Your solutions should be neat, correct and complete. Correct units must be given on answers and if you are omitting units in calculations then there should be a sentence explaining your custom. Finally, the answer must be boxed where appropriate.

Suggested Reading You may find the following helpful resources beyond lecture,

(a.) Chapters 3, 4 of my lecture notes (pdf posted in Canvas)

(b.) Lectures 9, 10, 11, 12, 13, 15, 16, 17, 19, 36 as posted on the course website (see http://www.supermath.info/PhysicsI.html)

(c.) Chapters 5, 6, 7 of Young and Freedman (see https://mylabmastering.pearson.com/ for the ebook, or better yet buy an old edition to read offline)

Problem 21: (2pts) Consider a box with mass $m = 20\,kg$ which rests on a floor with coefficient of static friction $\mu_s = 0.7$ and coefficient of kinetic friction $\mu_k = 0.5$.

(a.) If F_o is applied horizontally to the box, then what is the maximum force which can be applied without the box moving ?

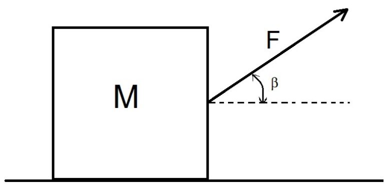
(b.) Supposing the box is given a nudge to start the box sliding, then what is the acceleration of the box if it continues to be pushed with force F_o horizontally after it begins moving ?

Problem 22: (2pts) A car travels on a flat circular track of radius $R = 50\,m$ with wheels that have a coefficient of friction of $\mu = 0.9$.

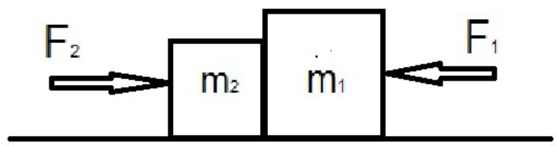
(a.) What is the maximum speed v possible for the car to stay on the track ?

(b.) At a particular time, the car is increasing its speed according to $dv/dt = 2m/s^2$. What is the maximum speed v the car have under such an acceleration if it is to stay on the track ?

Problem 23: (2pts) Suppose a mass $M = 20\,kg$ is pulled by a force $F = 100\ N$ at angle $\beta = 50^o$ as pictured. If the box accelerates at $a = 2.0m/s^2$ then what is the **coefficient of kinetic friction** between the box and the floor ?

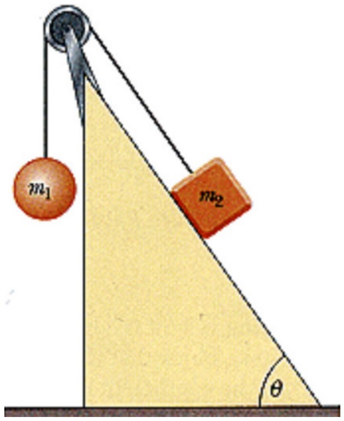


Problem 24: (2pts) Suppose $F_1 = 200\ N$ and $F_2 = 500\ N$ where $m_1 = 30\ kg$ and $m_2 = 20\ kg$. Find the **contact force** between m_1 and m_2 and determine the **acceleration** of the boxes. Assume plane is essentially frictionless.

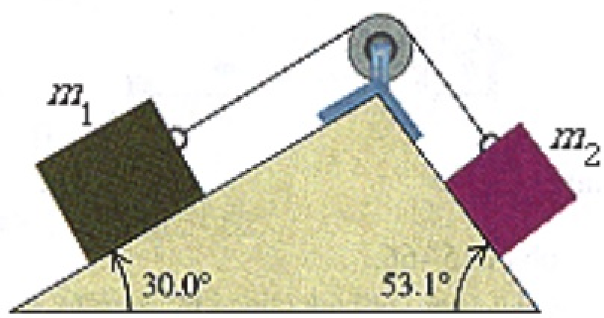


Problem 25: (2pts) Suppose the force of air friction on a mass m is given by $F_f = -\beta v^3$ where $\beta > 0$ is constant. Find the terminal velocity for this mass dropped from a tall building on Earth.

Problem 26: (2pts) Two objects are connected by a light string that passes over a frictionless pulley. The incline is frictionless, $m_1 = 2.00\,kg$, $m_2 = 10\,kg$, and $\theta = 50.0^o$. Find the tension in the string, the acceleration of the system and the speed after it is released from rest for $3.0\,s$.



Problem 27: (2pts) Two blocks connected by a cord passing over a small, frictionless pulley rest on frictionless planes. You're given $m_1 = 102\,kg$, and $m_2 = 53\,kg$. What is the magnitude of the acceleration of the blocks and what is the tension in the cord ?



Problem 28: (6pts) Let $\vec{F} = \langle 2x, 2y - x \rangle$. Calculate the work $W = \int_C \vec{F} \bullet d\vec{r}$ done by this force field on a particle which moves along the following paths:

(a.) C is the straight line from $(1, 0)$ to $(0, 1)$ given by $x = 1 - t, y = t$ for $0 \leq t \leq 1$

(b.) C is the quarter-circle given by $x = \cos t, y = \sin t$ for $0 \leq t \leq \pi/2$

(c.) Is $\vec{F}$ a conservative vector field on $\mathbb{R}^2$? (explain)

Problem 29: (3pts) For each force given below, find a potential energy function U for which $\vec{F} = -\nabla U$.

(a.) $\vec{F} = (x^2 + 1)\hat{\mathbf{x}} + \hat{\mathbf{y}} + ze^{-z^2}\hat{\mathbf{z}}$

(b.) $\vec{F} = \vec{F}_o$ where $\vec{F}_o = \langle a, b, c \rangle$ and a, b, c are constants.

Problem 30: (4pts) Consider a mass $M = 20\,kg$ which moves from $(1.00\,m, -2.00\,m)$ in a straight line from to the final position $(4.00\,m, 3.00\,m)$. Find

(a.) the work done by $\vec{F_1} = \langle 10N, 0\rangle$,

(b.) the work done by $\vec{F_2} = \langle 10N, 3N\rangle$,

(c.) work done by the variable force $\vec{F_3} = (10N/m)\langle x, y\rangle$

(d.) would the answers be different if the motion was not along a straight line ?

Problem 31: (2pts) Suppose $U(x) = x^2 - x^4$ is the potential energy function. Plot the energy diagram and comment on the stability of any critical points. If F is the force described by this potential energy function then explain where the force is directed right/left. Please give your answer in terms of interval notation. (for example if $2 \leq x \leq 3$ was where F points right then you would say "the force is directed to the right on $[2, 3]$)

Problem 32: (2pts) Suppose $\vec{F} = (3.2\,N)\hat{\mathbf{x}} - (6.1\,N)\hat{\mathbf{y}} + (13.1\,N)\hat{\mathbf{z}}$ acts on a mass $M = 20\,kg$ as the mass moves with constant velocity $\vec{v}(t) = \left(1.0\frac{m}{s}\right)\hat{\mathbf{x}} + \left(3.0\frac{m}{s}\right)\hat{\mathbf{y}} - \left(2.0\frac{m}{s}\right)\hat{\mathbf{z}}$. What is the power developed by the given force ? If the force is applied for the time interval $0 \leq t \leq 2.00\,s$ then what is the work done by the force on M ? What is the work done by the net-force on M ?

Problem 33: (3pts) We omit units here, my apologies. Consider $\vec{F}(x,y,z) = \langle 3x^2, 3y^3, -6z \rangle$.

(a.) Find the potential energy function for $\vec{F}$

(b.) Calculate the work done by $\vec{F}$ along a line-segment from $(1,2,3)$ to $(-2,0,4)$,

(c.) Calculate the work done by $\vec{F}$ along a curve which begins where it ends.

Problem 34: (4pts) A 30 kg crate is lifted by a constant force at a constant velocity from the ground to a shelf 1.2 m above the ground.

(a.) What is the work fone on the crate by the lifting force

(b.) What is the work done on the crate by the gravitational force

(c.) What is the work done on the crate by the net-force

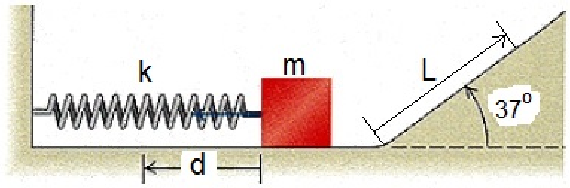
(d.) What is the net change in KE for the crate.

Problem 35: (2pts) Two tugboats pull a disabled supertanker. Each tug exerts a constant force of $1.50 \times 10^6\, N$, one 16^o north of west and the other 16^o south of west, as the pull the tanker $0.65\, km$ toward the west. What is the total work they do on the supertanker ?

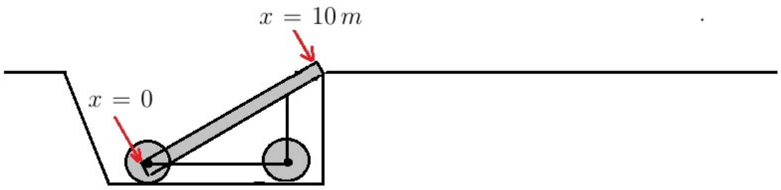
Problem 36: (2pts) A 25 kg crate is pushed across the floor of a factor starting from rest and ending at a speed of $2m/s$. If a constant pushing force of 150 N was applied and the floor which has $\mu_k = 0.5$ then how far was required to build up the given speed.

Problem 37: (2pts) A man stands on the roof of a $13.0\,m$ tall building and throws a rock with a velocity of magnitude $30.0\,m/s$ at an angle of 30^o above the horizontal. You can ignore air resistance. Assuming the building is on a horizontal plane, **find how far the rock travels horizontally from the point where it was thrown.**

Problem 38: (2pts) A $m = 3.00\ kg$ block is pushed against a spring with negligible mass and force constant $k = 220\ N/m$, compressing it $d = 1.300\ m$. When the block is released, it moves along a frictionless, horizontal surface and then up a frictionless incline with slope 37.0^o. Find the maximum length L the block slides up the incline. (see diagram for L)



Problem 39: (2pts) Suppose a projectile is propelled by explosive gases in the barrel of an experimental long gun according to the force $F(x) = \alpha x - \beta x^3$ where the projectile begins at rest where $x = 0$ and it exits the barrel at $x = 10\,m$. Given that the mass of the projectile is 30 grams and $\alpha = 3000\,N/m$ and $\beta = 20\,N/m^3$ find the maximum range of the gun assuming a level testing ground on Earth.



Problem 40: (7pts) A spring with spring constant $k = 200\ N/m$ is attached to mass $m = 250\ g$. If the spring is stretched $8\,cm$ from its equilbrium position and released from rest then find (**(a.)**-**(f.)**, write answers to right of problem statements, show work below)

(a.) the period T of the motion

____.

(b.) the angular frequency ω of the motion

____.

(c.) the position of the mass as a function of time t

____.

(d.) the velocity of the mass as a function of time t

____.

(e.) the potential energy in the spring at time t

____.

(f.) the kinetic energy of the mass at time t

____.

(g.) show the total mechanical energy is constant