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Department of Engineering Sciences
Phy101 Physics I
Final Examination
January 20, 2025 10:20 – 11:50
Good Luck!

NAME-SURNAME:

SIGNATURE:

ID:

DEPARTMENT:

INSTRUCTOR:

DURATION: 90 minutes

◇ **Answer all the questions.**
◇ **Write the solutions explicitly and clearly. Use the physical terminology.**
◇ **You are allowed to use Formulae Sheet.**
◇ **Calculator is allowed.**
◇ **You are not allowed to use any other electronic equipment in the exam.**
◇ **I declare hereby that I fulfilled the requirements for the attendance according to the University regulations and I accept that my examination will not be valid otherwise.**

Question	Grade	Out of
1A		15
1B		20
2		15
3		20
4		15
5		15
TOTAL		100

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1. A) A rescue team lifts an injured person directly upward by means of a motor-driven cable. The lift is performed in three stages, each requiring a vertical distance of 10.0 m:

    1) The initially stationary person is **accelerated** to a speed of 5.00 m/s;
    2) He is then lifted at the **constant speed** of 5.00 m/s;
    3) Finally, he is **decelerated** to zero speed.

    How much work is done on the 80.0 kg rescue by the force lifting him during each stage (W_1, W_2, W_3)?

Three stages lifting. each is 10m. m= 80.0 kg

i) Accelerated to a speed of 5.00 m/s (2)

$\vec{F}_1$, $m\vec{g}$

$F_1 - mg = ma = F_{net}$

(3) $F_1 d - mgd = F_{net} d$

$\underbrace{W_1 - mgd}_{\Delta K} = W = \Delta K_1$

$W_1 - mgd = \frac{1}{2} m v_f^2 - \cancel{\frac{1}{2} m v_i^2}$

$\Rightarrow W_1 = \frac{1}{2}(80.0\,kg)(5\,m/s)^2 + (80.\,kg)(9.8\,m/s^2)(10m)$

$\boxed{W_1 = 8.84\,kJ}$ (1) (1)

ii) Constant speed of 5.00 m/s

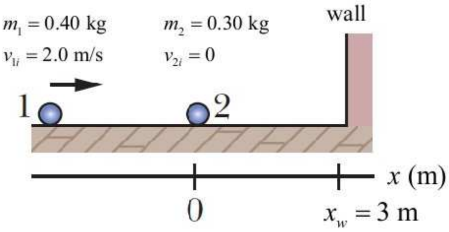
(2) $W_2 - mgd = \Delta K_2 = 0 \rightarrow W_2 = mgd \boxed{= 7.84\,kJ}$ (1) (1)

iii) Decelerated to zero speed.

$W_3 - mgd = \Delta K_3 = \cancel{\frac{1}{2} m v_f^2} - \frac{1}{2} m v_i^2 \;\Big|\; W_3 = mgd - \frac{1}{2} m \underbrace{v_i^2}_{5.0\,m/s} \boxed{= 6.84\,kJ}$

(2) (1) (1)

B) In the figure below, particle 1 of mass $m_1 = 0.40\ kg$ slides rightward along an x axis on a frictionless floor with a speed of $v_{1i} = 2.0\ m/s$. When it reaches $x = 0$, it undergoes a one-dimensional elastic collision with stationary particle 2 ($v_{2i} = 0$) of mass $m_2 = 0.30\ kg$.



i Calculate the particle velocities v_{1f} and v_{2f} after the elastic collision.

ii After the collision, particle 2 reaches a wall at $x_w = 3\ m$, it bounces from the wall during which 36% of its kinetic energy is lost (turned into thermal energy). At what position on the x axis does particle 2 collide again with particle 1?

i) Collision at $x=0$ Elastic collision → KE is conserved

$\vec{P}_i = \vec{P}_f$ (1)

$m_1 v_{1i} + \cancel{m_2 v_{2i}} = m_1 v_{1f} + m_2 v_{2f}$

$K_i = K_f$ (1)

$\frac{1}{2} m_1 v_{1i}^2 + \cancel{\frac{1}{2} m_2 v_{2i}^2} = \frac{1}{2} m_1 v_{1f}^2 + \frac{1}{2} m_2 v_{2f}^2$

$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i} = \frac{(0.4kg) - (0.3kg)}{(0.4kg) + (0.3kg)} 2.0\ m/s$ (4)

$v_{2f} = \frac{2 m_1}{m_1 + m_2} v_{1i} = \frac{2(0.4kg)}{(0.4kg) + (0.3kg)} 2.0\ m/s$ (4)

$\boxed{v_{1f} = 0.286\ m/s}$ $\boxed{v_{2f} = 2.286\ m/s}$

ii) $x_w = x_2 = v_{2f} \times t$ (1)

$t = \frac{3\ m}{2.286\ m/s} = \boxed{1.312\ s}$

$x_1 = v_{1f} \times t$

$= (0.286\ m/s) \times (1.312\ s)$

$\boxed{x_1 = 0.375\ m}$ (1)

when particle 2 reaches the wall

36% KE is lost bounce

$\frac{K_{2b}}{K_2} = 0.64$

$\frac{v_{2b}^2 / 2}{v^2 / 2} = 0.64$

$v_{2b} = \sqrt{0.64 \times (2.286\ m/s)^2}$

$\Rightarrow \boxed{v_{2b} = 1.839\ m/s}$ (2)

Second Collision Point

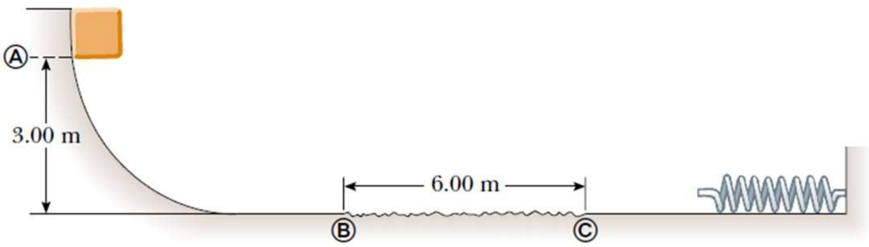
$0.375\ m + v_{1f} t = 3\ m - v_{2b} t$ (2)

$\Rightarrow t = \frac{3\ m - 0.375\ m}{1.839\ m/s + 0.286\ m/s}$

$\boxed{t = 1.241\ s}$ (2)

$x = 0.375\ m + 1.839\ m/s \times 1.241\ s = \boxed{0.73\ m}$ (2)

2. A 10.0 kg block is released from point A in figure. The track is frictionless except for the portion between B and C, which has a length of 6.00 m. The block travels down the track, hits a spring of force constant $k = 2250$ N/m, and compresses the spring 0.25 m from its equilibrium position before coming to rest momentarily. Determine the coefficient of kinetic friction between the block and the rough surface between B and C.



$m = 10$ kg

$L = 6$ m with friction

$h = 3$ m

$k = 2250$ N/m

$\Delta x = x_f - x_i = x = 0.25$ m

from A to B $\quad \Delta K + \Delta U = 0$

$K_f + \cancel{U_f} = \cancel{K_i} + U_i \rightarrow \frac{1}{2} m v_f^2 = mgh$ (3)

$\quad 0 \quad\quad 0$

$x = 0 \quad v = 0$

$\rightarrow \underline{v_f = \sqrt{2gh} = v_{f_1}}$ (2)

from B to C $\quad \Delta K + \Delta U = \vec{f} \cdot \vec{d} = W$

$K_f - K_i + \cancel{U_f - U_i} = \mu_k F_N L \cos 180°$

(2) $\quad 0 \quad U_f = U_i \quad$ (1)

$\frac{1}{2} m v_f^2 - \frac{1}{2} m v_{f_1}^2 = \mu_k mgL(-1)$

$v_f^2 = v_{f_1}^2 - 2\mu_k gL = 2gh - 2\mu_k gL$

$\rightarrow \underline{v_f = \sqrt{2(gh - \mu_k gL)} = v_{f_2}}$ (2)

from C $\quad \Delta K + \Delta U = 0 \quad \Delta U = \frac{1}{2} kx^2$

$\cancel{K_f} - K_i + \frac{1}{2} kx^2 = 0 \rightarrow \frac{1}{2} m v_{f_2}^2 = \frac{1}{2} kx^2$

$0 \quad v = 0 \quad$ (2)

$\frac{1}{2} m \, 2(gh - \mu_k gL) = \frac{1}{2} kx^2$

$\rightarrow \frac{(mgh - \frac{1}{2} kx^2)}{mgL} = \mu_k = \frac{(10\,kg)(9.8\,m/s^2)\,3m - \frac{1}{2}\,2250\,N/m\,(0.25m)^2}{(10\,kg)(9.8\,m/s^2)(6m)}$ (2)

$\rightarrow \boxed{\mu_k = 0.38}$ (1)

3. A soccer player kicks a soccer ball of mass 0.45 kg that is initially at rest. The foot of the player is in contact with the ball for 3.0×10^{-3} s, and the force of the kick is given by

$$F(t) = [(6.0 \times 10^6)t - (2.0 \times 10^9)t^2]\ N$$

for $0 \leq t \leq 3.0 \times 10^{-3}$ s, where t is in seconds. Find the magnitudes of

i the impulse on the ball due to the kick,

ii the average force on the ball from the player's foot during the period of contact,

iii the maximum force on the ball from the player's foot during the period of contact,

iv the ball's velocity immediately after it loses contact with the player's foot.

$m = 0.45$ kg
Initially at rest
Contact time $= 3.0 \times 10^{-3}$ s
$F(t) = [6.0 \times 10^6 t - 2.0 \times 10^9 t^2]$ N
$0 \leq t \leq 3.0 \times 10^{-3}$ s

i) $J = ?$ impulse $\vec{F}_{av} = \frac{\vec{J}}{\Delta t}$ OR 2 $J = \int F(t)\,dt = \int_0^{3\times10^{-3}} (6\times10^6 t - 2\times10^9 t^2)\,dt$

$\rightarrow J = 3\times10^6 t^2 - \frac{2\times10^9}{3} t^3 \Big]_0^{3\times10^{-3}} = 3\times10^6 (9\times10^{-6}) - \frac{2}{3}\times10^9 (27\times10^{-9}) \boxed{= 9\ Ns}$ 2 1

ii) $F_{av} = \frac{J}{\Delta t} = \frac{9\,Ns}{3.0\times10^{-3}\,s} \boxed{= 3\times10^3\ N}$ 2 2 1

iii) $F_{max} = ?$ during the period of contact

$\frac{dF(t)}{dt} \stackrel{!}{=} 0 \rightarrow 6\times10^6 - 4\times10^9 t = 0 \Rightarrow t = 1.5\times10^{-3}$ s 2

$\Rightarrow F(t = 1.5\times10^{-3}\,s) = F_{max} = 6\times10^6(1.5\times10^{-3}) - 2\times10^9(1.5\times10^{-3})^2$ 1

$\boxed{F_{max} = 4.5\times10^3\ N}$ 1 1

iv) $v = ?$ when contact is lost.

$\Delta\vec{p} = \vec{P}_f - \vec{P}_i = m\vec{v}_f - \cancel{m\vec{v}_i} \rightarrow \Delta p = mv = J \Rightarrow v = \frac{J}{m} = \frac{9\,Ns}{0.45\,kg} = 20\ \frac{kg\,m}{s^2}\frac{s}{kg}$ 2

$\boxed{v = 20\ m/s}$ 2 1

4. The angular position of a point on a rotating wheel is given by $\theta(t) = 2.0 + 4.0t^2 + 2.0t^3$, where θ is in radians and t is in seconds. At t = 0,

   i what is the point's angular position?

   ii what is its angular velocity?

   iii what is its angular velocity at t = 4.0 s?

   iv Calculate its angular acceleration at t = 2.0 s.

   v Is its angular acceleration constant? Why?

$\theta(t) = 2t^3 + 4t^2 + 2$

i) at $t=0$, $\theta(\phi) = 2$ rad 2

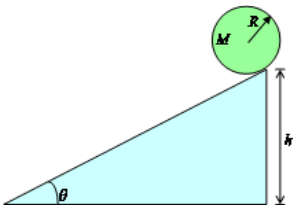
ii) $\omega(t) = \frac{d\theta(t)}{dt} = 6t^2 + 8t$ 2, at $t=0$, $\omega(\phi) = \phi$ 2

iii) $t=4 \rightsquigarrow \omega(t=4) = 6 * 4^2 + 8 * 4 = 128$ rad/s 3

iv) $\alpha(t) = \frac{d\omega(t)}{dt} = 12t + 8$ 2, at $t=2$, $\alpha(t=2) = 32$ rad/s^2 2

v) α has time dependency $\Rightarrow$ NOT constant 2

5. A solid ball of radius $R = 0.2\ m$ and mass $M = 3\ kg$ is placed at the top of a ramp of height $h = 1.2\ m$ and $\theta = 37°$. (Hint: $I = \frac{2}{5}mR^2$)



i If the ramp surface is frictionless, calculate the velocity of the ball's center of mass (v_{com}) and its angular velocity (ω) at the bottom of the ramp.

ii Calculate the minimum value of the coefficient of static friction (μ_s) that would cause smooth rolling (no slipping) of the ball down the ramp. Calculate v_{com} and ω at the bottom of the ramp for this case.

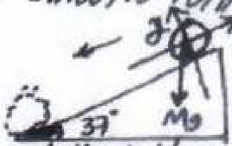
i) frictionless → no rolling ⇝ $v_{com} = v$ & $\boxed{\omega = 0}$

(2) $\cancel{U_f} + K_f = U_i + \cancel{K_i}$ (1) ⇝ $\frac{1}{2}mv^2 = mgh \to v = \sqrt{2gh}$ (1)

0

at the bottom ⇝ $v = \sqrt{2(9.8\,m/s^2)(1.2\,m)} = \boxed{4.85\,m/s}$ (1)

ii) smooth rolling, $a_{com,x} = \frac{g\sin\theta}{1 + I_{com}/MR^2}$ & $f_s = -I_{com}\frac{a_{com,x}}{R^2}$



$\to a_{com,x} = \frac{(9.8\,m/s^2)\sin 37}{1 + \frac{2}{5}MR^2/MR^2} = -4.21\,m/s^2$ (2) (1)

at the bottom ⇝ $f_s = -\frac{2}{5}MR^2(-4.21\,m/s^2)/R^2 = 5.05N$ (1) (1)

$\Rightarrow f_s = \mu_s F_N$ (1) $\to \mu_s = \frac{f_s}{F_N} = \frac{5.05N}{mg\cos 37} = \frac{5.05N}{(3\,kg)(9.8\,m/s^2)\cos 37} = \boxed{0.22}$

$\cancel{U_f} + K_f = U_i + \cancel{K_i}$ (2) ⇝ $\frac{1}{2}Mv_{com}^2 + \frac{1}{2}I_{com}\omega^2 = mgh$ | $v_{com} = \omega R$

$\frac{1}{2}Mv_{com}^2 + \frac{1}{2}\frac{2}{5}MR^2\left(\frac{v_{com}}{R}\right)^2 = mgh \to v_{com} = \sqrt{\frac{10}{7}gh} = \boxed{4.1\,m/s}$ (1)

iii) friction & motion & sliding $\omega = v_{com}/R = \frac{4.1\,m/s}{0.2\,m} = \boxed{20.5\,\frac{rad}{s}}$ (1)