Physics 106 Common Exam 3: Sample Exam 1 (answers on page 6)

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Name (Print): _________________________________ **4 Digit ID:**________ **Section:** ______

Instructions:

- Questions 1 through 10 are multiple choice questions worth 5 points each. Answer each of them on the Scantron sheet using #2 pencil. Answer all the questions as there is no penalty for guessing. You will need to do calculations on the exam paper for most of the questions and you may use the back for extra space.
- Questions A and B are workout problems worth 25 points each. Answer them on the exam booklet and show ALL work, otherwise there is no way to give partial credit.
- Be sure your name and section number are on both the Scantron form and the exam booklet. Also write your name, Id., and section at the top of each page with long answer questions A and B on them.
- You may bring and use your own formula sheet, using both sides of an 8.5 x 11 sheet or two 5x8 cards. A default formula sheet is also provided (see final page of this booklet).
- Make sure to bring your own calculator: sharing of calculators is not permitted.
- As you know, NJIT has a zero-tolerance policy for ethics code violations. Students are not to communicate with each other once the exam has started. All cell phones, pagers, or similar electronic devices should be turned off.
- If you have questions or need something call your proctor or instructor.

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1. When determining whether a rigid body is in equilibrium, the vector sum of the gravitational forces acting on the individual particles of the body can **always** be replaced by a single force acting at:

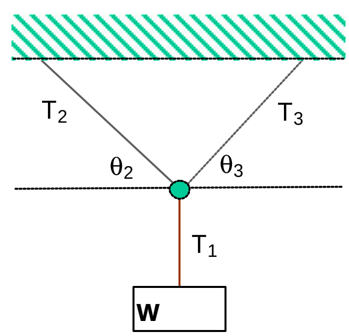
A) a point on the boundary B) the geometrical center C) the center of mass
D) the center of gravity E) any of the above

2. A 7- m- long beam of negligible mass is hanged horizontally and is supported at each end by vertical cables. A person of unknown weight is sitting on it somewhere between the cables. The tension in the left cable is 300 N, and that in the right cable is 400 N. How far is the person sitting from the **left** cable?

A) 3 m B) 4 m C) 7 m D) 6 m E) 5 m

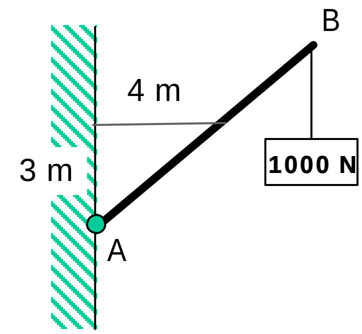
3. Find the tension T_2 in the left hand rope shown in the figure, for the case where $\theta_2 = 60^o, \theta_3 = 30^o$ and W= mg = 50 N.

A) 50 N B) 100 N C) 43 N D) 87 N E) 29 N



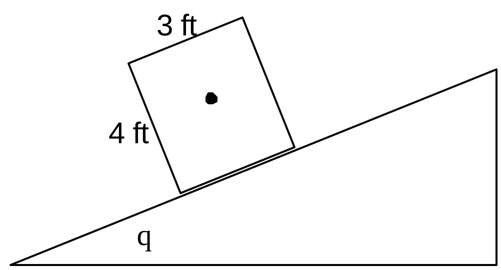
4. A 1000- N block is suspended as shown. The beam AB is weightless and is hinged to the wall at A. The beam is 10 m long. The 4-m-long horizontal cable is attached to the midpoint of the beam AB from a point 3 m above point A on the wall. Find the tension in the horizontal cable,

A) 667 N B) 2000 N C) 375 N
D) 2670 N E) 1000 N



5. A rectangular, uniform chest of drawers 4- feet high and 3-feet wide is standing on a ramp as shown. There is enough friction so that it cannot slide. What is the **largest angle** q for which the chest will **not** topple over?

A) 36.9^o B) 53.1^o C) 41.4^o D) 48.6^o
E) Cannot be determined from the information given



6. The magnitude of the **acceleration** of gravity for a planet in orbit around the Sun is proportional to:

A) the mass of the planet
B) the mass of the Sun
C) the distance between the planet and the Sun
D) the reciprocal of the distance between the planet and the Sun
E) the product of the mass of the planet and the mass of the Sun

7. A starship of mass m is traveling between a pair of binary stars that are a distance R apart. The mass of star 2 is exactly twice the mass of star 1. How far from star 1 will the gravitational force on the starship be equal to zero? Express the answer in terms of R.
A) 1.41R B) 2R C) R/0.41 D) R/2 E) R/2.41

8. The acceleration due to gravity on the planet Krypton is 3 times of that on the Earth. The planet's radius is 2 times that of the Earth. What is this planet's mass in terms of the mass of the Earth, M_e, ?
A) 0.75 M_e B) 1.33 M_e C) 12.0 M_e D) 4.0 M_e E) 0.08 M_e

9. One of Saturn's **moons** is in an orbit around Saturn. The moon's mean orbital radius is 1.86×10^8 m and its period for revolving around Saturn is 22.7 hours. What is the mass of Saturn?
A. 3.75×10^{26} kg B. 2.29×10^{26} kg C. 4.59×10^{26} kg
D. 6.81×10^{26} kg E. 5.69×10^{26} kg

10. The Moon takes 27.2 days to revolve around the Earth in an orbit whose radius R_m is about 383,000 km. What would be the approximate orbital radius for an Earth satellite that circles the Earth exactly once per day.
A) 43,000 km B) 25,000 km. C) 2700 km D) 3.4×10^6 km. E) 50,000 km

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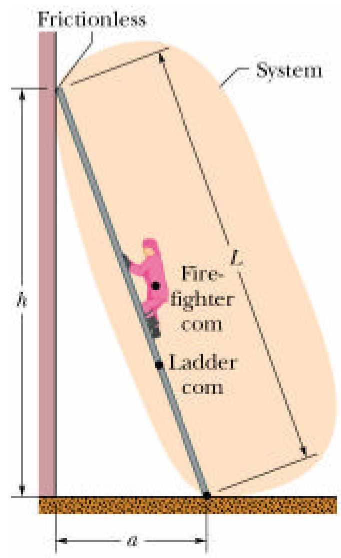
Show all equations and work for the following problem

Work-out problem A (25 points):



A ladder of mass m= 40 kg and length L = 13 m is leaning against a **frictionless wall**. Its lower end rests a distance a = 6.3 m from the corner (the pavement is **not frictionless**). The ladder's center of mass is 2/5 L from the lower end. A firefighter of mass M= 68 kg is located at the center of the ladder.

(a) (1 pt) Determine the **height h**:

(b) (8 pts.) Sketch all the forces on the ladder and explain separately what they are in a list below. (For example: W = weight of the ladder, etc....

(c) (4 pts.) Adopt a coordinate system. Then, write down **balance of forces** equations for the x and y axes (please, clearly indicate the axis in front of each equation):

(d) (5 pts.) Write down the balance of torques with respect to the lower end of the ladder:

(e) (3 pts) Find the reaction force that the wall exerts on the ladder, using your work in part (d):

(f) (4 pts) Determine the reactions from the pavement from part (c) and (e):

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Show all equations and work for the following problem:

Work-Out Problem B (25pts):

A spherical asteroid of uniform density has a radius of R= 600 km. The gravitational attraction on its surface is g=3.0 m/s^2.

(a) (4 pts) What is the **mass M** of the asteroid?

(b) (4 pts) What is the **escape speed v** from the asteroid?

(c) (6 pts) What is the **total mechanical energy E** of mass m = 1 kg at the surface of the asteroid **as it leaves** the asteroid's surface with a radial speed of 1,000 m/s?

(d) (6 pts) How far **from the surface** will a particle go if it leaves the asteroid with a radial speed of 1,000 m/s as in the previous part?

(e) (5 pts) With what speed will an object hit the asteroid's surface if it is dropped from an altitude of 1,000 km **above the surface?**

ANSWERS

Multiple Choice:

1. D
2. B
3. C
4. D
5. A
6. B
7. E
8. C
9. E
10. A

Question A:

a) $h = 11.4$ m
b) FBD should include Nwall, FH horizontal, WF, WL, FV vertical
c) Results for first equilibrium condition are: $N = F_H$ and $F_V = W_L + W_F$
d) Result is : $N_h = W_F a/2 + 2W_L a/5$
e) $N = 271$ N
f) $F_v = 107$ N, $F_H = N = 271$ N

Question B:

a) $M = 1.62 \times 10^{22}$ kg
b) $V_{esc} = 1.9 \times 10^3$ m/s
c) $E_{mech} = -1.03 \times 10^6$ Joules
d) Maximum altitude = 230 km
e) $v = 1.5 \times 10^3$ m/s

PHYSICS 106 FORMULAS

Physics 106:

360 degrees = 2π radians = 1 revolution. $s = r\theta$ $v_t = r\omega$ $a_t = r\alpha$ $a_c = a_r = v_t^2/r = \omega^2 r$ $a_{tot}^2 = a_r^2 + a_t^2$

$\omega = \omega_o + \alpha t$ $\theta_f - \theta_o = \omega_o t + ½\alpha t^2$ $\omega_f^2 - \omega_o^2 = 2\alpha(\theta - \theta_o)$ $\theta - \theta_o = ½(\omega + \omega_o)t$ $KE_{rot} = 1/2 I\omega^2$ $I = \Sigma m_i r_i^2$

$I_{point} = mr^2$ $I_{hoop} = MR^2$ $I_{disk} = 1/2\, MR^2$ $I_{sphere} = 2/5\, MR^2$ $I_{shell} = 2/3\, MR^2$ $I_{rod\ (center)} = 1/12\, ML^2$ $I_{rod\ (end)} = 1/3\, ML^2$

τ = force x moment arm = $F\sin(\phi)$ $\mathbf{t_{net}} = \Sigma t = I\,a$ $\mathbf{F_{net}} = \Sigma \mathbf{F} = m\,\mathbf{a}$ $t = \mathbf{r} \times \mathbf{F}$ $I_p = I_{cm} + Mh^2$

$W_{tot} = \Delta K = K_f - K_I$ $W = \tau_{net}\Delta\theta$ $K = K_{rot} + K_{cm}$ $E_{mech} = K + U$ $P_{average} = \Delta W/\Delta t$

$P_{instantaneous} = \tau.\omega$ (τ constant) $\Delta E_{mech} = 0$ (isolated system) $v_{cm} = \omega r$ (rolling, no slipping)

$\mathbf{l} = \mathbf{r} \times \mathbf{p}$ $\mathbf{p} = m\mathbf{v}$ $\mathbf{L} = \Sigma\, \mathbf{l_i}$ $t_{net} = d\mathbf{L}/dt$ $L = I\omega$ $l_{point\ mass} = mrv\sin(\phi)$

For isolated systems: $t_{net} = 0$ **L** is constant $\Delta\mathbf{L} = 0$ $L_0 = \Sigma I_0\omega_0 = L_f = \Sigma I_f\omega_f$

Equilibrium: Σforces = 0 and Σtorques = 0, If net force on a system is zero, then the net torque is the same for any chosen rotation axis. CG definition: point about which torques due to gravity alone add to zero.

$F = G\dfrac{m_1 \cdot m_2}{R^2}$; $G = 6.67 \times 10^{-11}$ ($N{*}m^2/kg^2$); $F_{net} = m\dfrac{v^2}{R}$; $a_g = G\dfrac{m}{R^2}$; $E_{mech} = K + U_g$ $K = \dfrac{1}{2}mv^2$;

$Ug = -G\dfrac{m_1 \cdot m_2}{R}$; $T^2 = \dfrac{4\pi^2}{GM}R^3$ $v_{escape} = \sqrt{\dfrac{2GM}{R}}$; (T^2 / R^3) = const for all satellites of a given body

Angular momentum and mechanical energy are conserved for masses moving under gravitational forces.
$E_{mech} < 0 \rightarrow$ Bound, elliptical orbit.; $E_{mech} > 0 \rightarrow$ Free particle, hyperbolic orbit; $E_{mech} = 0 \rightarrow$ Escape threshold. For circular orbits $F_{centri} = mv^2/r = F_{grav} = GmM/r^2$

Earth: $M_E = 5.98 \times 10^{24}$ kg, $R_E = 6.37 \times 10^6$ m, orbital radius about Sun = 1.5×10^8 km
Mars: $M_m = 6.4 \times 10^{23}$ kg, $R_m = 3.395 \times 10^6$ m
Moon: $M_{moon} = 7.36 \times 10^{22}$ kg, $R_{moon} = 1.74 \times 10^6$ m, orbital radius about earth = 3.82×10^5 km

Oscillators in SHM: ω = angular frequency (rad) = $2\pi f = 2\pi/T$. Period $T = 2\pi/\omega$

$x(t) = x_m\cos(\omega t + \phi)$ $v(t) = v_m\sin(\omega t + \phi)$ with $v_m = -\omega x_m$ $a(t) = a_m\cos(\omega t + \phi)$ with $a_m = -\omega^2 x_m$

Oscillator equation: $a(t) = d^2x(t)/dt^2 = -\omega^2 x(t)$

Energy: $E_{osc} = 1/2\, mv(t)^2 + 1/2\, k\, x(t)^2$ if no damping, then $dE_{osc}/dt = 0$ and E_{osc} is constant
Spring osc: $F = -kx$ $\omega = \text{sqrt}(k/m)$ Torsion pendulum.: $\tau = -\kappa\theta$ $\omega = \text{sqrt}(\kappa / I)$
Pendulums: Simple $\omega = \text{sqrt}(g / L)$ Physical $\omega = \text{sqrt}(mgh / I)$, h = dist to CM from pivot, I = rot. inertia

Physics 105:

$W = mg$ $g = 9.8\ m/s^2$ 1 m = 100 cm = 1000 mm, 1 kg = 1000 g
$v = v_o + at$ $x - x_o = v_o t + ½at^2$ $v^2 - v_o^2 = 2a(x - x_o)$ $x - x_o = ½(v + v_o)t$
$F_{net} = ma$ $\Sigma\mathbf{F} = m\mathbf{a} = d\mathbf{P}/dt$ $F_{s,max} = \mu_s N$ $F_k = \mu_k N$ incline: $W_{mgx} = mg\sin\theta$ $W_{mgy} = mg\cos\theta$
$F_r = ma_r = mv^2/r$ $a_r = v^2/r$ $f = 1/T$ $T = (2\pi r/v)$ Impulse: $F_{avr}\Delta t = mv_f - mv_I$
Momentum conserved if net impulse = 0. Then $(\Sigma mv)_{initial} = (\Sigma mv)_{final}$
Work: $W = Fd(\cos\theta)$, $W_{grav} = -mg(y - y_0)$, $W_{spring} = -1/2k(x^2 - x_0^2)$, $W_{frict} = -F_k d$, $W_{tot} = K_f - K_i$
$U_g = mg(y - y_0)$, spring: $F = -kx$, $U_s = 1/2kx^2$, $KE = 1/2mv^2$
$W_{nc} = K_f - K_I + U_{gf} - U_{gi} + U_{sf} - U_{si}$ or $K_I + U_{gi} + U_{si} + W_{nc} = K_f + U_{gf} + U_{sf}$
Mass center: $X_{cm} = \Sigma(x_i m_i)/\Sigma m_i$, similarly for Y_{cm}, Z_{cm}

Vectors:

Components: $a_x = a.\cos(\theta)$ $a_y = a.\sin(\theta)$ $a = a_x\mathbf{i} + a_y\mathbf{j}$ $a = \text{sqrt}[a_x^2 + a_y^2]$ $\theta = \tan^{-1}(a_y/a_x)$
Addition: $\mathbf{a} + \mathbf{b} = \mathbf{c}$ implies $c_x = a_x + b_x$, $c_y = a_y + b_y$
Dot product: $\mathbf{a}_o\mathbf{b} = a.b.\cos(\phi) = a_x b_x + a_y b_y + a_z b_z$ unit vectors: $\mathbf{i}_o\mathbf{i} = \mathbf{j}_o\mathbf{j} = \mathbf{k}_o\mathbf{k} = 1$, $\mathbf{i}_o\mathbf{j} = \mathbf{i}_o\mathbf{k} = \mathbf{j}_o\mathbf{k} = 0$
Cross product: $|\,\mathbf{a} \times \mathbf{b}\,| = a.b.\sin(\phi)$ $\mathbf{a} \times \mathbf{b} = -\,\mathbf{b} \times \mathbf{a}$, $\mathbf{a} \times \mathbf{a} = \mathbf{0}$ always. $\mathbf{c} = \mathbf{a} \times \mathbf{b}$ is perpendicular to **a-b** plane
$\mathbf{i} \times \mathbf{i} = \mathbf{j} \times \mathbf{j} = \mathbf{k} \times \mathbf{k} = 0$, $\mathbf{i} \times \mathbf{j} = \mathbf{k}$ $\mathbf{j} \times \mathbf{k} = \mathbf{i}$ $\mathbf{k} \times \mathbf{i} = \mathbf{j}$ etc.