P051 Practice Final Examination

You should try to take this exam under test conditions:
no book
no notes,
3 hours.
Solutions will be posted on on Tuesday

Item	Score
Multiple Choice questions:	21 Pts.
Problem 1	8 pts
Problem 2	8 pts
Problem 3	8 pts
Problem 4	8 pts
Problem 5	8 pts
Problem 6	8 pts
Problem 7	8 pts
Problem 8	8 pts
Short response questions:	15 points.
Total:	100 points.

ADVANCED PLACEMENT PHYSICS C TABLE OF INFORMATION

CONSTANTS AND CONVERSION FACTORS

Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg
Avogadro's number,	$N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$
Universal gas constant,	$R = 8.31\ \text{J/(mol}\cdot\text{K)}$
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}$ J/K
Electron charge magnitude,	$e = 1.60 \times 10^{-19}$ C
1 electron volt,	$1\ \text{eV} = 1.60 \times 10^{-19}$ J
Speed of light,	$c = 3.00 \times 10^{8}$ m/s
Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ (\text{N}\cdot\text{m}^2)/\text{kg}^2$
Acceleration due to gravity at Earth's surface,	$g = 9.8\ \text{m/s}^2$

1 unified atomic mass unit,	$1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg} = 931\ \text{MeV}/c^2$
Planck's constant,	$h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s} = 4.14 \times 10^{-15}\ \text{eV}\cdot\text{s}$
	$hc = 1.99 \times 10^{-25}\ \text{J}\cdot\text{m} = 1.24 \times 10^{3}\ \text{eV}\cdot\text{nm}$
Vacuum permittivity,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$
Coulomb's law constant,	$k = 1/(4\pi\varepsilon_0) = 9.0 \times 10^{9}\ (\text{N}\cdot\text{m}^2)/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
Magnetic constant,	$k' = \mu_0/(4\pi) = 1 \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
1 atmosphere pressure,	$1\ \text{atm} = 1.0 \times 10^{5}\ \text{N/m}^2 = 1.0 \times 10^{5}$ Pa

UNIT SYMBOLS								
meter,	m	mole,	mol	watt,	W	farad,	F
kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
second,	s	newton,	N	volt,	V	degree Celsius,	°C
ampere,	A	pascal,	Pa	ohm,	Ω	electron volt,	eV
kelvin,	K	joule,	J	henry,	H		

PREFIXES		
Factor	Prefix	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	$1/2$	$3/5$	$\sqrt{2}/2$	$4/5$	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	$4/5$	$\sqrt{2}/2$	$3/5$	$1/2$	0
$\tan\theta$	0	$\sqrt{3}/3$	$3/4$	1	$4/3$	$\sqrt{3}$	∞

The following assumptions are used in this exam.

I. The frame of reference of any problem is inertial unless otherwise stated.
II. The direction of current is the direction in which positive charges would drift.
III. The electric potential is zero at an infinite distance from an isolated point charge.
IV. All batteries and meters are ideal unless otherwise stated.
V. Edge effects for the electric field of a parallel plate capacitor are negligible unless otherwise stated.

ADVANCED PLACEMENT PHYSICS C EQUATIONS

MECHANICS

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

$$\vec{a} = \frac{\sum \vec{F}}{m} = \frac{\vec{F}_{net}}{m}$$

$$\vec{F} = \frac{d\vec{p}}{dt}$$

$$\vec{J} = \int \vec{F}\,dt = \Delta\vec{p}$$

$$\vec{p} = m\vec{v}$$

$$\left|\vec{F}_f\right| \le \mu\left|\vec{F}_N\right|$$

$$\Delta E = W = \int \vec{F} \cdot d\vec{r}$$

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

$$P = \frac{dE}{dt}$$

$$P = \vec{F} \cdot \vec{v}$$

$$\Delta U_g = mg\Delta h$$

$$a_c = \frac{v^2}{r} = \omega^2 r$$

$$\vec{\tau} = \vec{r} \times \vec{F}$$

$$\vec{\alpha} = \frac{\sum \vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$$

$$I = \int r^2 dm = \sum mr^2$$

$$x_{cm} = \frac{\sum m_i x_i}{\sum m_i}$$

$$v = r\omega$$

$$\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$$

$$K = \frac{1}{2}I\omega^2$$

$$\omega = \omega_0 + \alpha t$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

a = acceleration
E = energy
F = force
f = frequency
h = height
I = rotational inertia
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
L = angular momentum
m = mass
P = power
p = momentum
r = radius or distance
T = period
t = time
U = potential energy
v = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque
ω = angular speed
α = angular acceleration
ϕ = phase angle

$$\vec{F}_s = -k\Delta\vec{x}$$

$$U_s = \frac{1}{2}k(\Delta x)^2$$

$$x = x_{max}\cos(\omega t + \phi)$$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

$$T_s = 2\pi\sqrt{\frac{m}{k}}$$

$$T_p = 2\pi\sqrt{\frac{\ell}{g}}$$

$$\left|\vec{F}_G\right| = \frac{Gm_1m_2}{r^2}$$

$$U_G = -\frac{Gm_1m_2}{r}$$

ELECTRICITY AND MAGNETISM

$$\left|\vec{F}_E\right| = \frac{1}{4\pi\varepsilon_0}\left|\frac{q_1q_2}{r^2}\right|$$

$$\vec{E} = \frac{\vec{F}_E}{q}$$

$$\oint \vec{E} \cdot d\vec{A} = \frac{Q}{\varepsilon_0}$$

$$E_x = -\frac{dV}{dx}$$

$$\Delta V = -\int \vec{E} \cdot d\vec{r}$$

$$V = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$$

$$U_E = qV = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

$$\Delta V = \frac{Q}{C}$$

$$C = \frac{\kappa\varepsilon_0 A}{d}$$

$$C_p = \sum_i C_i$$

$$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$$

$$I = \frac{dQ}{dt}$$

$$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C(\Delta V)^2$$

$$R = \frac{\rho\ell}{A}$$

$$\vec{E} = \rho\vec{J}$$

$$I = Nev_d A$$

$$I = \frac{\Delta V}{R}$$

$$R_s = \sum_i R_i$$

$$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$$

$$P = I\Delta V$$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
$\mathcal{E}$ = emf
F = force
I = current
J = current density
L = inductance
ℓ = length
n = number of loops of wire per unit length
N = number of charge carriers per unit volume
P = power
Q = charge
q = point charge
R = resistance
r = radius or distance
t = time
U = potential or stored energy
V = electric potential
v = velocity or speed
ρ = resistivity
Φ = flux
κ = dielectric constant

$$\vec{F}_M = q\vec{v} \times \vec{B}$$

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I$$

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{\ell} \times \hat{r}}{r^2}$$

$$\vec{F} = \int I\,d\vec{\ell} \times \vec{B}$$

$$B_s = \mu_0 nI$$

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

$$\mathcal{E} = \oint \vec{E} \cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$$

$$\mathcal{E} = -L\frac{dI}{dt}$$

$$U_L = \frac{1}{2}LI^2$$

ADVANCED PLACEMENT PHYSICS C EQUATIONS

GEOMETRY AND TRIGONOMETRY

Rectangle

$A = bh$

Triangle

$A = \frac{1}{2}bh$

Circle

$A = \pi r^2$

$C = 2\pi r$

$s = r\theta$

Rectangular Solid

$V = \ell wh$

Cylinder

$V = \pi r^2 \ell$

$S = 2\pi r\ell + 2\pi r^2$

Sphere

$V = \frac{4}{3}\pi r^3$

$S = 4\pi r^2$

Right Triangle

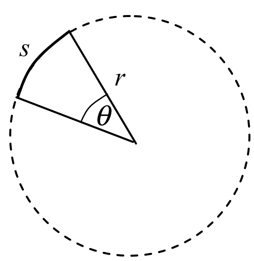
$a^2 + b^2 = c^2$

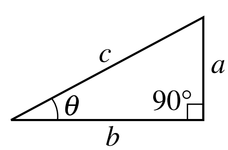
$\sin\theta = \frac{a}{c}$

$\cos\theta = \frac{b}{c}$

$\tan\theta = \frac{a}{b}$

A = area
C = circumference
V = volume
S = surface area
b = base
h = height
ℓ = length
w = width
r = radius
s = arc length
θ = angle





CALCULUS

$$\frac{df}{dx} = \frac{df}{du}\frac{du}{dx}$$

$$\frac{d}{dx}\left(x^n\right) = nx^{n-1}$$

$$\frac{d}{dx}\left(e^{ax}\right) = ae^{ax}$$

$$\frac{d}{dx}(\ln ax) = \frac{1}{x}$$

$$\frac{d}{dx}[\sin(ax)] = a\cos(ax)$$

$$\frac{d}{dx}[\cos(ax)] = -a\sin(ax)$$

$$\int x^n\,dx = \frac{1}{n+1}x^{n+1},\ n \neq -1$$

$$\int e^{ax}\,dx = \frac{1}{a}e^{ax}$$

$$\int \frac{dx}{x+a} = \ln\left|x+a\right|$$

$$\int \cos(ax)\,dx = \frac{1}{a}\sin(ax)$$

$$\int \sin(ax)\,dx = -\frac{1}{a}\cos(ax)$$

VECTOR PRODUCTS

$$\vec{A}\bullet\vec{B} = AB\cos\theta$$

$$\left|\vec{A}\times\vec{B}\right| = AB\sin\theta$$

Constants

$$g = 9.81\frac{m}{s^2} \quad \text{(near Earth's surface)}$$

$$G = 6.67 \times 10^{-11}\frac{Nm^2}{kg^2}$$

Quadratic Equation

$$Ax^2 + Bx + C = 0$$

$$x = -\frac{B}{2A} \pm \frac{1}{2A}\sqrt{B^2 - 4AC}$$

Kinematical relations

$$\vec{v} = \frac{d\vec{x}}{dt},$$

$$\vec{a} = \frac{d\vec{v}}{dt},$$

Expressions for constant acceleration

$$x(t) = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$

$$v_x(t) = v_{0x} + a_x t$$

$$v_x^2 = v_{0x}^2 + 2a_x dx$$

(equivalent equations for the y and z directions)

$$a_c = \frac{v^2}{r} = \omega^2 r \quad \text{centripetal accel.}$$

Problem solving with Newton's Laws

1. Draw a picture.
2. Draw a detailed Free Body Diagram for the body in question.
3. Choose a coordinate system and origin.
4. Resolve forces into the x, y, and z directions.
5. Apply Newton's second law for each direction.
   ask first whether the object is accelerating in which direction(s)
6. Choose point to take torques about.
7. Apply 2^{nd} law in rotational form (is there ang. accel?)
8. Solve equations.
9. Check answer to see if it makes sense.
10. Round to appropriate number of sigfigs, include units, and box answer.

Problem solving: energy, momentum, work

1. Draw a picture.
2. Choose a coordinate system and origin.
3. Ask whether energy is conserved.
   If not, decide if problem can be solved via energy methods. It may require dividing the problem into portions where energy is conserved, finding work done by non-conservative forces, or using momentum during collisions.
4. Write down the energy at the initial and final points.
5. If energy conserved, set $E_i = E_f$. (If not, find work due to non-conservative forces).
6. Solve equations.
7. Check answer, sigfigs, units, box answer.

Formulas; Work, Energy, etc.

$K =$	$\frac{1}{2}mv^2$	kinetic energy
$U_g =$	mgh	grav. potential energy (surface of Earth)
$U_g =$	$-G\frac{Mm}{r}$	grav. potential energy (general)
$U_S =$	$\frac{1}{2}kx^2$	elastic potential energy of spring
$W =$	$\int \vec{F} \cdot d\vec{r}$	work
$P =$	$\vec{F} \cdot \vec{v} = \frac{dW}{dt}$	average power is work done by time
$\vec{F} =$	$-G\frac{m_1 m_2}{r^2}\hat{r}_{12}$	Newton's Universal law of gravity

Rotational equations from linear forms

$x \longrightarrow \theta,$	$(s = r\theta).$
$v \longrightarrow \omega,$	$(v_{tang} = r\omega).$
$a \longrightarrow \alpha,$	$(a_{tang} = r\alpha).$
$m \longrightarrow I,$	$(I = \int r^2 dm).$
$F \longrightarrow \tau,$	$(\tau = \vec{r} \times \vec{F} = \frac{d\vec{L}}{dt}).$
$p \longrightarrow L,$	$(L = \vec{r} \times \vec{p} = I\omega).$

Some Moments of Inertia

All objects of mass m and radius r with axis of rotation through CM and along symmetry axis, unless otherwise stated

particle traveling in circle.	mr^2
ring or cylindrical shell	mr^2
uniform disk or cylinder.	$\frac{1}{2}mr^2$
thin spherical shell.	$\frac{2}{3}mr^2$
solid sphere	$\frac{2}{5}mr^2$
thin rod, length L, $\perp$ to axis of rot.	$\frac{1}{12}mL^2$
thin rod, length L, about one end	$\frac{1}{3}mL^2$

$$I = \int r^2 dm = \sum mr^2$$

Some calculus, a is a constant

$$\frac{df}{dx} = \frac{df}{du}\frac{du}{dx}$$

$$\frac{d}{dx}x^n = nx^{n-1}$$

$$\frac{d}{dx}e^{ax} = ae^{x} \qquad \frac{d}{dx}\ln ax = \frac{1}{x}$$

$$\frac{d}{dx}\sin x = \cos x \qquad \frac{d}{dx}\cos x = -\sin x$$

$$\int x^n dx = \frac{x^{n+1}}{n+1},\ \text{n} \neq \text{-1} \qquad \int e^{ax}dx = \frac{e^{ax}}{a}$$

$$\int \cos ax dx = \frac{1}{a}\sin ax \qquad \int \sin ax dx = -\frac{1}{a}\cos ax$$

Vector products

Given three perpendicular unit vectors $\hat{\imath}, \hat{\jmath}, \hat{k}$.

Dot : $\hat{\imath} \cdot \hat{\imath} = \hat{\jmath} \cdot \hat{\jmath} = \hat{k} \cdot \hat{k} = 1, \quad \hat{\imath} \cdot \hat{\jmath} = \hat{\imath} \cdot \hat{k} = \hat{k} \cdot \hat{\jmath} = 0$

Cross: $\hat{\imath} \times \hat{\imath} = \hat{\jmath} \times \hat{\jmath} = \hat{k} \times \hat{k} = 0 \quad \hat{\imath} \times \hat{\jmath} = \hat{k},\ \hat{\jmath} \times \hat{\imath} = -\hat{k}$

$\hat{\imath} \times \hat{k} = -\hat{\jmath},\ \hat{k} \times \hat{\imath} = \hat{\jmath},\ \hat{\jmath} \times \hat{k} = \hat{\imath},\ \hat{k} \times \hat{\jmath} = -\hat{\imath}$

Multiple choice

The speed v of an automobile moving on a straight road is given in meters per second as a function of time t in seconds by the following equation:

$$v = 4 + 2t^3$$

1. What is the acceleration of the automobile at $t = 2s$?

a) $12m/s^2$

b) $16m/s^2$

c) $20m/s^2$

d) $24m/s^2$

e) $28m/s^2$

2. How far has the automobile traveled in the interval between t= 0 and t= 2 s?

a) $16m$

b) $20m$

c) $24m$

d) $32m$

e) $72m$

3. Consider the International Space Station (ISS) that orbits at an altitude of roughly $250km$ above the surface of the Earth. If the force of gravity on the ISS due to Earth has magnitude F_0 when it is on the Earth's surface, which value is closest in magnitude to the force of gravity, due to Earth, when it is in orbit?

a) 0

b) 0.1 F_0

c) 0.5 F_0

d) 0.9 F_0

e) F_0

4. The sum of all the external forces on a system of particles is zero. Which of the following must be true of the system?

a) The total mechanical energy is constant.

b) The total potential energy is constant.

c) The total kinetic energy is constant.

d) The total linear momentum is constant.

e) It is in static equilibrium.

5. A disk X rotates freely with angular velocity, ω, on frictionless bearings about its center. A second identical disk Y, initially not rotating, is placed on top of X so that both disks rotate together without slipping. The two disks are collinear (symmetry axes are the same). When the disks are rotating together, which of the following is half what it was before?

a) Moment of inertia of X

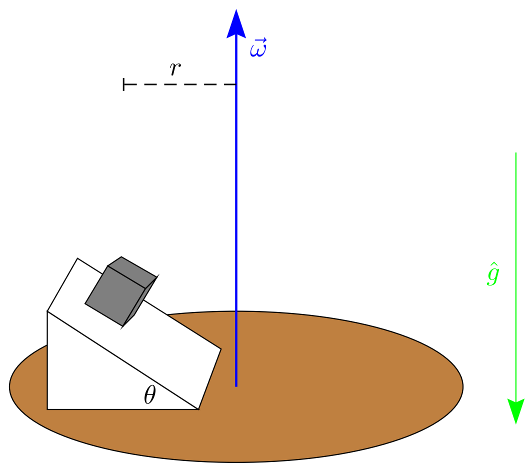
b) Moment of inertia of Y

c) Angular velocity of X

d) Angular velocity of Y

e) Angular momentum of both disks

Problem 1



An inclined plane of angle θ is fixed to a rotating disk. A block is placed on the inclined plane a distance r from the axis of rotation of the disk. The turntable is rotating at an angular velocity of ω. There is friction between the block and the ramp and the coefficient of static friction is μ.

a) Draw a free body diagram for the block.

b) What is the minimum value of angular velocity ω_{min} that will keep the block from sliding down the plane. Give your answer in terms of r, g, μ, and θ.

c) What is the maximum value of angular velocity ω_{max} such that the block does not slide *up* the plane?

Problem 2

An hour glass filled with sand sits on a weight scale. Initially all of the sand (of total mass m) in the glass (of mass M) is held in the upper reservoir. At time $t = 0$ the sand is released and falls at a constant rate of $\lambda = \frac{dm}{dt}$ to the bottom of the lower reservoir. Find the reading of the scale as a function of time for the time below.

a) From the time $t = 0$ when the sand is first released until time $t = t_1$ at which it just starts to arrive at the bottom of the reservoir.

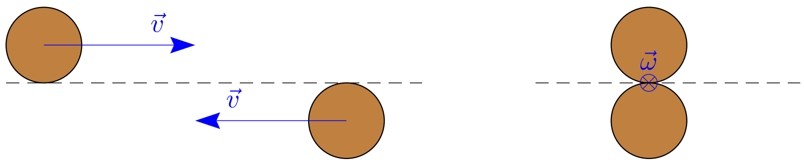
b) From time $t = t_1$ to time $t = t_2$ at which the last grain just falls from the upper reservoir.

c) From time $t = t_2$ until time $t = t_3$ when the last grain arrives at the bottom.

d) After time t_3. Use this to obtain a relation between t_1, t_2, t_3.

e) Sketch the reading of the scale as a function of time, noting that $m < M$.

Problem 3



Before After

Two cylindrical disks, each of mass M and radius R, slide towards each other on a frictionless table. Initially they are traveling in opposite directions at speed v. They are offset so that when they have a glancing collision, they stick to each other at their edges.

a) What is the total angular momentum of this system before the collision about the center of mass of the system?

b) What is the momentum of inertia of the two disks, stuck together, after the collision has occurred? (about their center of mass).

c) What is the angular velocity ω of the two pucks after the collision?

d) How much energy was lost in the collision?

Problem 4

A ladder, of mass $10kg$ and length $5m$, leans against a wall at an initial angle of 75^o from the horizontal. There is no friction between the ladder and the wall but there is friction between the ladder and the floor, with coefficient of static friction $\mu = 0.1$. A boy of mass $50kg$ begins to climb the ladder.

How far up the ladder does he get before the ladder starts to slide down. Give your distance as measured along the ladder from the ground.

Problem 5

A large block of mass m_1 undergoes simple harmonic motion as it slides across a frictionless floor while connected to a spring (on the left) with spring constant k. A block of mass m_2 rests on top of the m_1 block. The coefficient of static friction between the two blocks is μ. The upper block initially does not slip with respect to the lower block.

a) Draw a diagram for the situation and make free body diagrams for each block when the spring is stretched a distance x from its equilibrium point to the right.

b) What is the angular frequency of oscillation, ω of the system?

c) What is the maximum amplitude, A, that the system can have if m_2 does not slip relative to m_1. (Answer in terms of ω).

Problem 6

Consider a forced harmonic oscillator consisting of a block of mass m resting on a frictionless surface attached to a spring with spring constant k (on the left). An outside entity supplies a periodic driving force to the block (this could be a simple motor with an arm attached to the block) of the form $F(t) = F_0 \cos \omega t$ (F_0 a positive constant). The equilibrium position of the spring is at $x = 0$ and the block moves along the x axis only.

a) Show (explicitly) how you obtain the following differential equation from your free body diagram,

$$\ddot{x} + \omega_0^2 x = \frac{F_0}{m} \cos \omega t,$$

where $\omega_0^2 \equiv \frac{k}{m}$ and $\ddot{x} \equiv \frac{d^2 x}{dt^2}$.

b) From this differential equation come up with a general solution, $x(t) =$

Inserting this general form back into the differential equation, determine any unknown constants you may have introduced.

c) When $\omega < \omega_0$ how are the driving force $F(t)$ and the position $x(t)$ related in phase? What about when $\omega > \omega_0$?

d) Given your solution to this driven harmonic oscillator, find the mechanical energy of the spring-block part of the system, $E = KE + PE_{elastic}$.

e) Discuss briefly what happens when the driving frequency matches the natural frequency of this system, that is when $\omega = \omega_0$. What happens to the energy found in the previous part?

Problem 7

Consider a projectile launched from the surface of the Earth (fired from a canon) of mass m. However some evil madman has turned on a forcefield that envelopes the Earth that has a potential energy function for the projectile of the form,

$$U_{evil} = \frac{am}{r^2}$$

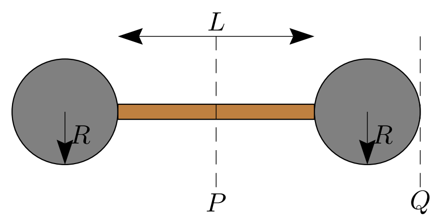
This potential is in addition to the normal gravitational potential due to the Earth ($r = 0$ is the center of the Earth). Use the following values [$R_{Earth} = 6.37 \times 10^6 m$, $M_{Earth} = 5.98 \times 10^{24} kg$, and $a = 1.00 \times 10^{21} \frac{Jm^3}{kg}$]

a) Find the escape velocity of the projectile with this additional potential in place and compare it with the escape velocity without the the evil forcefield.

b) Find the distance r_{equil} where the net force on the projectile vanishes. Locate where this position is in relation to the Earth.

Problem 8

Consider the following object,



The spheres have mass M and radius R and the rod connecting them is of length L and has mass m. Find the moment of inertia about the two points indicated on the diagram.

a) Moment of inertia about the central axis P.

b) Moment of inertia about the edge Q.

Short Response Questions

Question 9

As the Earth orbits the Sun its axis of rotation (which currently points towards the north star *Polaris*) is tilted by 11.25^o from the normal to the plane of Earth's orbit. The Earth is not a perfect sphere but is an ellipsoid (oblate spheroid), it is bulged around the equator by a small amount.

Use these two facts to *qualitatively* describe why the axis of rotation of the Earth precesses (with a period of 25,800 years). Make a free body diagram of the Earth and the forces due to the Sun acting on it at different points. (The summer solstice is a nice point to analyze this from -that is when the north pole points toward the Sun and the south pole away from it).

Question 10

What would happen if the Sun instantaneously turned into a black hole. The Earth will not become a black hole but for sake of this problem let's say it can. A black hole is an object whose mass has been compressed down beyond the *Schwarzschild radius* defined by

$$R_S = \frac{2GM}{c^2}$$

For the Sun, this value is $R_S = 3000m$. That means ***if*** you could compress the Sun into a ball $3km$ in radius, it would form a black hole.

Describe any potential change in the orbits of the planets (say Mercury and Earth) if this were to happen. Where would a change be noticeable? (Neglect other effects like it would be dark, etc. Just concentrate on the orbits).