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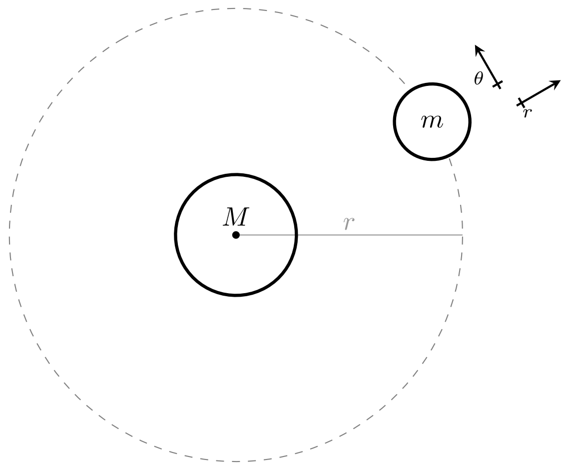
Example problems



Description	Symbol	Quantity
Gravitational Constant	G	$6.67 \times 10^{-11} \mathrm{N \cdot m^2/kg^2}$
Electrostatic Constant	k_e	$8.99 \times 10^{9} \mathrm{N \cdot m^2/C^2}$
Boltzmann's Constant	k_B	$1.38 \times 10^{-23} \mathrm{J/K}$
Avogado's Number	N_A	6.02×10^{23}
Plank's Constant	h	$6.63 \times 10^{-34} \mathrm{J \cdot s}$
Speed of Light	c	$3.0 \times 10^{8} \mathrm{m/s}$
Fundamental Charge	e	$1.6 \times 10^{-19} \mathrm{C}$
Mass of the Electron	m_e	$9.1 \times 10^{-31} \mathrm{kg}$
Mass of Proton	m_p	$1.7 \times 10^{-27} \mathrm{kg}$
Gas Constant	R	$8.31 \ \mathrm{J/mole \cdot K}$
Vacuum Permativity	ε_0	$8.85 \times 10^{-12} \mathrm{F/m}$
Vacuum Permeablity	μ_0	$4\pi \times 10^{-7} \mathrm{T \cdot m/A}$
Bohr Radius	a_0	$0.53 \times 10^{-10} \mathrm{m}$
Fine Structure Constant	α	$1/137$

Table 1: A list of physical quantities with SI units and dimensions.

Description	Symbol	Quantity
Gravitational Constant	G	$6.67 \times 10^{-11} \mathrm{N \cdot m^2/kg^2}$
Mass of Earth	m_{earth}	$5.98 \times 10^{24} \mathrm{kg}$
Mass of Moon	m_{moon}	$7.36 \times 10^{22} \mathrm{kg}$
Radius of Earth	R_{earth}	$6.38 \times 10^{6} \mathrm{m}$
Radius of Moon	R_{moon}	$1.74 \times 10^{6} \mathrm{m}$
Orbital Radius of Earth	r_{earth}	$1.50 \times 10^{11} \mathrm{m}$
Orbital Radius of Moon	r_{moon}	$3.84 \times 10^{8} \mathrm{m}$
Period of Earth's Orbit	T_{earth}	365.24 days
Period of Moon's Orbit	T_{moon}	27.3 days

Table 2: A list of physical quantities.

The first question of the exam is worth 30 points. The above table is required.

1) Consider the earth moving around the sun.

a. Determine the orbital angular velocity of the earth.

$$\omega = \frac{\Delta\theta}{\Delta t}$$

$$\omega = \frac{2\pi}{T_{earth}}$$

$$\omega = \frac{2\pi}{365.24 * 24 * 60 * 60}$$

$$\omega = 1.99 \times 10^{-7} \frac{\text{rad}}{\text{sec}}$$

b. Determine the speed of the earth relative to the sun.

$$v = \frac{2\pi r}{T}$$

$$v = \omega r_{earth}$$

$$v = 1.99 \times 10^{-7} * 1.5 \times 10^{11}$$

$$v = 3.0 \times 10^{4} \frac{\text{m}}{\text{s}}$$

c. Determine centripetal acceleration of the earth relative to the sun.

$$a_{cent} = \frac{v^2}{r_{earth}}$$

$$a_{cent} = \frac{(3 \times 10^4)^2}{1.5 \times 10^{11}}$$

$$a_{cent} = 6.0 \times 10^{-3} \frac{\text{m}}{\text{s}^2}$$

d. Determine the net force on the earth considering this acceleration.

$$F_{net} = m_{earth} a$$

$$F_{net} = 5.98 \times 10^{24} * 6.0 \times 10^{-3}$$

$$F_{net} = 3.6 \times 10^{22} \text{N}$$

e. Determine the mass of the sun from the above.

$$M = \frac{F_g r^2}{mG}$$

$$M = \frac{(3.6 \times 10^{22})(1.5 \times 10^{11})^2}{5.98 \times 10^{24} * 6.67 \times 10^{-11}}$$

$$M = 2.0 \times 10^{30}\text{kg}$$

The second question is worth 30 points. The table is required.

2) Consider gravitation at the surface of the moon.

a. Determine the acceleration due to gravity on the surface of the moon.

$$F_g = \frac{\cancel{m}MG}{r^2} = \cancel{m}a$$

$$F_g = \frac{M_{moon}G}{R_{moon}^2} = a$$

$$F_g = \frac{(7.36 \times 10^{22})(6.67 \times 10^{-11})}{(1.74 \times 10^6)^2} = a$$

$$a = 1.62\frac{\text{m}}{\text{s}^2}$$

b. Determine the launch velocity for circular orbit.

$$a = a_{cent} = \frac{v^2}{R_{moon}}$$

$$1.62 = \frac{v^2}{R_{moon}}$$

$$v = \sqrt{1.62 * 1.74 \times 10^6}$$

$$v = 1680\frac{\text{m}}{\text{s}}$$

c. Determine the launch velocity for escape from the moon's gravity.

$$E = 0$$

$$KE + PE = 0$$

$$\frac{1}{2}\cancel{m}v^2 - \frac{\cancel{m}M_{moon}G}{R_{moon}} = 0$$

$$v = \sqrt{\frac{2M_{moon}G}{R_{moon}}}$$

$$v = \sqrt{\frac{2 * 7.36 \times 10^{22} * 6.67 \times 10^{-11}}{1.74 \times 10^6}}$$

$$v = 2370\frac{\text{m}}{\text{s}}$$

d. Determine the result of launching an object at 2000 m/s into the moon's horizon.

An elliptical orbit, since that velocity is in between the launch velocity and the escape velocity.

Question three is worth 40 points.

3) Consider a capacitor. Two very large parallel conducting plates are connected to the leads of a 9 Volt battery.

a. Determine the separation between the plates to generate a 30.0 $\frac{\text{N}}{\text{C}}$ electric field.

$$E = \frac{-\Delta V}{x}$$

$$x = \frac{-\Delta V}{E}$$

$$x = \frac{9}{30}$$

$$x = 0.3\text{m}$$

b. Determine the force of this electric field on a 0.012 Coulomb charge.

$$F = qE$$

$$F = (0.012)(30)$$

$$F = 0.36\text{N}$$

c. Determine the change in potential energy for the 0.012 C charge moving from the 9V plate to the 0V plate.

$$PE = qV$$

$$PE_{9V} = qV = (0.012)(9) = 0.108$$

$$PE_{0V} = qV = (0.012)(0) = 0$$

$$\Delta PE = -0.108 \text{ Joules}$$

d. Draw the parallel plates and the electric field between them.

Figure 1: Electric field between 0V and 9V parallel plates

1 Example Calculations of Finding Specific Heat Capacity of Metals

This is the calculation for the specific heat capacity of copper.

$$C_{metal} = \frac{m_{water}}{m_{metal}} \frac{\Delta T_{water}}{\Delta T_{metal}} C_{water}$$

$$\Delta T_{water} = 24.8 - 20.8 = 4.0\text{Celcius}$$

$$\Delta T_{metal} = 100 - 24.8 = 75.2\text{Celcius}$$

$$C_{metal} = \frac{0.350\text{kg}}{0.203\text{kg}} \frac{4.0\text{Celcius}}{75.2\text{Celcius}} 4180 \ {}^{\text{J}}/_{\text{kg}\cdot{}^\circ\text{C}} = 383.3 \ {}^{\text{J}}/_{\text{kg}\cdot{}^\circ\text{C}}$$

The percent error is calculated as follows.

$$Error = \frac{387 - 383.3}{387} = 0.944\%$$

2 Other Formulas

$$F = \frac{mMG}{r^2}$$

$$Fe = \frac{qQk}{r^2}$$

$$F = qE$$

$$PE = qV$$

$$E = -\frac{\Delta v}{\Delta x}$$

$$E = \frac{QKe}{r^2}$$

$$PE = -\frac{mMG}{r}$$

$$PE = \frac{qQKe}{r}$$

$$V = \frac{QKe}{r}$$

$$PE = -\frac{4Pie^2}{MG}r^3$$