Phys 131
Fall 2022

Fundamental Mechanics: Class Exam 2

21 October 2022

Name: SOLUTION **Total:** /70

Instructions

- There are 8 questions on 6 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

$g = 9.81\,\mathrm{m/s^2}$

Question 1

A 40 kg crate is initially at rest on the ground. It is then raised vertically by a rope which exerts a constant force. At an instant 3.0 s after the moment when it leaves the ground, it moves with speed 12.0 m/s. Neglecting air resistance, determine the tension in the rope.

Need acceleration: $v_y = v_{oy} + a_y t$] +1

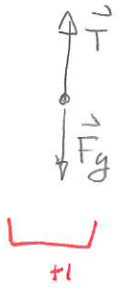
☐ $v_y = 12.0\,m/s$

$12.0\,m/s = 0\,m/s + a_y\,3.0\,s \Rightarrow a_y = 4.0\,m/s^2$

+2

Then consider forces

☐ $v_{oy} = 0$



+1

$\Sigma F_y = ma_y \Rightarrow T - mg = ma_y$] +2

+1

$\Rightarrow T = mg + ma_y$

$= m(g + a_y)$

$= 40\,kg\,(9.81\,m/s^2 + 4.0\,m/s^2)$ +1

$= 550\,N$

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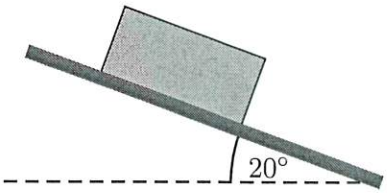
Question 2

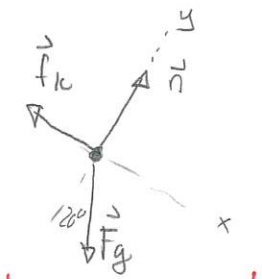
A 30 kg crate slides down a ramp inclined at 20°. The crate *moves with constant speed.* Determine the kinetic friction force and the coefficient of kinetic friction between the crate and the ramp.



The acceleration = 0 since speed is constant

$\sum F_x = ma_x = 0$]
$\sum F_y = ma_y = 0$] (+1)

$F_g = mg$](+1) $f_k = \mu_k n$](+1)



(+1)

We need components. For F_g

$F_{gx} = mg \sin 20°$
$F_{gy} = -mg \cos 20°$] (+3)

	x	y
$\vec{n}$	0	n
$\vec{f}_k$	$-f_k$	0
$\vec{F}_g$	$mg\sin 20°$	$-mg\cos 20°$

$\sum F_x = 0 \Rightarrow -f_k + mg\sin 20° = 0$](+2)

$\Rightarrow f_k = mg\sin 20° = 30\,kg \times 9.81\,m/s^2 \times \sin 20°$

$\Rightarrow$ $f_k = 100N$](+1)

$\sum F_y = 0 \Rightarrow n - mg\cos 20° = 0 \Rightarrow n = mg\cos 20° \Rightarrow n = 277N$ (+2)

Then $f_k = \mu_k n \Rightarrow 100N = \mu_k\, 277N$

$\Rightarrow$ $\mu_k = 0.37$](+1)

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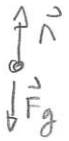
Question 3

A book of mass m lies on the surface of a horizontal board. The board is lowered by hand and while this happens its speed decreases. Throughout the process, the book is in contact with the board. Which of the following (choose one) is true regarding the magnitude of the normal force, n, exerted by the board on the book?

i) $n = 0$
ii) $n = mg$
iii) $n > mg$
iv) $0 < n < mg$



The velocity is negative but speed decreases $\Rightarrow a_y > 0$

$\sum F_y = ma_y \Rightarrow n - mg = ma_y$

$\Rightarrow n = mg + ma_y \Rightarrow n > mg$

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Question 4

A box slides down an inclined ramp with constant speed.

a) Explain whether the *net* force on the box is zero or not.

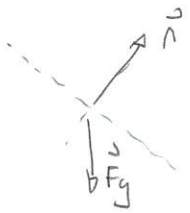
$\vec{F}_{net} = m\vec{a} = 0$ since speed is constant (+2)

$\vec{F}_{net} = 0$ (+1)

b) Someone on the internet claims that the only two forces acting on the box are gravity and a normal force. Explain whether this claim is true or false.

If there were only these two then the FBD would have two forces which cannot cancel. (+2)

The claim is false (+1)



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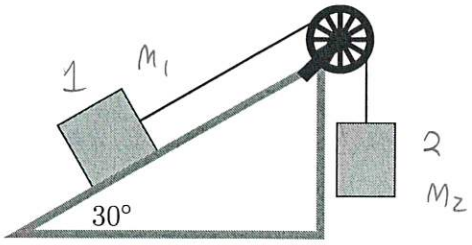
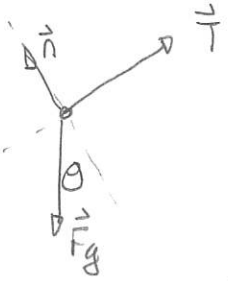
Question 5

Two blocks are connected by a string, which runs over a pulley. A 4.0 kg block is on a frictionless ramp which is inclined at an angle of 30° to the horizontal. The string connected to the block on the ramp runs parallel to the ramp. A 6.0 kg block is suspended vertically from the other end of the string. Determine the acceleration of the block on the ramp.



For block 1



+1 [$F_g = m_1 g$

$\sum F_x = m a_x$

$\sum F_y = m a_y = 0$] +1

$T - mg\sin\theta = m a_x$] (+2)

$\Rightarrow T = m_1 a_x + m_1 g \sin\theta$ (+1)

$\sum F_y = m_2 a_y \Rightarrow T - m_2 g = m_2 a_y$] (+2)

For block 2

+1 [

Let a be the magnitude of the acceleration Then

$a_x = a \qquad a_y = -a$ (+1)

Combining $\Rightarrow T = m_1 a + m_1 g \sin\theta$

$T = m_2 g + m_2(-a)$

Setting equal $\Rightarrow m_2 g - m_2 a = m_1 a + m_1 g \sin\theta$

$\Rightarrow (m_2 - m_1 \sin\theta) g = (m_1 + m_2) a$ (+5)

$\Rightarrow a = \dfrac{m_2 - m_1 \sin\theta}{m_1 + m_2} g = \dfrac{6.0\,kg - 4.0\,kg \sin 30^\circ}{10\,kg} 9.81\,m/s^2$ (+1) accel not negated

$= 0.40 \times 9.81\,m/s^2 = 3.9\,m/s^2$

(+1) for accels

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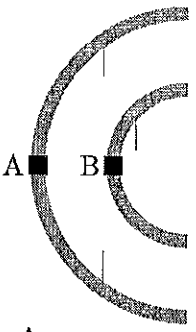
Question 6

Two cars travel on a rough horizontal surface at the same speed. Both follow circular curves while cornering with B having a smaller radius than A. The diagram illustrates this viewed from above, with the cars going clockwise.



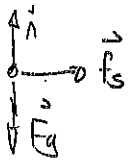
a) Which of the following (choose one) is true regarding the magnitude of the acceleration of A, a_A, versus that of B, a_B?

i) $a_A = a_B = 0$
ii) $a_A = a_B \neq 0$
iii) $a_A > a_B$
iv) $a_A < a_B$

$a = \frac{v^2}{r}$ ✓ same
r ↑ larger for A
$\Rightarrow a_A < a_B$

b) Which of the following (choose one) is true?

i) The friction force on A is the same as that on B.
ii) The friction force on A larger than that on B.
iii) The friction force on A smaller than that on B.
iv) There is no friction force on either car.



$\Sigma F_x = ma_x$
$f_s = m\frac{v^2}{r}$

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Question 7

A 4.0 kg red ball collides with a 1.0 kg blue ball that is initially at rest. After the collision the two balls stick and move together. Let $F_{\text{red on blue}}$ be the magnitude of the force exerted by the red on the blue and $F_{\text{blue on red}}$ be the magnitude of the force exerted by the blue on the red while they are colliding. Which of the following (choose one) is true during the collision?

i) $F_{\text{red on blue}} = \frac{1}{4} F_{\text{blue on red}}$.
ii) $F_{\text{red on blue}} = \frac{1}{2} F_{\text{blue on red}}$.
iii) $F_{\text{red on blue}} = F_{\text{blue on red}}$.
iv) $F_{\text{red on blue}} = 2\, F_{\text{blue on red}}$.
v) $F_{\text{red on blue}} = 4\, F_{\text{blue on red}}$.

Explain your choice.

Newton's third law states that the red will exert a force with equal magnitude to the blue.

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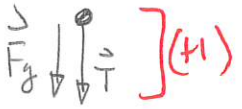
Question 8

A 0.100 kg ball swings *in a vertical circle* at the end of a string with length 0.80 m. The ball maintains a constant speed of 4.0 m/s throughout its motion.

a) Determine the tension in the string when the ball is at its highest point.



$\vec{F}_g$ $\vec{T}$] (+1)

$\downarrow a = v^2/r$] (+1)

$\sum F_y = ma_y$ (+1)

$\Rightarrow -T - mg = m\left(\frac{-v^2}{r}\right)$ (+1) (+1)

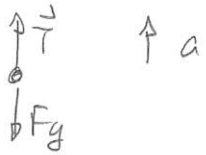
$\Rightarrow T + mg = mv^2/r$

$\Rightarrow T = m\left(\frac{v^2}{r} - g\right)$

$= 0.100\,\text{kg}\left(\frac{(4.0\,\text{m/s})^2}{0.80\,\text{m}} - 9.81\,\text{m/s}^2\right)$

$= 1.02\,\text{N}$ (+1)

b) Is the tension when the ball is at its lowest point larger than, smaller than or the same as the tension when it is at the highest point?. Explain your answer.



$\vec{T}$ $\uparrow a$

$\vec{F}_g$

$T - mg = mv^2/r$

$T = m\left(\frac{v^2}{r} + g\right)$ (+3)

larger

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