Lecture 19: Problem Solving Review For test 2
How to identify type of problem?

• If the problem mentions planets, moons, stars, spaceships, meteorites... Universal gravitation \((U, F)\)
• If the problem is a collision or explosion:
  Linear momentum is conserved
  Mechanical energy changes
  Only if the collision is elastic:
    Linear momentum and mechanical energy are both conserved
• If external forces dominate, such as spring, gravity, friction: Energy/Work

Caution: some problems may require several tools!
Tips for multiple choice

• Take enough time. The multiple choice page is worth as many points as each of the other pages.
• Identify the concept that is tested by the question.
• Recall what you know about this concept.
• If possible, try to answer the question as if it were open-ended, without looking at the answer options.
• Sketching a diagram or working out a few lines of equations may be necessary.
Concepts

• Force perpendicular to path does zero work
• Conservative force: work independent of path
• Force component as negative derivative of potential energy
• Potential energy diagrams
• Free fall acceleration from universal gravitation
• Satellite motion
• Escape speed
• Impulse = change in momentum vector
• Inelastic, perfectly inelastic, elastic collisions
• Center of mass motion under external forces
Example 1

A block of mass $M$ is pushed against a spring with unknown spring constant, compressing it a distance $L$. When the block is released from rest, it travels a distance $d$ on a frictionless horizontal surface and then up a rough incline that has a coefficient of kinetic friction $\mu$ with the box. The incline makes an angle $\theta$ above the horizontal. When the block reaches height $H$ on the incline, its speed is $V$.

Derive an expression for the force constant $k$ of the spring in terms of system parameters.
Planet A has mass $4M$ and radius $2R$. Planet B has mass $3M$ and radius $R$. They are separated by center-to-center distance $8R$. A rock of mass $m$ is placed halfway between their centers at point $O$ and released from rest. (Ignore any motion of the planets.)

Derive an expression for the magnitude and direction of the acceleration of the rock at the moment it is released.
Derive an expression, in terms of relevant system parameters, for the speed with which the rock crashes into a planet.
Example 3

Bilbo and Thorin slide on a frozen pond. The pond surface is frictionless and horizontal. Thorin with mass $M$ is originally moving eastwards with speed $v_{Ti}$. Bilbo with mass $m$ is originally sliding northward. They collide and after the collision Thorin is moving with speed $v_{Tf}$ at angle $\theta$ north of east (i.e. above the positive $x$-axis), while Bilbo is moving at angle $\phi$ south of east (i.e. below the positive $x$-axis). Derive expressions for the speed of Bilbo before and after the collision, in terms of system parameters.
Derive an expression for the average force exerted on Thorin by Bilbo in unit vector notation, if the two are in contact for a time span $\Delta t$. 