Physics 1145 Fall 2022 Test 2 (4 pages)

Name: Solutions **October 19, 2022** **Total Score:** 120 /120

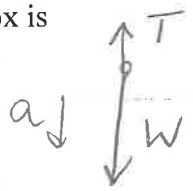
$\sum F_x = ma_x$ $\sum F_y = ma_y$ $f_S \leq \mu_S N$ $f_k = \mu_k N$ g= 9.8m/s^2

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

C 1. (5) A box hangs from a vertical rope. The tension in the rope is smallest when the box is

A) moving up with constant velocity B) moving down with constant velocity

C) moving down and speeding up D) moving up and speeding up



A 2.(5) Frodo the cat is asleep on a horizontal shelf. The reaction force to the normal force acting on Frodo is

A) the force by Frodo on the shelf.

B) the force of gravity by Frodo on the Earth.

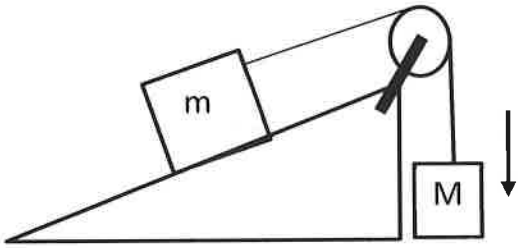
C) the weight force acting on Frodo.

D) There is no reaction force because Frodo is at rest.

C 3. (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* moves downwards at constant speed, the tension T in the rope:

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

a = 0



B 4. (5)) Satellite A orbits a planet with speed V. Satellite B is three times as massive as satellite A and orbits at the same the distance from the center of the planet. What is the speed of satellite B?

A) ⅓V B) V C) 3V D) 9V

B 5. (5) The gravitational force of a star on an orbiting planet 1 is F_1. The gravitational force of the star on Planet 2, which has three times the mass of planet 1 and orbits at three times the distance from the star, is F_2. The ratio F_2/F_1 equals

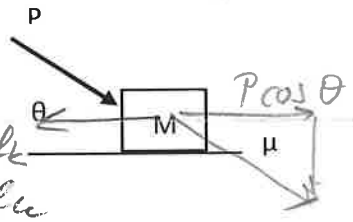
A) 1/9 B) 1/3 C) 1 D) 3

$F_1 = \frac{GMm}{r^2}$ $F_2 = \frac{GM\,3m}{(3r)^2}$

C 6. (5) A box of mass M is pushed along a rough horizontal surface with force magnitude *P* at an angle θ >0 with respect to the horizontal. The box is moving to the right at constant speed. You know that the magnitude *f* of the frictional force satisfies

a = 0

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



$P\cos\theta = f_k$

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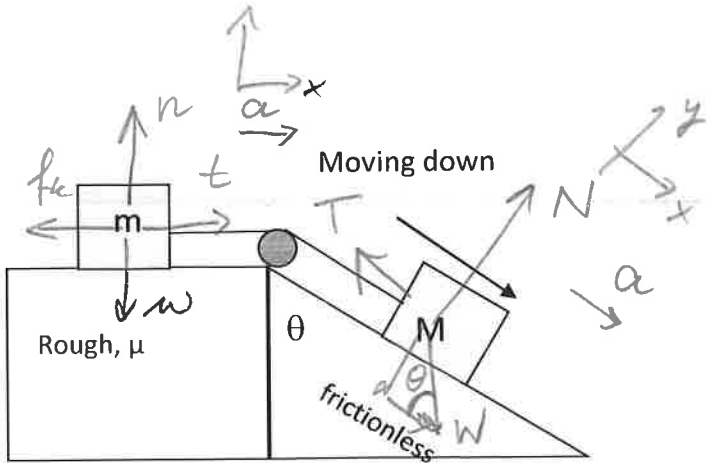
7.(40) Two blocks are connected by a massless string which passes over a massless frictionless pulley. The block of mass *m* is on a **rough horizontal** surface. The coefficient of kinetic friction between block and surface is μ. The block of mass *M* slides down a **frictionless incline** that makes an angle θ with the vertical.



a) In the figure, superimpose fully labeled free-body diagrams for each of the blocks, including all information needed to solve part b below.

b) Begin with Newton's 2nd Law for each of the blocks and derive an expression for the acceleration in terms of system parameters.

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

$-f_k + t = ma_x$

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

$n - mg = 0$ $\quad n = mg$

$f_k = \mu n = \mu mg$

M: $\Sigma F_x = T_x + n_x + w_x = Ma_x$

$-T + Mg\cos\theta = Ma_x$ $\quad t = T$ massless rope

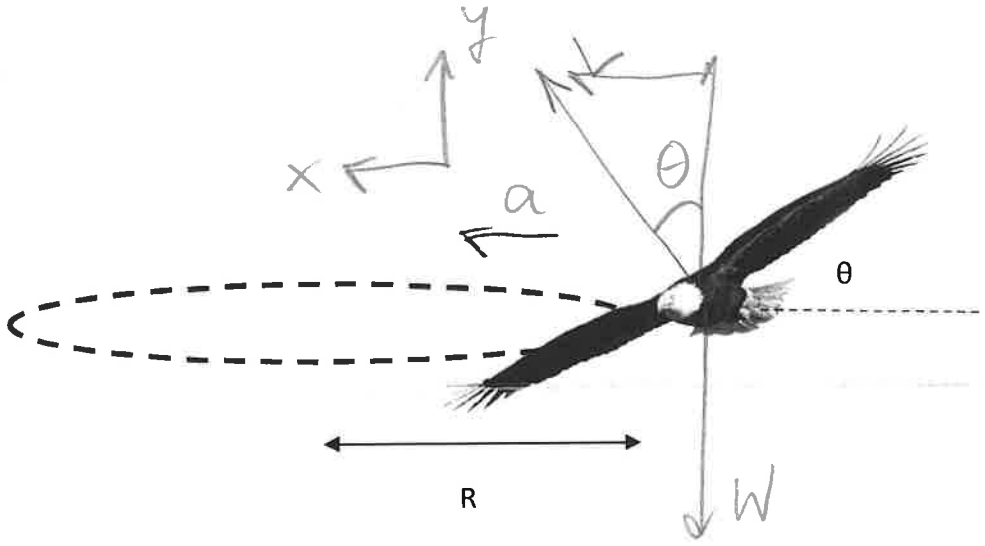
Combine:

$-\mu mg - T + Mg\cos\theta = ma_x + Ma_x$

$$a_x = \frac{M\cos\theta - \mu m}{m + M} g$$

40/40 points for this page

8. (30) Birds experience a lift force that is **perpendicular to the wings.** An eagle is flying in a **horizontal** circle of radius R at constant speed. The eagle achieves this by tilting his wings at angle θ with respect to the horizontal.



a) Draw a fully labeled free-body diagrams for the eagle, including all information necessary to solve part b).

b) Derive an expression for the speed of the eagle in terms of g, R, and θ.

$$\Sigma F_x = L_x + W_x^{0} = Ma_x$$

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

$$\Sigma F_y = L_y + W_y = M\cancel{a_y}^{0}$$

$$L\cos\theta - Mg = 0 \longrightarrow L = \frac{Mg}{\cos\theta}$$

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

$$g\tan\theta = \frac{v^2}{R}$$

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

30 /30 points for this page

9.(20) Mars has a radius of 3.4×10^6 m and a mass of 6.5×10^{23} kg. Its moon Phobos is orbiting in a circular orbit with a radius 9.4×10^6 m.

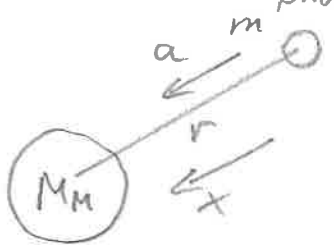
a) Find a symbolic answer and calculate a numerical value for the free-fall acceleration on Mars.

$$F_G = \frac{GM_M m}{R_M^2} = m g_M$$

$$\boxed{g_M = \frac{GM_M}{R_M^2}}$$

$$g_M = \frac{6.67\times10^{-11}\ \frac{Nm^2}{kg^2}\cdot 6.5\times10^{23}\ kg}{(3.4\times10^6\ m)^2} = 3.75\ \frac{m}{s^2}$$

b) Find a symbolic answer and calculate a numerical value for the orbital period of Phobos.



$$\Sigma F_x = ma_x$$

$$\frac{GM_M m}{r^2} = m\frac{v^2}{r}$$

$$\frac{GM}{r} = v^2 = \frac{(2\pi r)^2}{T^2}$$

$$T^2 = \frac{4\pi^2 r^3}{GM} \rightarrow \boxed{T = \sqrt{\frac{4\pi^2 r^3}{GM}}}$$

$$T = \sqrt{\frac{4\pi^2(9.4\times10^6\ m)^3}{6.67\times10^{-11}\ \frac{Nm^2}{kg^2}\cdot 6.5\times10^{23}\ kg}} = 27{,}500\ s$$

or

7.6 hr

or

0.3 days

20/20 points for this page