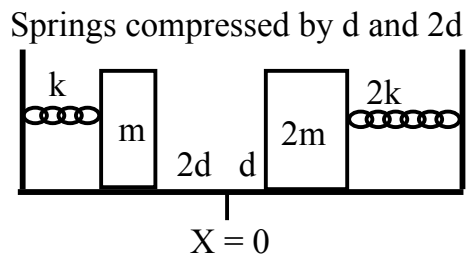
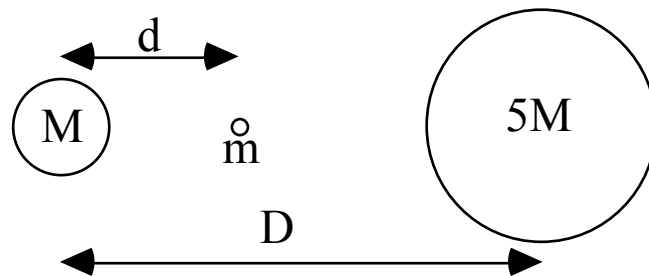


~~2d and the right mass is pulled to the right a distance d. Both masses are released from rest at the same time. Explain why both masses get back to X=0 at the same time.~~



B) The diagram shows a binary star system with one star of mass M and the other of mass $5M$ with the centers of the two stars separated by a distance D as shown. Assume that a third small object of mass m is located a distance d from the center of the left star. The centers of all three objects are on the same line.



- i) Is there a value of d for which the total gravitational force on the small mass is zero? If so, write the equation you would solve to find this value of d . Note that you do **NOT** need to find the value of d . If there is no such value, explain why not.
- ii) Using the standard equation for potential energy due to gravity far from the surface, is there a value of d for which the total gravitational potential energy of the small mass is zero? If so, write the equation you would solve to find this value of d . Note that you do **NOT** need to find the value of d . If there is no such value, explain why not.

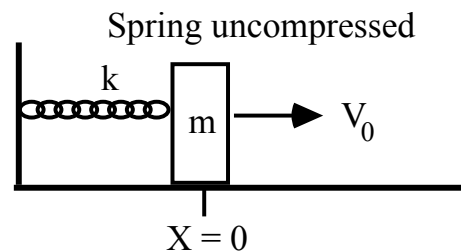
Problem 13

~~Rocket A propels an object of mass m from the surface of the Earth to an altitude $3R_E$ (R_E is the radius of the Earth) above the surface of the Earth at which point the object stops momentarily before falling back. Rocket B propels an object of the same mass into a circular orbit at an altitude of R_E above the surface. Which rocket does more work? Assume that the initial velocity due to the rotation of the Earth can be ignored. Justify your answer.~~

Problem 14

~~An object of mass m is attached to a spring of spring constant k and moves on a frictionless horizontal surface. The mass is at $X=0$ (where the spring is unstretched) and it has an initial velocity of V_0 in the positive X direction as shown. The subsequent position and velocity of the object as a function of time are given by:~~

~~$X(t) = A \sin(Ct)$ and $V(t) = B \cos(Ct)$~~



- a) Find the values of A, B, and C in terms of k , m , and V_0 .
- b) Since $X=0$ at $t=0$, the average velocity between $t=0$ and a later time can be written simply as

$V_{avg}(t) = X(t)/t$

~~Find the average velocity between $t=0$ and $t=T/2$, where T is the period of oscillation of the mass on the spring. Hint: If you think carefully, you can get the answer with almost no calculations.~~

- c) Find the average velocity between $t=0$ and $t=T/3$, where T is the period of oscillation of the mass on the spring. Express your answer in terms of V_0 only. Your answer can contain trigonometric functions (like sin, cos, tan, etc.) and numerical constants but no variables other than V_0 .

Problem 11

a) $E = \frac{1}{2}mv_0^2 - \frac{GmM_E}{R_E}$

b) $\frac{1}{2}mv^2 - \frac{GmM_E}{2R_E} = \frac{1}{2}mv_0^2 - \frac{GmM_E}{R_E}$, $v^2 = v_0^2 - \frac{GM_E}{R_E}$

c) $v = 0$, if $v_{0,min} = \sqrt{\frac{GM_E}{R_E}}$

d) $\frac{mv^2}{2R_E} = \frac{GmM_E}{(2R_E)^2}$, $v = \sqrt{\frac{GM_E}{2R_E}}$

Problem 12

A) $\omega_{left} = \sqrt{\frac{k}{m}}$, $\omega_{right} = \sqrt{\frac{2k}{2m}} = \sqrt{\frac{k}{m}}$

Same $\omega \Rightarrow$ same period \Rightarrow same time to $x = 0$.

B) i) Let right be positive direction: $F_{TOT} = 0 = \frac{G(5M)m}{(D-d)^2} - \frac{G(M)(m)}{d^2}$

Two forces can cancel. Could also write $(D-d)^2 = 5d^2$
(Not required: $d = 0.31D$)

B) ii) $PE_{TOT} = \frac{-G(5M)m}{(D-d)} - \frac{GMm}{d}$, $D > d$ so both terms are negative, so $\boxed{\text{it can NEVER be zero}}$.

Problem 13

Rocket A: $E_I = \frac{-GMm}{R_E}$, $E_F = \frac{-GMm}{4R_E}$, $W_A = \Delta E = \frac{-GMm}{4R_E} - \left(-\frac{GMm}{R_E}\right) = \frac{3GMm}{4R_E} = W_A$

Rocket B: $E_I = \frac{-GMm}{R_E}$, $\frac{GMm}{(2R_E)^2} = \frac{mv^2}{2R_E}$, $v^2 = \frac{GM}{2R_E}$, $KE_F = \frac{1}{2}GMm - \frac{1}{4}GMm$

$PE_F = \frac{-GMm}{2R_E}$, $E_F = \frac{1}{4}GMm - \frac{GMm}{2R_E} = -\frac{GMm}{4R_E}$, $W_B = \Delta E = \frac{3GMm}{4R_E} \Rightarrow$ Same as A.

Problem 14

a) $C = \omega = \sqrt{\frac{k}{m}}$, $B = V_0$, $\frac{1}{2}kA^2 = \frac{1}{2}mV_0^2 \Rightarrow A = \sqrt{\frac{m}{k}}V_0$

b) At $T/2$, block returns to $x = 0$, so $V_{AVG} = 0$ at $t = T/2$

c) $V_{AVG} = \frac{\sqrt{\frac{m}{k}}V_0 \sin(\sqrt{\frac{k}{m}}\frac{T}{3})}{T/3}$, But $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$, so: $V_{AVG} = \frac{3V_0}{2\pi} \sin\left(\frac{2\pi}{3}\right)$

(Not required: $V_{AVG} = 0.4V_0$)