Physics 1A, Section 2

November 1, 2010

Office Hours

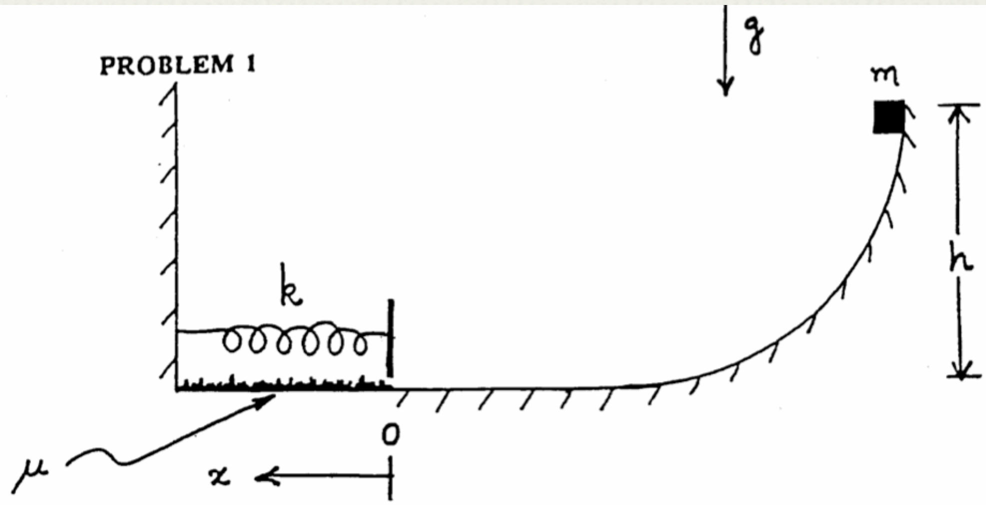
- Office hours will now be:
  - Tuesday, 3:30 – 5:00 PM (half an hour later)
  - still in Cahill 312

Today’s Agenda

- Finish energy problem from Thursday
- forces and potential energy
- potential energy of a fictitious force?
- potential energy applied to orbits
  - Lagrange points for Sun/Earth/satellite

Quiz Problem 50

PROBLEM 1



A block of mass m starts at rest and slides down a frictionless circular ramp from a height h. At the bottom, it hits a massless spring with spring constant k and in addition begins to experience a frictional force. The coefficient of kinetic friction is given by μ.

(1 point) (a) What is the speed of the block at the bottom of the ramp just before it hits the spring?

(2 points) (b) Find the total horizontal force on the mass after it hits the spring as a function of the coordinate x given in the diagram.

The mass first comes to rest instantaneously at $x=x_s$. It then rebounds back up the ramp, reaching a maximum height $h'<h$. In the following, express your answer in terms of x_s:

(2 points) (c) What is the total work done on the mass by the spring and friction between $x=0$ and $x=x_s$?

(2 points) (d) What is the total energy W_f that has been dissipated by friction when the spring first returns to $x=0$?

(2 points) (e) Find the vertical height h' up the ramp to which the block rebounds. You may express your answer in terms of W_f.

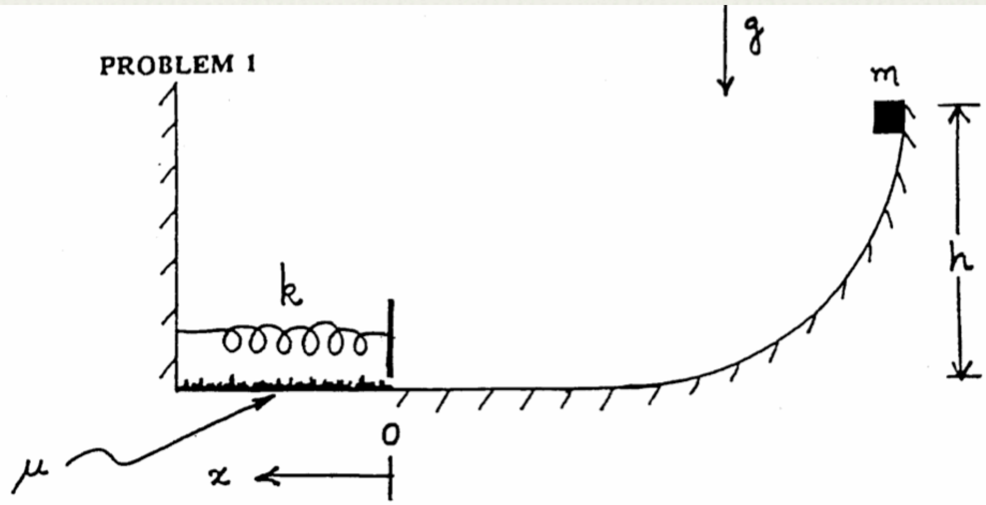
(1 point) (f) Find x_s in terms of the quantities shown above.

Quiz Problem 50

- Answer:

a) $v = \text{sqrt}(2gh)$
b) $F = -kx - \mu mg$, to the right
c) $W = -kx_s^2/2 - \mu mgx_s$
d) $W_f = 2\mu mgx_s$
e) $h' = h - 2\mu x_s$
f) $x_s = [-\mu mg + \text{sqrt}(\mu^2 m^2 g^2 + 2kmgh)]/k$

PROBLEM 1



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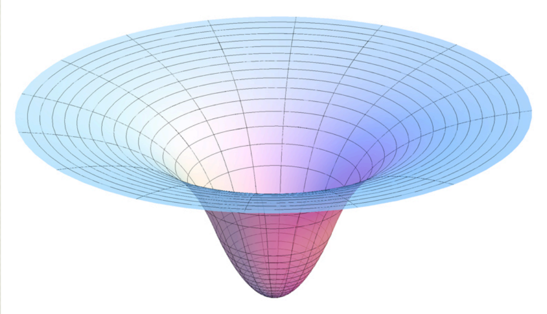
Conservative and Non-Conservative Forces

- A *conservative* force **F** can be associated with a potential energy U
  - $F = -dU/dr$ or $-dU/dx$ in Physics 1a
    - $\mathbf{F} = (-\partial U/\partial x, -\partial U/\partial y, -\partial U/\partial z)$ more generally
  - Force is a function of position only.
  - example: uniform gravity: $U = mgz$
  - example: Newtonian gravity: $U = -GMm/r$
  - example: ideal spring: $U = kx^2/2$



- *Non-conservative* forces
  - friction: force depends on direction of motion
  - normal force: depends on other forces
    - but does no work because it has no component in direction of motion.

Potential Energy from a Fictitious (Inertial) Force

- It can be useful to associate the centrifugal force in a rotating frame with a potential energy:
  - $F_{centrifugal} = m\omega^2 r$ (outward)

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  - $F_{centrifugal} = m\omega^2 r$ (outward)
  - $\Rightarrow U_{centrifugal} = -m\omega^2 r^2/2$

Consider circular orbits (again)

- Work in the rotating (non-inertial) frame.
- planet orbiting the Sun:
  - $U_{total} = U_{gravity} + U_{centrifugal}$
  - Equilibrium where $dU_{total}/dr = 0 \Rightarrow GM_{Sun} = \omega^2 r^3$

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- planet orbiting the Sun ($M_{planet} << M_{sun}$):
  - $U_{total} = U_{gravity} + U_{centrifugal}$
  - Equilibrium where $dU_{total}/dr = 0 \Rightarrow GM_{Sun} = \omega^2 r^3$
- Satellite and Earth orbiting the Sun ($M_{satellite} << M_{Earth} << M_{Sun}$)
  - $U_{total} = U_{gravity,Sun} + U_{gravity,Earth} + U_{centrifugal}$
  - Equilibria at 5 Lagrange points

Sun-Earth Lagrange Points

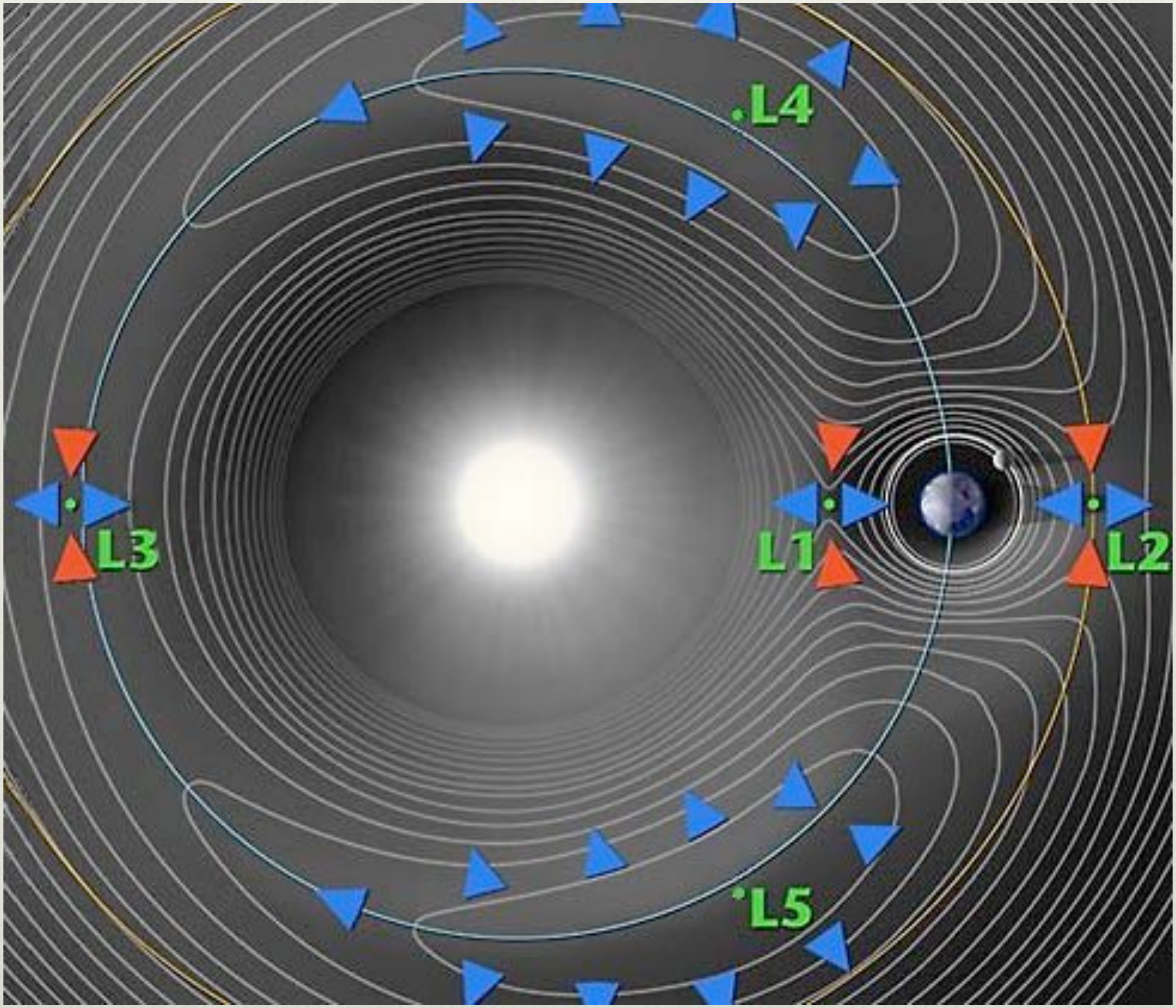
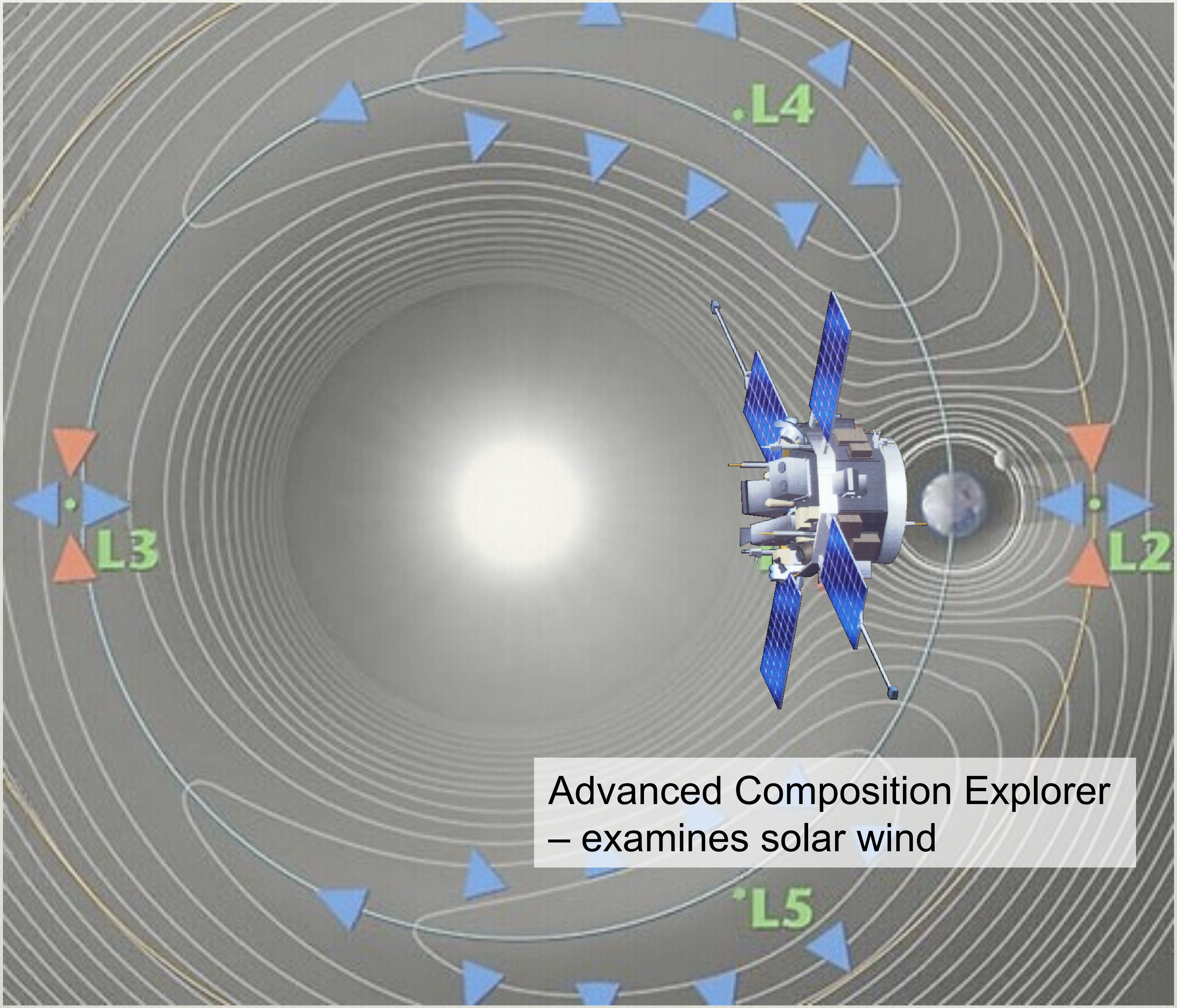


image from
wikipedia

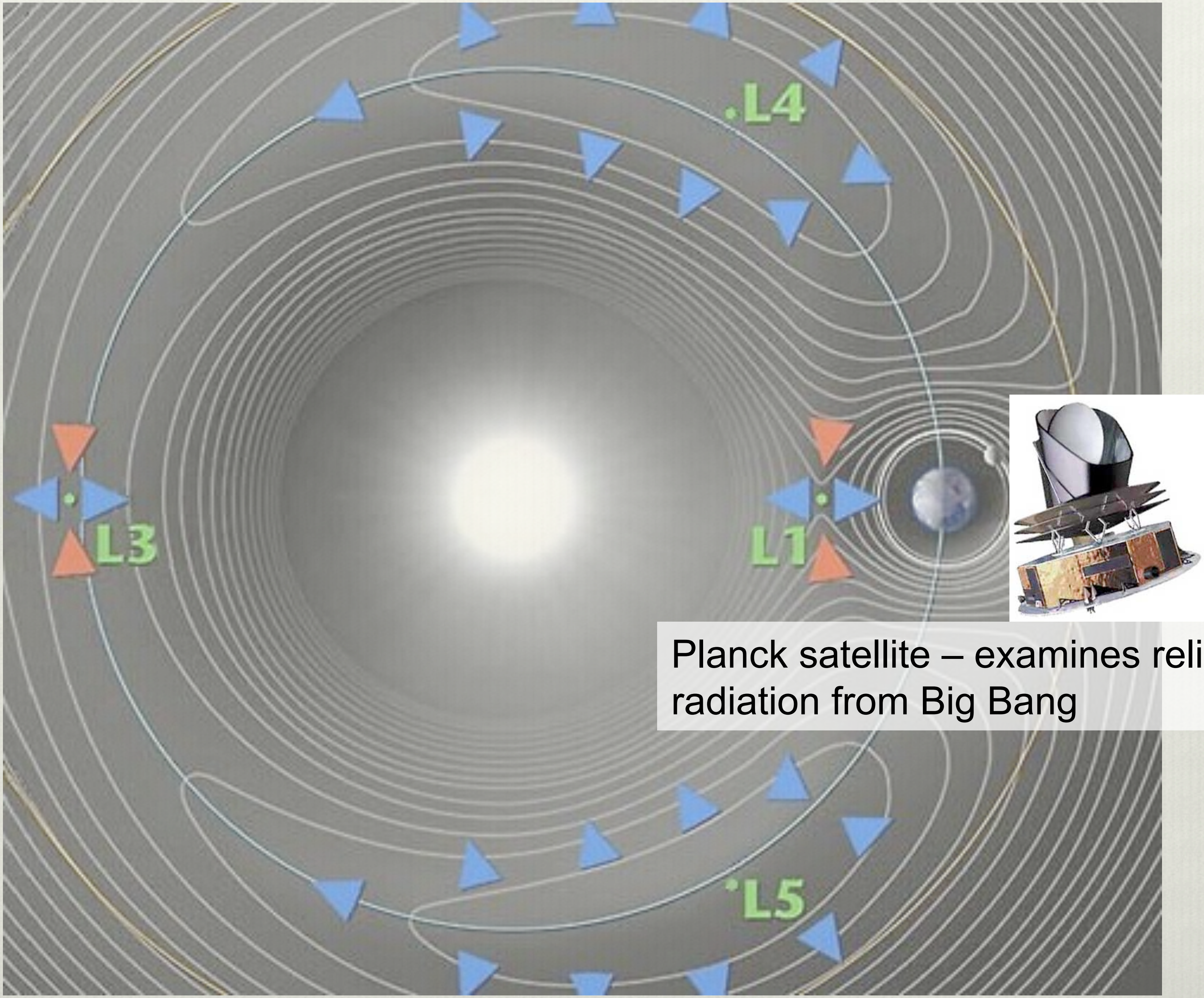
Location of Lagrange points

- L1,L2: $\Delta R \approx R(M_E/3M_S)^{1/3}$
  - about 0.01 A.U. from Earth toward or away from Sun
  - unstable equilibria
- L3: orbital radius $\approx R[1 + (5M_E/12M_s)]$
  - very unstable equilibrium
- L4,L5: three bodies form an equilateral triangle
  - stable equilibria (via Coriolis force)

1 A.U. = astronomical unit = distance from Earth to Sun



Advanced Composition Explorer
– examines solar wind



Planck satellite – examines relic radiation from Big Bang

Thursday, November 4:

- Quiz Problem 38 (collision)

- *Optional, but helpful, to try this in advance.*