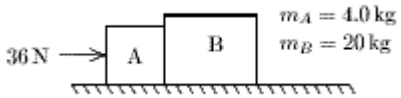
Calculus-based Physics 201
Test #2:
Force, Newton's Laws, Work, Kinetic & Potential Energy, Conservation of Energy
Fall 2026

Numerical Answers: Use the MKS Metric System unless explicitly told to do otherwise.
Give Numerical Answers to at least Three Significant Figures.
NO: Notes, Formula Cards, Formulas or Constants in your Calculators, or any other aids.
Vectors are indicated in Bold Print (**v**).
Unit Vectors in the x, y, & z directions are symbolized by **i**, **j**, & **k** respectively.
Multiple Choice are 5 Points each. The Problems are 15 Points each.
One of the 15 Multiple Choice is a Bonus unless it is found that one of the Multiple Choice Questions is bad for some reason and must be eliminated.

Chapter 5: $F_{net} = (m+M)a \Rightarrow a \Rightarrow F_M = Ma$ & $F_{AB} = F_{BA}$ <-3rd Law

| 1> Two blocks, A & B, are in contact on a horizontal frictionless surface. A F=36 N force is applied to A as shown. The Force exerted on A by B is
a) 36 N ->b) 30 N c) 29 N d) 6.0 N e) 1.5 N



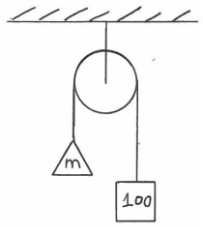
$F_{A\&B} = m_{A\&B}a \Rightarrow a = F/M = 36/(20+4) = 3/2$ & $F_{BA} = m_Ba = (20)(3/2) = 30$ & $F_{AB} = F_{BA}$
Check $F_A = m_Aa \Rightarrow 36-30 = 4(3/2) \Rightarrow 6 = 6$

Chapt 5: F = ma

| 2> Eric has a mass of 70 kg. He is standing on a scale in an elevator that is accelerating upward at 1.7 m/s^2. What is the reading on the scale in Newtons?
a) 0 b) 119 c) 567 d) 686 ->e) 805
$\mathbf{F}_{net} = m\mathbf{a} \Rightarrow N - mg = ma \Rightarrow N = ma+mg = 70(9.8+1.7) = 805.00000$ N

Chapt 5: F = ma and the **Atwood Machine**

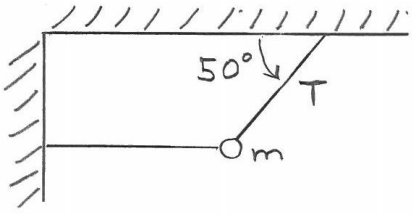
| 3> In the Atwood machine shown, m = 70 kg. What is the magnitude of the acceleration of the 100 kg block in m/s^2 when it is released from rest?
->a) 1.7 b) 2.9 c) 4.0 d) 8.1 e) 9.8



Eq^{n}s of Motion for m & M: $\mathbf{F}^{net}_{on_m} = m\mathbf{a}$ or $ma = T - mg$ & $\mathbf{F}^{net}_{on_M} = M\mathbf{a}$ or $Ma = Mg - T$
add Eq^{n}s $\Rightarrow (m+M)a = T-T+Mg - mg \Rightarrow a = [(M-m)/(M+m)]g = 30(9.8)/170 = 1.729411765$

Chapt 5: F = ma = 0

| 4> A 2.00 kg ball is suspended by two light strings as shown. What is the tension, T, in Newtons in the angled string?
a) 16.4 b) 19.6 c) 23.4 ->d) 25.6 e) 30.5



$\mathbf{F}_{net} = m\mathbf{a} = 0 \Rightarrow F_{net,vert} = 0 \Rightarrow T_y - mg = 0 \Rightarrow T\sin 50° = mg = 0 \Rightarrow T = 25.585982876$N

Chapt 6: F = ma Constant Velocity with Kinetic friction:

| 5> A football player at practice pushes a 60 kg blocking sled horizontally across the field at a constant speed of 2.0 m/s. The coefficient of static friction between the grass and sled is 0.4, and the coefficient of kinetic friction between the grass and sled is 0.3.
How much force is he applying to the sled so it moves with constant speed?
a) 18 N b) 24 N ->c) 176 N d) 235 N e) 588 N
$F_{net,vert} = 0$ (=> N = mg) & $F_{net,horz} = ma$ => F-f=ma=0 => $F-\mu_k(N=mg)=0$ =>
$F = \mu_k mg = 0.3(60)(9.8) = 176.400000000$ N

Chapt 6: F = ma with kinetic friction

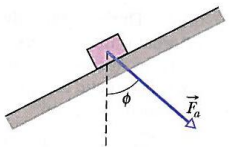
| 6> A crate of mass m is sliding down an incline tilted at an angle θ to the horizontal, with μ_k the coefficient of kinetic friction between the incline and the crate. Which of the answers below gives the magnitude of the acceleration as it slides down the plane? g is the magnitude of the acceleration due to gravity.
a) $\mu_k g\sin\theta$ b) $\mu_k g\cos\theta$ c) $g(\sin\theta + \mu_k\cos\theta)$ ->d) $g(\sin\theta - \mu_k\cos\theta)$ e) $g\sin\theta$
$\mathbf{F}_{net} = m\mathbf{a}$ => $F_{net,y} = 0$ => $N - mg\cos\theta = 0$ => $N = mg\cos\theta$ &
$F_{net,x} = mg\sin\theta - [f_k=\mu_k(N=mg\cos\theta)] = ma$ => $a = g[\sin\theta - \mu_k\cos\theta]$

Chapt. 7: Work done by a Constant Force:

| 7> A constant force $\mathbf{F} = 1.0\mathbf{i} + 4.0\mathbf{j} + 0.0\mathbf{k}$ N acts on an object as it moves along a straight-line path. If the object's displacement is $\mathbf{d} = 6.0\mathbf{i} - 1.0\mathbf{j} + 2.0\mathbf{k}$ m, then what is the work in Joules done by this given force?
a) $6.0\mathbf{i} - 4.0\mathbf{j} + 2.0\mathbf{k}$ b) -2 ->c) +2 d) -10 e) +10
$W = \mathbf{F}.\mathbf{d} = F_xd_x + F_yd_y + F_zd_z = 1(6) + 4(-1) + 0(2) = 2$

Chapt. 7: Net-Work Kinetic-Energy Theorem:

| 8> A constant force $\mathbf{F}_a$ of magnitude 80.0 N is applied to a 3.33 kg block at an angle of $\phi = 53.0°$ with respect to the vertical, causing the block to move up a frictionless ramp at constant speed. How much work in Nm is done on the block by $\mathbf{F}_a$ when the block has moved through a vertical distance of h = 0.175 m?
->a) 5.71 b) 8.43 c) 11.2 d) 14
e) cannot be determined from the information given!



$W_{net} = \Delta K$ => $W_F + W_g = 0$ => $W_F = -Wg = \Delta U = mg\Delta y = mgh = 3.33(9.80)0.175 = 5.710950000$ J

Chapt. 7: Power

| 9> A 50 N Force is the only force acting on a 2 kg crate that starts from rest. At the instant the crate has moved 2.0 m the rate at which the force is doing work is
a) 2.5 W b) 25 W c) 75 W d) 100 W ->e) 500 W
$W_{net} = \Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2$ => $v_f^2 = 2W_{net}/m = 2\mathbf{F}\cdot\mathbf{d}/m = 2Fd/m = 2(50)2/2 = 100$
$v_f = 10$ m/s & $P = \mathbf{F}\cdot\mathbf{v} = Fv = 50(10) = 500$ or there are other ways this can be done...
F=ma => $a=F/m=50/2=25$ & $v^2 = v_o^2 + 2a(x-x_o)$ => $v = \sqrt{[2a(x-x_o)]} = \sqrt{[2(25)2]} = 10$
$P = dW/dt = \mathbf{F}.\mathbf{v} = Fv = 50(10) = 500$; or you could so the following:
F=ma => $a=F/m=50/2=25$ & $x=\frac{1}{2}at^2$ => $t = \sqrt{[2x/a]} = \sqrt{[2(2)/25]} = 2/5$ & $v = v_o + at$ =>
$v = 0 + 25(2/5) = 10$ => $P = dW/dt = \mathbf{F}.\mathbf{v} = Fv = 50(10) = 500$

Chapt. 7: Constant Power Motion: $\mathbf{F}_{net}.\mathbf{v} = dK/dt = \text{Constant} = \Delta K/\Delta t$ =>

|10> A funny car accelerates from rest with the engine operating at constant power P. After a time t, the velocity of the car is v and it is easy to express this v in terms of the constant Power (P), the mass of the car (m) and the time (t). This expression for the velocity of the car, ie v = v(P,m,t) allows for the determination of the position of the car as a function of the time, x(t), where x(t=0) = 0. The position of the car, x(t), is proportional to (HINT: v = dx/dt)
a) $t^{1/3}$ b) $t^{1/2}$ c) t ->d) $t^{3/2}$ e) t^2
$P = \mathbf{F}_{net}.\mathbf{v} = dK/dt = \text{constant} = \Delta K/\Delta t = \frac{1}{2}mv^2/t$ => $v = \sqrt{[2Pt/m]} = \sqrt{[2P/m]}t^{\frac{1}{2}}$.
$v = dx/dt$ => $dx = vdt$ => $\int_{x=0}^{x=x}dx = \int_{t=0}^{t=t}vdt$ => $x|_{x=0}^{x=x} = \int_{t=0}^{t=t}\sqrt{[2P/m]}t^{\frac{1}{2}}dt$ =>
$x = \sqrt{[2P/m]}\int_{t=0}^{t=t}t^{\frac{1}{2}}dt = \sqrt{[2P/m]}\int_{t=0}^{t=t}t^{\frac{1}{2}}dt = = \sqrt{[2P/m]}\{t^{\frac{1}{2}+1}/(\frac{1}{2}+1)\}_{t=0}^{t=t} = (2/3)\sqrt{[2P/m]}t^{3/2}$
OR: knowing that:

$P = \mathbf{F}_{net}.\mathbf{v} = dK/dt = \text{constant} = \Delta K/\Delta t = \frac{1}{2}mv^2/t \Rightarrow v = \sqrt{[2Pt/m]} = \sqrt{[2P/m]}t^{1/2}$.
differentiate choice (d) to find $v \propto d(x = Ct^{3/2}) = C(3/2)t^{1/2}$ ... done

Chapt. 8: Spring Potential Energy & Spring Constant:

|11> What is the spring constant of a spring in N/m that stores 2.5 Joules of elastic potential energy when compressed by 10 cm?

a) 0.03 b) 0.06 c) 2.5 d) 300 ->e) 500

$U_{Spring} = \frac{1}{2}kx^2 \Rightarrow 2.5 = \frac{1}{2}k0.1^2 \Rightarrow k = 500$ or $k = 2U/x^2$

Chapt. 8: U => F via F = -dU/dx

|12> The potential energy of a particle moving along the x-axis is given by:

$U(x) = (8.0\ J/m^2)x^2 + (2.0\ J/m^4)x^4$

The **F**orce on the particle at x = +½ m is

a) +9.0 ->b) -9.0 c) +0.35 d) -0.35 e) -4.3

$\mathbf{F} = -\text{gradient}(U) = (-dU/dx)\mathbf{i} = -(8(2)x + 2(4)x^3)\mathbf{i} = -(8x^3 + 16x)\mathbf{i} = -(1 + 8)\mathbf{i} = -9\mathbf{i}$

Chapter. 8: Potential Energy Curve:

|13> The potential energy of a particle moving along the x-axis is given by:

$U(x) = (8.0\ J/m^2)x^2 + (2.0\ J/m^4)x^4$

If the total Mechanical Energy of the particle is 9.0 J, then the "turning points" or the x-limits of the motion of the particle in meters are:

HINT: you may need to use the solution to a quadratic equation

->a) -0.96; +0.96 b) -2.2; +2.2 c) -1.6; +1.6 d) -0.96; +2.2 e) -0.96; +1.6

The turning points are given by $K = E_{tot} - U(x) = 0$; or $E_{tot} - (8x^2 + 2x^4) = 0$

let $y=x^2 \Rightarrow E_{tot} - (8y + 2y^2) = 0 \Rightarrow 2y^2 + 8y - 9 = 0$

$y = x^2 = \{-8 \pm \sqrt{[64+72]}\}/4 = \{-8 \pm 11.66190379\}/4 = 0.9154759474 \Rightarrow x = \pm 0.9568050728$

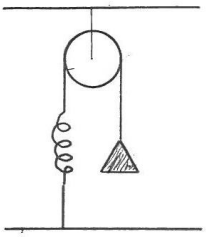
Chapt. 8: Work-Energy Theorem:

|14> A light spring has one end attached to the floor and the other end attached to an inextensible (ie it can't be stretched) light cord that passes over a pulley and is attached to a 20 kg mass as shown. The spring has a spring constant k = 380 N/m. The pulley is frictionless and massless.

The mass is released from rest when the spring is unstretched.

After the mass has dropped 0.40 m, what is its speed in m/s?

a) 1.5 b) 1.9 ->c) 2.2 d) 2.5 e) 3.3



$W_{ext} = \Delta E_{sys} = \Delta E_{mech} + \Delta E_{thermal} + \Delta E_{internal} \Rightarrow 0 = \Delta K + \Delta U_g + \Delta U_s \Rightarrow$
$0 = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 + \Delta mgy + \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2 \Rightarrow 0 = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 + mg\Delta y + \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2 \Rightarrow$
$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 - mg\Delta y - \frac{1}{2}kx_f^2 + \frac{1}{2}kx_i^2$. $x_i = v_i = 0$ & $\Delta y < 0$ with $\Delta y = -x_f$ of spring
$\frac{1}{2}mv_f^2 = 0 + mgx_f - \frac{1}{2}kx_f^2 + 0. \Rightarrow v_f^2 = 0 + 2gx_f - kx_f^2/m + 0$
$v_f^2 = 2gx_f - kx_f^2/m = 2(9.8)(0.4) - 380(0.4)^2/20 \Rightarrow v_f = 2.190890230$

Chapt. 8: Internal Energy Changes via the Work-Energy Theorem showing the inefficiency of animals (based on Class Example of Click Beetle):

|15> Consider either of the two Systems:

1> A human jumping up on the surface of the Earth: System = human plus Earth
Initial = when human begins the jump & Final = when human is at the top of jump.

2> A human throwing a baseball horizontally: System = human
Initial = when human begins to throw baseball & Final = when baseball leaves the human's hand.

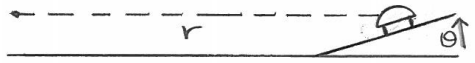
Consider the *Magnitudes* of the three quantities that are the changes between the Initial & Final States of the System: $\Delta E_{Mechanical}$; $\Delta E_{Thermal}$, and $\Delta E_{Internal}$

Logical values for the *Magnitudes* of these three quantities are respectively:

a) 2; 3; 5 ->b) 1; 4; 5 c) 2; 5; 3 d) 4; 1; 3 e) 4; 1; 5

|P1> A block of mass m is in Uniform Circular Motion on a frictionless banked circular track of radius r. The speed of the block is v, and the banking angle of the track is θ. My sketch shows the block moving into this page while turning to the left.

a) Draw a free-body diagram using my sketch to show only the Forces acting on the block. Give these Forces symbolic names, ie label the Forces with these symbolic names. 2 points



b) Write out "the vertical component of the Equation of Motion for the block". Solve this Equation for the magnitude of the Normal Force on the block. 3 Points

$F_v^{net} = ma_v = 0 \Rightarrow N\cos\theta - mg = 0 \Rightarrow N\cos\theta = mg \Rightarrow N = mg/\cos\theta$

c) Write out "the radial component of the Equation of Motion for the block". Solve this Equation (additionally using the result of part (b)) for the magnitude of the velocity of the Uniform Circular Motion, v, in terms of the given parameters of the problem, ie r, θ, and g (acceleration due to gravity). 5 Points

$F_r = ma_r \Rightarrow F_r = N\sin\theta = m(v^2/r)$ since $a_r = a_c = v^2/r$
from (b: $N\cos\theta = mg$; divide this Equation into the above to get: $\tan\theta = v^2/(gr)$
$v^2 = gr\tan\theta \Rightarrow v = \sqrt{[gr\tan\theta]}$

d) use the above results to find an expression for the Period, T, of the Uniform Circular Motion in terms of the parameters of the problem. 2 points

NOTE that $v = 2\pi r/T \Rightarrow T = 2\pi r/v = 2\pi r/\sqrt{[gr\tan\theta]} = 2\pi\sqrt{[r/(g\tan\theta)]}$

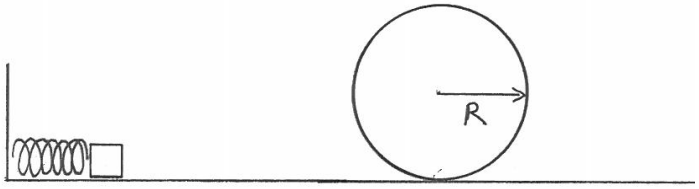
e) What will happen to the block's trajectory if the speed of the block is less than the value v it has when undergoing Uniform Circular Motion, and when it is more than that value for Uniform Circular Motion? 3 Points

if v is smaller than the above v, then the block curves off the road to the left to radial distances from the center less than the radius of the circular track. Because the centripetal Force $N\sin\theta = (mg/\cos\theta)\sin\theta = mg\tan\theta$ is too large
if v is larger than the above v, then the block curves off the road to the right to radial distances from the center more than the radius of the circular track. Because the centripetal Force $N\sin\theta = (mg/\cos\theta)\sin\theta = mg\tan\theta$ is too small

NOTE: $N\sin\theta = m(v^2/r)$ optimally when driving the correct speed
when $v_{small} < v$ optimum, then $N\sin\theta$ is too big
when $v_{large} > v$ optimum, then $N\sin\theta$ is too small

or think of it this way, ie in the extreme:
If v = 0, then the car slides down the incline curving off the road to the left.
If v is huge the too little centripetal force does almost nothing and the car follows a near straight line trajectory curving off the road to the right.

|P2> You have built a spring-loaded horizontal track with a loop-the-loop that will propel a *small* block of mass "m" = 50 grams through the loop-the-loop. The radius of the loop-the-loop is "R" = 80 cm, and the spring constant of the launcher is "k" = 450 N/m. The block is not held onto the track. What is the minimum distance "x" you must compress the spring in order that the car just makes it around the loop-the-loop without losing contact with the track (ie it will be on the verge of leaving the track at the top of the loop-the-loop)?
The block is not attached to the spring.
The track and loop-the-loop are frictionless. Treat the block as a small particle.



a) Identify two points along the trajectory of the block (identify them with i for initial and f for final) to which you can apply Energy Considerations for the block in order to solve this problem. (1 points)

i = initial = maximum compression of spring
f = final = when block is at the top of the loop-the-loop

b) Write an 'Equation' using *Energy Considerations* applied to the two moments identified in the previous step. **Use the symbols** given in the problem statement, and the usual symbols for other quantities you may need. Simplify the 'Equation', but **do NOT substitute in NUMERICAL values.** (6 Points)

System = Track + Block + Earth + Spring
$W_{ext} = \Delta E_{sys} = \Delta E_{mech} + \Delta E_{thermal} + \Delta E_{internal} \Rightarrow 0 = \Delta K + \Delta U_g$
$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 + mgy_f - mgy_i + \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2 = 0$
$\frac{1}{2}mv_f^2 - 0 + mg2R - 0 + 0 - \frac{1}{2}k(x_i = x)^2 = 0$

c) In order to solve for x, you need another 'Equation' in addition to the one in the previous step. Apply *Newton's 2nd Law* to the "Critical Point on the Trajectory" of the block to obtain this 'Equation'. Draw a free-body diagram showing all the forces acting on the block. **Use ONLY Symbols!** (5 Points)

Even though the block's speed decreases as it goes up the Loop and increases as it comes down the Loop. Its speed at the top is constant for a small distance allowing us to say its acceleration is pure Centripetal.
Critical Point on the Trajectory: N points down and m**g** points down to the center of the Loop-the-Loop. Take Positive Vectors to be "toward the Center". The acceleration of the block is Centripetal and therefore positive.
$\mathbf{F}_c = m\mathbf{a}_c \Rightarrow F_c = mg + N = m(v^2/R)$ The Block is on the verge of leaving the track when N≡0.
$\Rightarrow mg = m(v^2/R) \Rightarrow v^2 = gR$

d) Combine the Equations from (b) & (c) to solve for x using only Symbols. After you obtain this Equation substitute in numerical values to find the numerical value for x? (3 Points)

$\frac{1}{2}mgR + mg2R - \frac{1}{2}kx^2 = 0 \Rightarrow x = \sqrt{[5mgR/k]} = \sqrt{[5*0.05*9.8*0.8/450]} = 0.066 \text{ m} = 6.6 \text{ cm}$