Problem 1: For objects near the surface of the Earth, the universal law of gravitation can be simplified to $F = mg$, where $g = 9.81$ m/s^2.

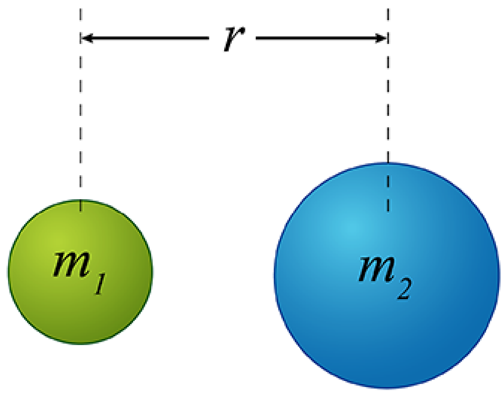
Part (a) If the mass of the Earth were doubled while at the same time its radius remained constant, by what factor would this change its acceleration due to gravity at it's surface?
MultipleChoice :

1) 4
2) 1/2
3) 1/4
4) 2

Part (b) If the radius of the Earth were doubled while at the same time its mass remained constant, by what factor would this change its acceleration due to gravity at the surface?
MultipleChoice :

1) 4
2) 2
3) 1/4
4) 1/2

Problem 2: Object 1 with m_1 = ***3.5*** kg and Object 2 with m_2 = ***14.5*** kg are separated by r = ***0.86*** m.



Part (a) Express the magnitude of the gravitational force F in terms of m_1, m_2, r, and the gravitational constant G.
Expression :
F = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, π, θ, d, G, h, i, j, m, m_1, m_2, P, r, t

Part (b) Calculate the magnitude of F in N.
Numeric : A numeric value is expected and not an expression.
F = ____

Problem 3: A satellite is located *295* km above Earth.

Find the ratio of the acceleration due to gravity at the position of a satellite located *295* km above the earth's surface to the free-fall acceleration at the surface of Earth.
Numeric : A numeric value is expected and not an expression.
g_d/g = ____

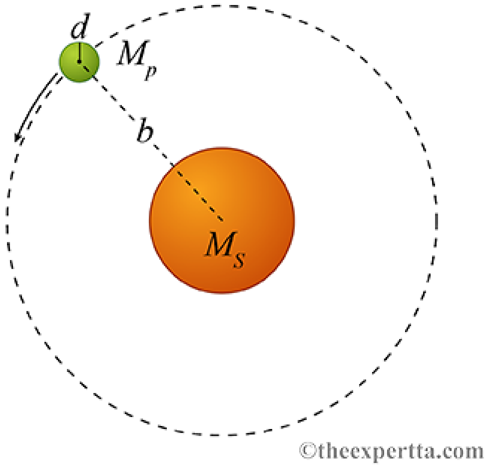
Problem 4: You are a scientist exploring a mysterious planet. You have performed measurements and know the following things:

•The planet has radius *d*.

•It is orbiting his star in a circular orbit of radius *b*.

•It takes time *T* to complete one orbit around the star.

•The free-fall acceleration on the surface of the planet is *a*.



Part (a) Derive an expression for the mass M_P of the planet in terms of *a*, *d* and *G* the universal gravitational constant. Assume that the gravitational effect of the star at the planet's surface is negligible.
Expression :
M_P = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, π, θ, a, b, d, g, G, h, i, m, n, P, T, z

Part (b) Derive an expression for the mass M_S of the star in terms of *b*, *T*, and *G* the universal gravitational constant.
Expression :
M_S = ____

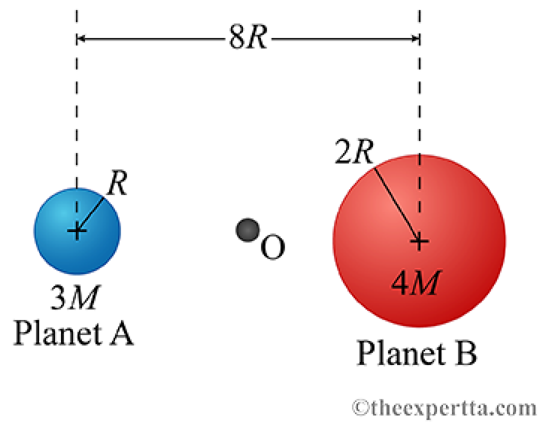
Select from the variables below to write your expression. Note that all variables may not be required.
π, θ, a, b, d, g, G, h, i, m, n, P, T, y, z

Problem 5: The Sun has a mass of 1.99×10^{30} kg and a radius of 6.96×10^{8} m.

Part (a) Calculate the acceleration due to gravity, in meters per square second, on the surface of the Sun.
Numeric : A numeric value is expected and not an expression.
$g_{\mathbf{Sun}}$ = ____

Part (b) By what factor would your weight increase if you could stand on the Sun?
Numeric : A numeric value is expected and not an expression.
$g_{\mathbf{Sun}}/g_{\mathbf{Earth}}$ = ____

Problem 6: Planet A has mass 3*M* and radius *R*, while Planet B has mass 4*M* and radius 2*R*. They are separated by center-to-center distance 8*R*. A rock is released halfway between the planets' centers at point *O*. It is released from rest. Ignore any motion of the planets.



Part (a) Enter an expression for the magnitude of the acceleration of the rock immediately after it is released, in terms of *M*, *R*, and the gravitational constant, *G*.
Expression :
a = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, π, θ, d, G, h, i, j, k, l, M, P, R, t

Part (b) Calculate the magnitude of the rock's acceleration, in meters per second squared, for $M = 8.9 \times 10^{23}$ kg and $R = 4.1 \times 10^{6}$ m.
Numeric : A numeric value is expected and not an expression.
a = ____

Part (c) Toward which planet is the rock's acceleration directed?
MultipleChoice :

1) Not enough information
2) Planet B
3) Planet A

Problem 7: Astronomical observations of our Milky Way galaxy indicate that it has a mass of about $8.0 \cdot 10^{11}$ solar masses. A star orbiting on the galaxy's periphery is about $6.0 \cdot 10^{4}$ light years from its center.

Part (a) What should the orbital period of that star be in years?
Numeric : A numeric value is expected and not an expression.
T = ____

Part (b) If its period is $6.0 \cdot 10^7$ years instead, what is the mass of the galaxy in solar masses? Such calculations are used to imply the existence of "dark matter" in the universe and have indicated, for example, the existence of very massive black holes at the centers of some galaxies.
Numeric : A numeric value is expected and not an expression.
M = ____

Problem 8: Jupiter has many moons orbiting it.

Parent	Satellite	Average orbital radius r(km)	Period T(y)	$r^3/T^2(km^3/y^2)$
Earth	Moon	3.84×10^5	0.07481	1.01×10^{18}
Sun	Earth	1.496×10^8	1.000	3.35×10^{24}
	Jupiter	7.783×10^8	11.86	3.35×10^{24}
Jupiter	Io	4.22×10^5	0.00485 (1.77 d)	3.19×10^{21}
	Europa	6.71×10^5	0.00972 (3.55 d)	3.20×10^{21}
	Ganymede	1.07×10^6	0.0196 (7.16 d)	3.19×10^{21}
	Callisto	1.88×10^6	0.0457 (16.19 d)	3.20×10^{21}

Find the mass of Jupiter, in kg, based on data for the orbit of one of its moons.
Numeric : A numeric value is expected and not an expression.
M_J = ____

Problem 9: The Earth's orbit around the Sun is very close to circular.

Parent	Satellite	Average orbital radius r(km)	Period T(y)	$r^3/T^2(km^3/y^2)$
Earth	Moon	3.84×10^5	0.07481	1.01×10^{18}
Sun	Earth	1.496×10^8	1.000	3.35×10^{24}
	Jupiter	7.783×10^8	11.86	3.35×10^{24}
Jupiter	Io	4.22×10^5	0.00485 (1.77 d)	3.19×10^{21}
	Europa	6.71×10^5	0.00972 (3.55 d)	3.20×10^{21}
	Ganymede	1.07×10^6	0.0196 (7.16 d)	3.19×10^{21}
	Callisto	1.88×10^6	0.0457 (16.19 d)	3.20×10^{21}

Calculate the mass of the Sun, in kg, based on data for Earth's orbit.
Numeric : A numeric value is expected and not an expression.
M = ____

Problem 10: A geosynchronous Earth satellite is one that has an orbital period of precisely 1 day. Such orbits are useful for communication and weather observation because the satellite remains above the same point on Earth (provided it orbits in the equatorial plane in the same direction as Earth's rotation).

Parent	Satellite	Average orbital radius r(km)	Period T(y)	r^3 / T^2 (km^3 / y^2)
Earth	Moon	3.84×10^5	0.07481	1.01×10^{19}
Sun	Earth	1.496×10^8	1.000	3.35×10^{24}
	Jupiter	7.783×10^8	11.86	3.35×10^{24}
Jupiter	Io	4.22×10^5	0.00485 (1.77 d)	3.19×10^{21}
	Europa	6.71×10^5	0.00972 (3.55 d)	3.20×10^{21}
	Ganymede	1.07×10^6	0.0196 (7.16 d)	3.19×10^{21}
	Callisto	1.88×10^6	0.0457 (16.19 d)	3.20×10^{21}

Calculate the radius of such an orbit based on the data for the moon in the figure in km.
Numeric : A numeric value is expected and not an expression.
r = ____

Problem 11:

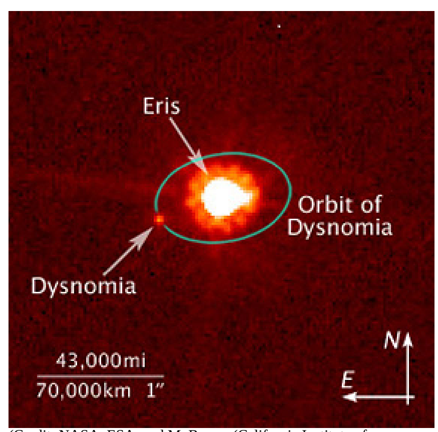
Great Problems in Physics Series

Dr. Kathleen Blackett earned her B.S. in physics from the University of Michigan-Dearborn, and her Ph.D. in experimental particle physics from the University of Tennessee. Kathy's career includes participating in searches for mesons with exotic quantum numbers as a postdoc at Brookhaven National Laboratory, working as systems/test engineer for AT&T, and taking some time to raise her family. In addition, Kathy taught physics and math for several years at the University of South Florida, St. Petersburg College and Eckerd College. Currently Kathy is a content author on the Expert TA team and volunteers for NASA as a Solar System Ambassador.

The following problem, while not especially complicated, is powerful. Like most individuals of my generation, I grew up believing that there were nine planets in our solar system. Period. This problem has convinced me otherwise. Sorry Pluto! You will always be special to me!

Pluto was discovered in 1930, and was unquestionably considered a planet until the discoveries of many other trans-Neptunian objects (TNOs) in the 1990's and early 2000's. As more TNOs were being discovered, it was looking like Pluto had much more in common with these objects than the other eight planets. In 2006, it was decided by the International Astronomical Union (IAU) that Pluto be reclassified as a dwarf planet.

One of these trans-Neptunian objects is the dwarf planet, Eris, discovered by the team of Michael Brown, David Rabinowitz and Chad Trujillo in 2005. Later that same year, the team discovered Dysnomia, a moon of Eris. Eris and Dysnomia are pictured to the right. The discovery of Dysnomia was fortunate, because it allowed scientists to calculate the mass of Eris. After careful observation, it was determined that Dysnomia has an orbit that is approximately circular with a radius of about 37,350 km and a period of about 15.79 days.



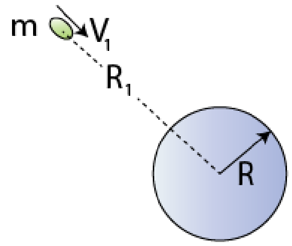
(Credit: NASA, ESA, and M. Brown (California Institute of Technology))

Part (a) Determine the mass, in kilograms, of Eris.
Numeric : A numeric value is expected and not an expression.
M_{Eris} = ____ kg

Part (b) Pluto has a mass of 1.309×10^{22} kg. Which is more massive, Pluto or Eris?
MultipleChoice :

1) Pluto
2) Eris

Problem 12: A meteoroid is moving towards a planet. It has mass $m = 0.74 \times 10^{9}$ kg and speed $v_1 = 4.7 \times 10^{7}$ m/s at distance $R_1 = 1.8 \times 10^{7}$ m from the center of the planet. The radius of the planet is $R = 0.86 \times 10^{7}$ m. The mass of the planet is $M = 9.2 \times 10^{25}$ kg. There is no air around the planet.



Part (a) Enter an expression for the gravitational potential energy PE_1 of the meteoroid at R_1 in terms of defined quantities and the gravitational constant G. Assume the potential energy is zero at infinity.
Expression :
PE_1 = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, d, g, G, h, m, M, P, q, R, R_1, t, v_1

Part (b) Calculate the value of PE_1, in joules.
Numeric : A numeric value is expected and not an expression.
PE_1 = ____ J

Part (c) Enter an expression for the total energy E_1 of the meteoroid at R_1 in terms of defined quantities.
Expression :
E_1 = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, d, g, G, h, m, M, P, q, R, R_1, t, v_1

Part (d) Calculate the value of E_1, in joules.
Numeric : A numeric value is expected and not an expression.
E_1 = ____ J

Part (e) Enter an expression for the total energy E of the meteoroid at R, the surface of the planet, in terms of defined quantities and v, the meteoroid's speed when it reaches the planet's surface.
Expression :
E = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, d, g, G, h, m, M, P, q, R, R_1, t, v

Part (f) Enter an expression for v, the meteoroid's speed at the planet's surface, in terms of G, M, v_1, R_1, and R.
Expression :
v = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, d, g, G, h, m, M, P, q, R, R_1, t, v_1

Part (g) Calculate the value of v in meters per second.
Numeric : A numeric value is expected and not an expression.
v = ____ m/s

Problem 13: Consider a spherical planet of radius *R* and mass *M*. The planet has uniform density.

Part (a) Someone has drilled a hole straight through the center of this planet to the other side and is about to drop a small object of mass *m* into the hole. We can show that the object will experience simple harmonic motion in the hole by showing that the gravitational force on the object will obey Hooke's law, $F_{grav} = -kx$, where *k* is the force constant and *x* denotes the displacement from equilibrium position, which is the planet's center. Enter an expression for *k*, in terms of *R*, *M*, *m*, and the gravitational constant, *G*.
Expression :
k = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, **γ**, **π**, **θ**, **d**, **G**, **h**, **j**, **k**, **m**, **M**, **n**, **P**, **R**, **S**

Part (b) When the object is dropped into the hole, what will be its period of oscillation, in seconds, if $R = 4\times10^6$ m and $M = 5\times10^{24}$ kg?
Numeric : A numeric value is expected and not an expression.
T = ____

Part (c) What would be the period of oscillation, in seconds, if the planet were Earth? The radius of Earth is 6.38×10^6 m and its mass is 5.9×10^{24} kg. Assume the mass is distributed uniformly.
Numeric : A numeric value is expected and not an expression.
T = ____

Problem 14: In this problem you will answer a few questions about "escape speed".

Part (a) True or false: Planets with low escape speeds, such as Mercury, generally don't have atmospheres because the average speed of gas molecules is close to the escape speed.
TrueOrFalse :

1)
2)

Part (b) True or false: A spacecraft would have the same escape speed as a gas molecule.
TrueOrFalse :

1)
2)

Part (c) Which of the following best describes escape speed?
MultipleChoice :

1) The speed required to overcome atmospheric resistance.
2) The speed an object has after leaving the gravitational pull of the Earth.
3) The speed required to exit the Earth's gravitational pull.

4) The speed attained when an object moves faster than influence of gravity.

Problem 15: An object of mass m is launched from a planet of mass M and radius R.

Part (a) Derive and enter an expression for the minimum launch speed needed for the object to escape gravity, *i.e.* to be able to just reach $r = \infty$.
Expression :
v = ____

Select from the variables below to write your expression. Note that all variables may not be required.
α, β, θ, a, d, G, h, j, k, m, M, P, R, t, z

Part (b) Calculate this minimum launch speed (called the *escape speed*), in meters per second, for a planet of mass $M = 5.18 \times 10^{24}$ kg and $R = 86.7 \times 10^{4}$ km.
Numeric : A numeric value is expected and not an expression.
v = ____ m/s

Problem 16: A *3500*-kg spaceship is in a circular orbit *210* km above the surface of Earth. It needs to be moved into a higher circular orbit of *390* km to link up with the space station at that altitude. In this problem you can take the mass of the Earth to be 5.97 × 10^{24} kg.

How much work, in joules, do the spaceship's engines have to perform to move to the higher orbit? Ignore any change of mass due to fuel consumption.
Numeric : A numeric value is expected and not an expression.
W = ____

Problem 17: When researching a planetoid with a radius of 599 km and a mass of 6.33×10^{21} kg, a projectile with a mass of 3.62 kg is launched from its surface at escape velocity. Disastrously, the projectile collides with the spaceship that is orbiting at an altitude of 1705 km above the surface.

With what speed, in meters per second, does the projectile hit the spaceship?
Numeric : A numeric value is expected and not an expression.
v = ____ $\mathrm{m/s}$