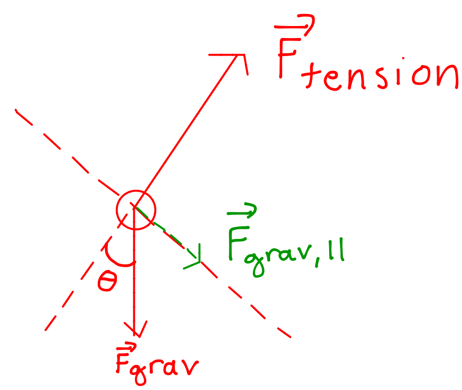
$$\vec{F}_{net} = \vec{F}_{tension} + \vec{F}_{grav}$$

$$\vec{F}_{net,\parallel} = \vec{F}_{tension,\parallel} + \vec{F}_{grav,\parallel}$$

$$= \vec{F}_{grav,\parallel}$$

$$|\vec{F}_{net,\parallel}| = |\vec{F}_{grav,\parallel}|$$

$$= \boxed{mg\sin\theta}$$



-1 Clerical
-2 Math error / Minor physics error
-4 Major physics error
-8 BTN

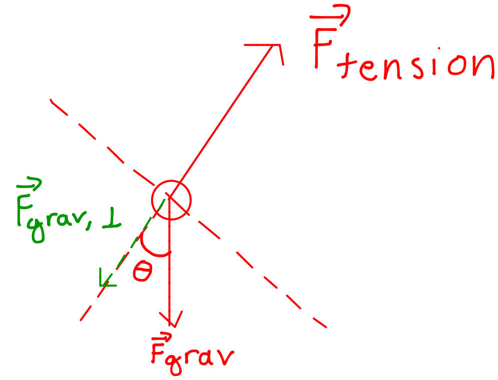
Common Mistakes
-4 including tension somehow
-4 incorrect trig

B. [10 pts] Determine the magnitude of the tension in the string when the ball is at angle θ and the ball has velocity $\vec{v}$ (the instant shown in the diagram).

$$\vec{F}_{net} = \vec{F}_{tension} + \vec{F}_{grav}$$

$$\vec{F}_{net,\perp} = \vec{F}_{tension,\perp} + \vec{F}_{grav,\perp}$$

$$\frac{mv^2}{L}\hat{n} = |\vec{F}_{tension}|\hat{n} - mg\cos\theta\,\hat{n}$$



$$\boxed{|\vec{F}_{tension}| = \frac{mv^2}{L} + mg\cos\theta}$$

-1 Clerical
-2 Math error / Minor physics error
-4 Major physics error
-8 BTN

Common Mistakes
-2 incorrect signs
-4 incorrect trig

C. [5 pts] The ball continues to swing upward until it reaches a maximum angle θ_{max}, momentarily comes to rest, and swings back down. Determine the magnitude of the net force acting on the ball at θ_{max}.

$$v = 0$$

$$\vec{F}_{net} = \vec{F}_{net,\parallel} + \vec{F}_{net,\perp}$$

$$= mg\sin\theta_{max}\hat{p} + \frac{mv^2}{L}\hat{n}$$

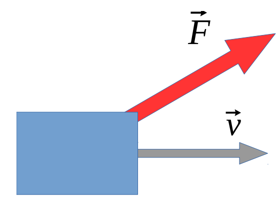
$$= mg\sin\theta_{max}\,\hat{p}$$

$$\boxed{|\vec{F}_{net}| = mg\sin\theta_{max}}$$

All or nothing
Except -1 clerical

Problem 2 [25 pts] Grader & Score: Key

A. [3 pts] A block moves to the right a distance of 2 m while acted on by a force of 3 N. The force makes an angle of 30 degrees with respect to the displacement as shown in the diagram. Calculate the work done on the box by this force and indicate if the box is accelerating or decelerating.



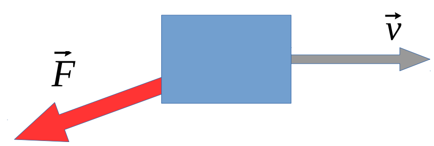
$W = F \cdot r$

$= Fr\cos\theta = (3)(2)\cos 30^\circ$ Nm

$= \boxed{5.196 \text{ Nm}}$

All or nothing
Except -1 for units or clerical
-2 for not indicating or incorrectly indicating acceleration

B. [3 pts] A block moves to the right a distance of 2 m while acted on by a force of 3 N. The force makes an angle of 200 degrees with respect to the displacement as shown in the diagram. Calculate the work done on the box by this force and indicate if the box is accelerating or decelerating.



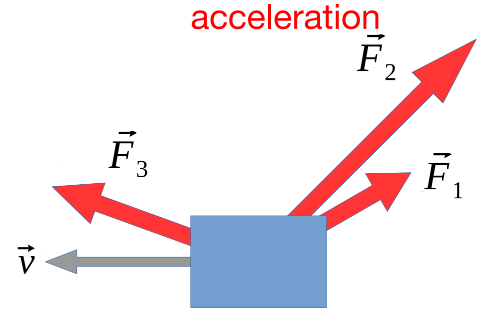
$W = F \cdot r$

$= Fr\cos\theta = (3)(2)\cos(200^\circ)$ Nm

$= \boxed{-5.638 \text{ Nm}}$

All or nothing
Except -1 for units or clerical
-2 for not indicating or incorrectly indicating acceleration

C. [6 pts] A block moves to the left a distance of 2 m while acted upon by three forces. Force $\vec{F}_1$ has a magnitude of 2 N and makes and angle of 150 degrees with the displacement. Force $\vec{F}_2$ has a magnitude of 4 N and makes and angle of 135 degrees with the displacement. Force $\vec{F}_3$ has a magnitude of 3 N and makes and angle of 20 degrees with the displacement. Calculate the total work done on the box and indicate if the box is accelerating or deaccelerating.

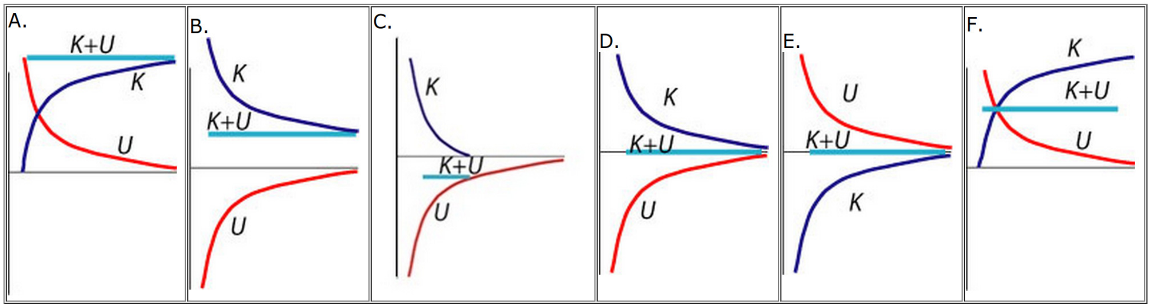


$W = F \cdot r = F_1 r\cos\theta_1 + F_2 r\cos\theta_2 + F_3 r\cos\theta_3$

$= (2)(2)\cos 150^\circ + (4)(2)\cos 135^\circ + (3)(2)\cos 20^\circ$ Nm

$= \boxed{-3.483 \text{ Nm}}$

All or nothing
Except
-1 for units or clerical
-2 for not indicating or incorrectly indicating acceleration
+3 for recognizing they need to add up 3 works



All D. [3 pts] Which of the diagram(s) above are NOT physically possible? (Choose all that apply)

A B C D E F

All E. [3 pts] Which of the diagram(s) above indicate a bound state? (Choose all that apply)

A B C D E F

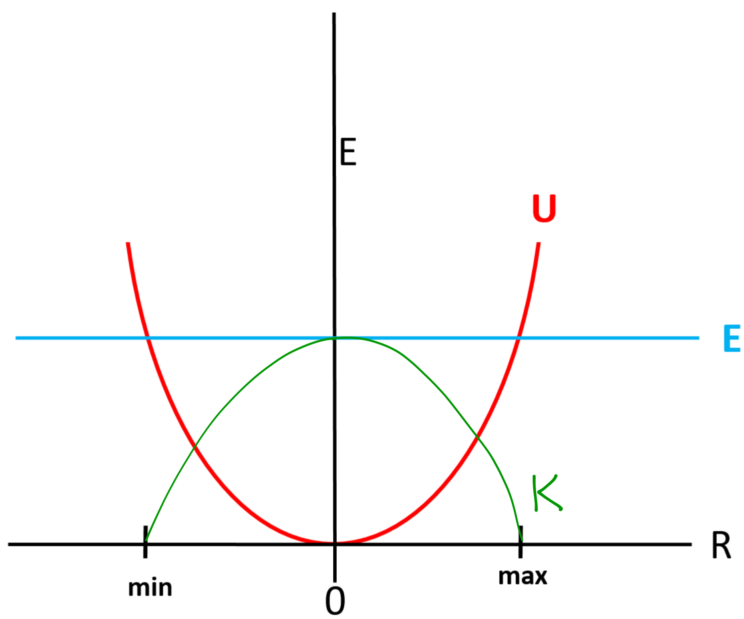
All F. [3 pts] Which of the diagram(s) above correspond to a proton and electron that when very far apart are unbound and moving apart from each other? (Choose all that apply)

A B C D E F

All G. [4 pts] The energy graph below shows the potential energy of an oscillating spring in red as a function of position. The maximum and minimum positions of the oscillating spring are shown by the black min and max marks and the total energy of the oscillating spring is shown by the blue line. Draw on this graph the corresponding kinetic energy.

$E = K + U$

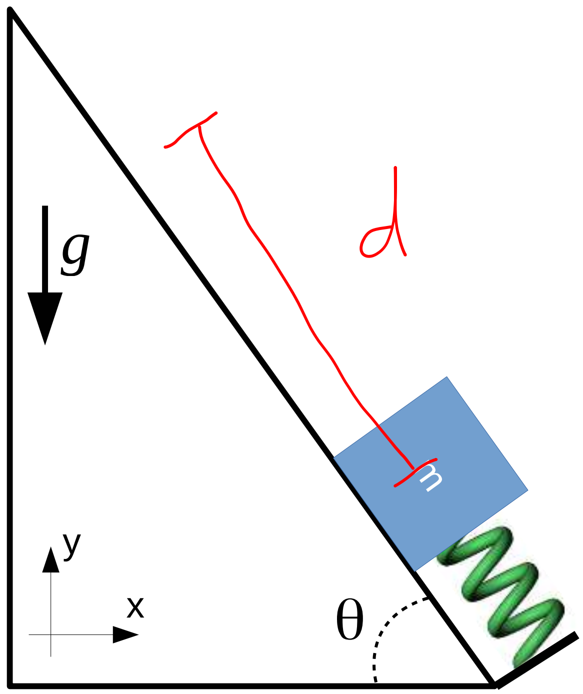
$K = E - U$



Problem 3 [25 pts]

Grader & Score: Key

A. [15 pts] Using your hand, you push a block of mass m against a spring until the spring has length L. The spring has stiffness k_s, rest length L_0, and the block is not attached to the spring. You release the block from rest and it slides upward along a frictionless surface. This surface makes an angle of θ with the horizontal and the Earths gravity points down. Determine how far along the ramp the block slides (i.e. total distance traveled) before coming to rest.



Energy Principle
Initial state: compressed at rest
Final state: at rest, not touching spring
System: block, spring, Earth

(Note, students may choose a different system or different reference point for potential energy, but the answer should still be the same)

$$\Delta E = 0$$

$$\Delta K + \Delta U_{spring} + \Delta U_{Earth} = 0$$

$$0 - \frac{1}{2} k_s s_i^2 + mg\Delta h = 0$$

$$s_i = L_0 - L \qquad \Delta h = d\sin\theta$$

$$mgd\sin\theta = \frac{1}{2} k_s (L_0 - L)^2$$

$$\boxed{d = \frac{k_s (L_0 - L)^2}{2mg\sin\theta}}$$

-1 Clerical
-3 Math error / Minor physics error
-6 Major physics error
-12 BTN

Common Mistakes
-3 incorrect change in height
-3 incorrect stretch
-6 energy not consistent with choice of system

B. [10 pts] Using your hand, you push a block with mass m_1 and positive charge Q_1 against a spring until the spring has length L. The spring has stiffness k_s, rest length L_0, and the block is not attached to the spring. You release the block from rest and it slides along a flat frictionless surface towards a second block with mass m_2 and positive charge Q_2. Initially the blocks are far apart and their electric interaction can be ignored. As they get closer to each other you can model the blocks as point charges. How far apart are the blocks (center to center) when they momentarily come to rest? You can ignore the gravitational interaction between the blocks.

Energy Principle
Initial state: compressed at rest
Final state: at rest, not touching spring
System: blocks and spring

$$\Delta E = 0$$

$$\Delta K + \Delta U_{spring} + \Delta U_{elec} = 0$$

$$0 - \frac{1}{2} k_s s_i^2 + \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{d} = 0$$

$$s_i = L - L_0$$

$$\boxed{d = \frac{2 Q_1 Q_2}{4\pi\varepsilon_0 k_s (L-L_0)^2}}$$

-1 Clerical
-2 Math error / Minor physics error
-4 Major physics error
-8 BTN

Common Mistakes
-2 incorrect stretch
-4 energy not consistent with choice of system

Problem 4 [25 pts]

Grader & Score: Key

A. [4 pts] Prof. Fenton purchases a 5.5 kg cake from the store. When he arrives home the cake is at room temperature, 24 C, and placed in the refrigerator. The refrigerator cools the cake down to a temperature of 5 C. Calculate the change in thermal energy of the cake? You can approximate the specific heat of a cake as 3.2 J/gC.

$$\Delta E_{th} = mc\Delta T$$
$$= (5.5\,kg)(3.2\,J/gC)\left(\frac{1000\,g}{1\,kg}\right)(5°C - 24°C)$$
$$= \boxed{-3.344 \times 10^5\ J}$$

All or nothing
Except -1 for units or clerical
And -1 for not converting units

B. [6 pts] Take the cake to by the system and the refrigerator to tbe the surroundings. Calculate the transfer of energy Q due to the difference in temperature. Briefly explain if this quantity is positive or negative.

$$\Delta E = Q + W$$
$$= Q + 0$$

POE should have same sign as part a

+3 for Q
+3 for explanation

$$\boxed{Q = -3.344 \times 10^5\ J}$$

It is negative because heat is leaving the system

C. [5 pts] Dr. Greco prepares an icing for the cake by heating a mixture on the stove. The stove transfer $Q = 14,500$ J of energy to the icing. While the icing is heated, Dr. Greco used a paddle to stir the mixture. The paddle does 300 J of work. Calculate the change in thermal energy of the icing.

$$\Delta E = Q + W$$
$$= 14,500\,J + 300\,J$$
$$\boxed{\Delta E = 14800\ J}$$

All or nothing
-1 units or clerical

D. [4 pts] The icing Dr. Greco created has a mass of 1.5 kg and the temperature of the icing increased from 24 C to 44 C. Calculate the heat capacity of the icing.

$$\Delta E_{th} = mc\Delta T$$

Watch for POE

All or nothing

$$c = \frac{\Delta E_{th}}{m\Delta T}$$

$$= \frac{14800\ J}{(1.5\ kg)(44°C - 24°C)}$$

$$\boxed{c = 493.33\ J/kgC}$$

E. [6 pts] Prof. Curtis takes the cake out of the fridge and covers it with the icing. The cake was initially at 5 C and the icing was initially at 44 C. The cake and icing are placed in a closed container with NO interaction with the surroundings (i.e. a closed system). Calculate the final temperature of the cake and icing.

Watch for POE
-1 Clerical
-2 Math error / Minor physics error
-3 Major Physics error

$$\Delta E_{th,icing} = -\Delta E_{th,cake}$$

$$m_{icing} c_{icing} \Delta T_{icing} = -m_{cake} c_{cake} \Delta T_{cake}$$

$$m_{icing} c_{icing} (T_f - T_{i,icing}) = -m_{cake} c_{cake} (T_f - T_{i,cake})$$

$$m_{icing} c_{icing} T_f - m_{icing} c_{icing} T_{i,icing} = -m_{cake} c_{cake} T_f + m_{cake} c_{cake} T_{i,cake}$$

$$T_f (m_{icing} c_{icing} + m_{cake} c_{cake}) = m_{cake} c_{cake} T_{i,cake} + m_{icing} c_{icing} T_{i,icing}$$

$$T_f = \frac{m_{cake} c_{cake} T_{i,cake} + m_{icing} c_{icing} T_{i,icing}}{m_{cake} c_{cake} + m_{icing} c_{icing}}$$

$$= \frac{(5.5\ kg)(3.2\ J/gc)\left(\frac{1000g}{1\ kg}\right)(5°C) + (1.5\ kg)(493.33\ J/kgc)(44°C)}{(5.5\ kg)(3.2\ J/gc)\left(\frac{1000g}{1\ kg}\right) + (1.5\ kg)(493.33\ J/kgc)}$$

$$= \boxed{6.574\ °C}$$

This page is for extra work, if needed.

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Things you must have memorized

The Momentum Principle Definition of Momentum	The Energy Principle Definition of Velocity	The Angular Momentum Principle Definition of Angular Momentum
Definitions of angular velocity, particle energy, kinetic energy, and work		

Other potentially useful relationships and quantities

$$\gamma \equiv \frac{1}{\sqrt{1-\left(\frac{|\vec{v}|}{c}\right)^2}} \qquad E^2-(pc)^2=\left(mc^2\right)^2$$

$$\frac{d\vec{p}}{dt}=\frac{d|\vec{p}|}{dt}\hat{p}+|\vec{p}|\frac{d\hat{p}}{dt} \qquad \vec{F}_{\parallel}=\frac{d|\vec{p}|}{dt}\hat{p} \text{ and } \vec{F}_{\perp}=|\vec{p}|\frac{d\hat{p}}{dt}=|\vec{p}|\frac{|\vec{v}|}{R}\hat{n}$$

$$\vec{F}_{grav}=-G\frac{m_1m_2}{|\vec{r}|^2}\hat{r} \qquad U_{grav}=-G\frac{m_1m_2}{|\vec{r}|}$$

$$\left|\vec{F}_{grav}\right|\approx mg \text{ near Earth's surface} \qquad \Delta U_{grav}\approx mg\Delta y \text{ near Earth's surface}$$

$$\vec{F}_{elec}=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{|\vec{r}|^2}\hat{r} \qquad U_{elec}=\frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{|\vec{r}|}$$

$$\left|\vec{F}_{spring}\right|=k_ss \qquad U_{spring}=\frac{1}{2}k_ss^2$$

$$U_i\approx\frac{1}{2}k_{si}s^2-E_M \qquad \Delta E_{thermal}=mC\Delta T$$

$$\vec{r}_{cm}=\frac{m_1\vec{r}_1+m_2\vec{r}_2+\dots}{m_1+m_2+\dots} \qquad I=m_1r_{1\perp}^2+m_2r_{2\perp}^2+\dots$$

$$K_{tot}=K_{trans}+K_{rel} \qquad K_{rel}=K_{rot}+K_{vib}$$

$$K_{rot}=\frac{L_{rot}^2}{2I} \qquad K_{rot}==\frac{1}{2}I\omega^2$$

$$\vec{L}_A=\vec{L}_{trans,A}+\vec{L}_{rot} \qquad \vec{L}_{rot}=I\vec{\omega}$$

$$\omega=\sqrt{\frac{k_s}{m}} \qquad v=d\sqrt{\frac{k_{si}}{m_a}}$$

$$Y=\frac{F/A}{\Delta L/L}\text{ (macro)} \qquad Y=\frac{k_{si}}{d}\text{ (micro)}$$

$$\Omega=\frac{(q+N-1)!}{q!\,(N-1)!} \qquad S\equiv k\ln\Omega$$

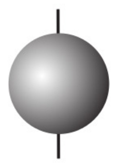
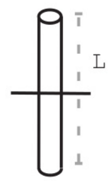
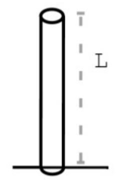
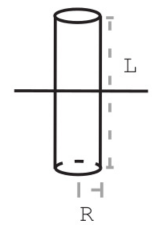
$$\text{prob}(E)\propto\Omega(E)\,e^{-\frac{E}{kT}} \qquad E_N=-\frac{13.6\text{eV}}{N^2}\text{ where } N=1,2,3\dots$$

$$E_N=N\hbar\omega_0+E_0 \text{ where } N=0,1,2\dots \text{ and } \omega_0=\sqrt{\frac{k_{si}}{m_a}} \text{ (Quantized oscillator energy levels)}$$

Moment of inertia for rotation about indicated axis

The cross product

$\vec{A} \times \vec{B} = \langle A_y B_z - A_z B_y, A_z B_x - A_x B_z, A_x B_y - A_y B_x \rangle$

				
$I = \frac{2}{5} MR^2$	$I = \frac{1}{2} MR^2$	$I = \frac{1}{12} ML^2$	$I = \frac{1}{3} ML^2$	$I = \frac{1}{12} ML^2 + \frac{1}{4} MR^2$

Constant	**Symbol**	**Approximate Value**
Speed of light	c	3×10^8 m/s
Gravitational constant	G	6.7×10^{-11} N $\cdot$ m^2/kg^2
Approx. grav field near Earth's surface	g	9.8 N/kg
Electron mass	m_e	9×10^{-31} kg
Proton mass	m_p	1.7×10^{-27} kg
Neutron mass	m_n	1.7×10^{-27} kg
Electric constant	$\frac{1}{4\pi\epsilon_0}$	9×10^9 N $\cdot$ m^2/C^2
Proton charge	e	1.6×10^{-19} C
Electron volt	1 eV	1.6×10^{-19} J
Avogadro's number	N_A	6.02×10^{23} atoms/mol
Plank's constant	h	6.6×10^{-34} joule $\cdot$ second
hbar $= \frac{h}{2\pi}$	$\hbar$	1.05×10^{-34} joule $\cdot$ second
specific heat capacity of water	C	4.2 J/g/K
Boltzmann constant	k	1.38×10^{-23} J/K

milli	m	1×10^{-3}	kilo	k	1×10^3
micro	μ	1×10^{-6}	mega	M	1×10^6
nano	n	1×10^{-9}	giga	G	1×10^9
pico	p	1×10^{-12}	tera	T	1×10^{12}