Physics 1145 Fall 2023 Test 2 (4 pages)

Name: Solution **October 18, 2023** **Total Score:** 120 /120

$\sum F_x = ma_x$ $\sum F_y = ma_y$ $f_S \le \mu_S N$ $f_k = \mu_k N$ g= 9.8m/s^2

$a_c = \frac{v^2}{R}$ $v = \frac{2\pi R}{T} = \omega R$ $\omega = 2\pi f = \frac{2\pi}{T}$ $F_G = \frac{GmM}{r^2}$ G=6.67×10^{-11} Nm^2/kg^2

D 1. (5) You are standing on a scale in an elevator. In which of the following situations does the scale show **more** than your actual weight? The elevator is moving…

A)…upwards at constant speed B) …upwards and slowing down

C) …downwards and speeding up D)… downwards and slowing down

Scale shows N. N > W if $\vec{a}$ is upwards

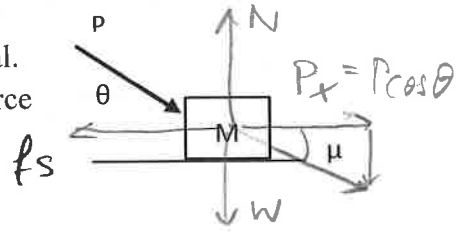
B 2.(5) Dr. Vojta's cats Frodo (weight 14 lbs) and Raisin (weight 8 lbs) are playing. Frodo jumps and collides with Raisin. The magnitude of the force Frodo exerts on Raisin is _____ the magnitude of the force Raisin exerts on Frodo:

A) smaller than B) equal to C) larger than D) not enough information

Newton's 3rd Law

C 3. (5) A box of mass M on a rough horizontal surface experiences a pushing force of magnitude P at an angle $\theta > 0$ with respect to the horizontal. The box remains at rest. You know that the magnitude f of the frictional force satisfies

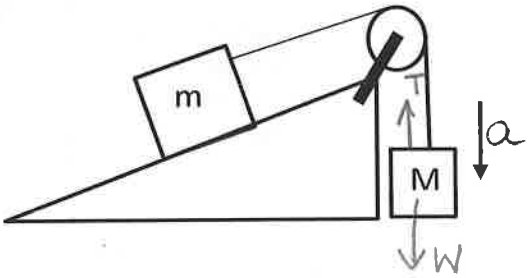
A) $f > P$ B) $f = P$ C) $f < P$ D) $f = \mu Mg$



$a = 0$ if $f = P\cos\theta < P$

B 4. (5) Mass m on a frictionless incline is connected to mass M by a rope that runs over a massless, frictionless pulley. If mass M accelerates downwards, the tension T in the rope:

A) T=Ma B) T<Mg C) T=Mg D) T>Mg



$\vec{a}$ down $\Rightarrow$ $W > T$

B 5. (5) Planet A orbits a star with speed V. Planet B has twice the mass of planet A and orbits at twice the distance from the center of the star. What is the speed of planet B?

A) ¼V B) $\frac{1}{\sqrt{2}}$V C) V D) 2V

Typo

$\frac{GMm}{r^2} = \frac{mv^2}{r}$

$v^2 = \frac{GM}{r}$

B 6. (5). The free-fall acceleration on planet X is 4 m/s^2. The radius and mass of planet Z are twice the radius and mass of planet X. The free-fall acceleration on planet Z equals, in m/s^2

A) 1 m/s^2 B) 2 m/s^2 C) 4 m/s^2 D) 8 m/s^2

$\frac{GMm}{r^2} = mg$ $M \to 2M$, $R \to 2R$, $R^2 \to 4R^2$, $g \to \frac{1}{2}g$

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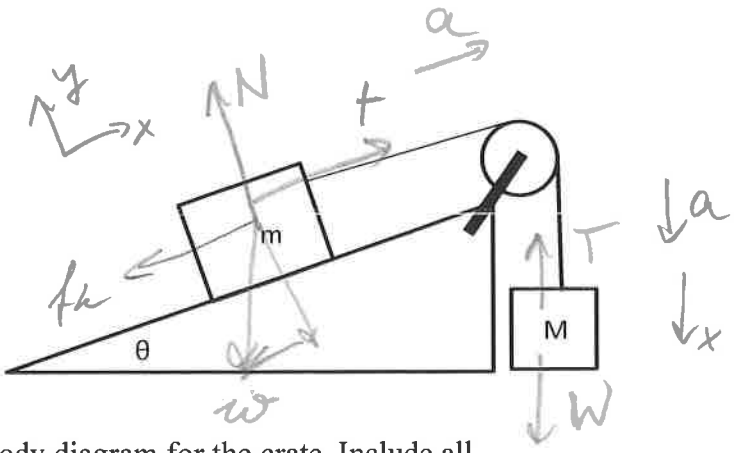
7.(30) Two blocks are connected by a massless string. One block of mass *m* is **moving up** a **rough** inclined plane that makes angle θ with the horizontal. The block and the plane have a coefficient of kinetic friction μ between them. The other block, of mass *M*, hangs over a massless frictionless pulley.



a) In the figure, superimpose a fully labeled free-body diagram for the crate. Include all information necessary to solve part b) below.

b) Set up Newton's 2nd Law for each of the blocks and derive an expression for the acceleration in terms of m, M, θ, μ, and g.

M: $\Sigma F_x = T_x + W_x = Ma_x$

$-T + Mg = Ma_x$

m: $\Sigma F_x = t_x + w_x + N_x + f_{kx} = ma_x$

$t - mg\sin\theta - \mu N = ma_x$

$\Sigma F_y = t_y + w_y + N_y + f_{ky} = ma_y$

$-mg\cos\theta + N = 0 \rightarrow N = mg\cos\theta$

Combine:

$T = Mg - Ma_x$

$Mg - Ma_x - mg\sin\theta - \mu mg\cos\theta = ma_x$

$$a_x = \frac{1}{M+m}\left[Mg - mg\sin\theta - \mu mg\cos\theta\right]$$

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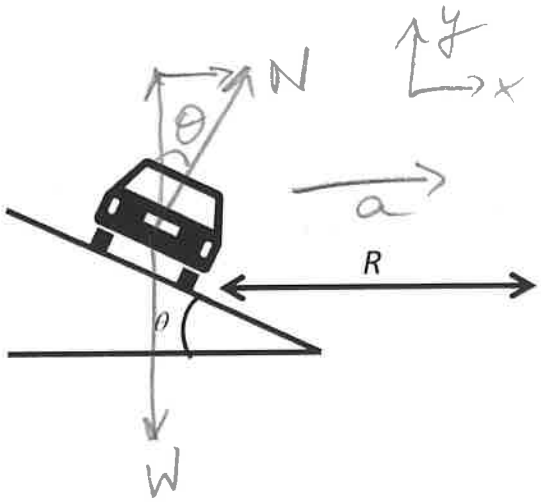
8. (30) A car of mass M is driving with constant speed on a road which makes a curve of radius R. The road is banked at an angle θ with the horizontal. The figure shows a side view with the car's velocity out of the paper.



a) In the figure, draw a complete free-body diagram for the car. **Make sure to draw in the acceleration vector and choose an appropriate coordinate system.**

b) Derive a symbolic expression, in terms of R, g, and θ, for the speed at which the car can go around the curve **without friction**.

$\Sigma F_x = N_x + W_x = Ma_x$ ($W_x = 0$)

$N\sin\theta = M\frac{v^2}{R}$

$\Sigma F_y = N_y + W_y = Ma_y$ ($a_y = 0$)

$N\cos\theta - Mg = 0$

Combine: $N = \frac{Mg}{\cos\theta}$

$\frac{Mg}{\cos\theta}\sin\theta = M\frac{v^2}{R}$

$$v = \sqrt{gR\tan\theta}$$

30/30 points for this page

9.(30) Earth has a radius of 6.38×10^6 m, and the free-fall acceleration on its surface is $9.8 m/s^2$.

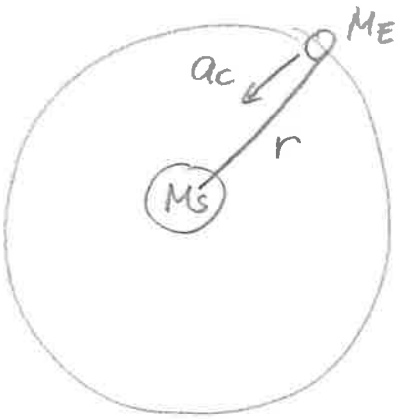
It takes Earth one year to orbit the sun at a radius of 1.5×10^{11} m.

Find symbolic expressions and calculate numerical values for the mass of Earth and the mass of the sun.

$$\frac{GM_E m}{R_E^2} = mg$$

$$\boxed{M_E = \frac{gR_E^2}{G}} = \frac{9.8\frac{m}{s^2}\cdot(6.38\times10^6 m)^2}{6.67\times10^{-11}\frac{Nm^2}{kg^2}}$$

$$M_E = 5.98\times10^{24} kg$$



$$F_G = \frac{GM_E M_S}{r^2} = M_E a_c = M_E \frac{v^2}{r}$$

$$\frac{GM_S}{r} = v^2 = \left(\frac{2\pi r}{T}\right)^2$$

$$\boxed{M_S = \frac{4\pi^2 r^3}{GT^2}}$$

$$M_S = \frac{4\pi^2\cdot(1.5\times10^{11} m)^3}{6.67\times10^{-11}\frac{Nm^2}{kg^2}\,(1\cdot365\cdot24\cdot3600\,s)^2} = 2\times10^{30} kg$$

30/30 points for this page