Past Exam 2025: Ch.5 to Ch.8

Physics 103: Classical Mechanics

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Version 1

Outline

1. Ch.5: The Laws of Motion

2. CH.6: Applications of Newton's Laws in Circular Motion

3. CH.7: Energy and Energy Transfer

4. CH.8: Potential Energy and Conservation of Energy

5. Additional problems

Question 1.1

What happens to an object at rest according to Newton's First Law?

A) It remains at rest unless acted upon by an external force.

B) It starts moving on its own after some time.

C) It accelerates in the absence of force.

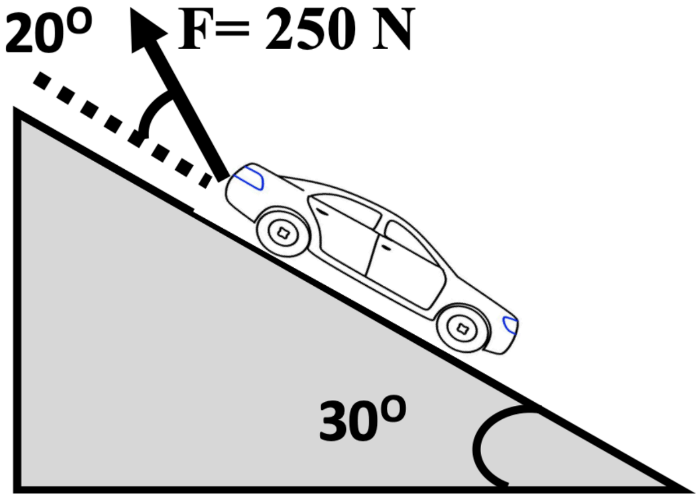
D) It moves with constant speed.

Answer 1.1

The Newton's first law states that an object at rest stays at rest and an object in motion stays in motion with the same speed and direction unless acted upon by an external force.

Question 1.2

A **1500 kg** car is sliding down a frictionless incline with a **30°** slope. Simultaneously, a force of **250 N** pulls the car upward at an angle of **20°** above the inclined surface. The car starts from rest. Calculate the distance the car travels along the incline after **12 seconds**.



A) 341.3 m B) 285. 6 m C) 405.5 m D) 195.2 m

Answer 1.2

$$\sum f_x = mg\sin\theta - F\cos\theta = ma_x$$

$$\Rightarrow a_x = g\sin\theta - \left(\frac{F}{m}\right)\cos\theta$$

From $d = v_i t + \frac{1}{2}a_x t^2$ and $v_i = 0$:

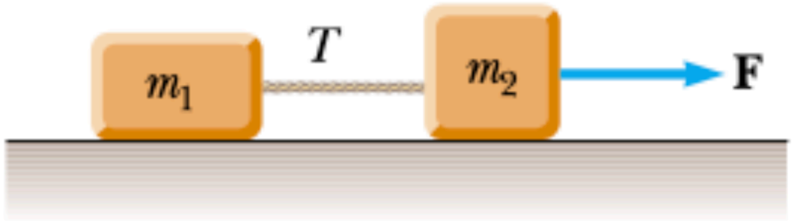
$$d = \frac{1}{2}\left(g\sin\theta - \left(\frac{F}{m}\right)\cos\theta\right)t^2$$

$$d = \frac{1}{2}\left(9.8\sin 30^\circ - \left(\frac{250}{1500}\right)\cos 30^\circ\right)12^2$$

$$d = 342.4 \quad \text{m}$$

Question 1.3

Two blocks connected by a rope of negligible mass are being dragged by a horizontal force F as shown in the figure. Suppose that $\boldsymbol{F}$ =**60 N**, $\boldsymbol{m_1}$ =**10 kg**, $\boldsymbol{m_2}$ =**20 kg**, and the coefficient of kinetic friction between each block and the surface is **0.100**. The tension $\boldsymbol{T}$ on the rope is:



A) 20.0 N

B) 10.2 N

C) 59.0 N

D) 40.4 N

Answer 1.3

- For the system:

$$\sum F_x = F - f_k = F - [\mu_k(m_1 + m_2)g] = (m_1 + m_2)a$$

$$\Rightarrow a = \frac{F - \mu_k(m_1 + m_2)g}{m_1 + m_2}$$

- For Block 1

$$\sum F_x = T - f_k = T - \mu_k m_1 g = m_1 a$$

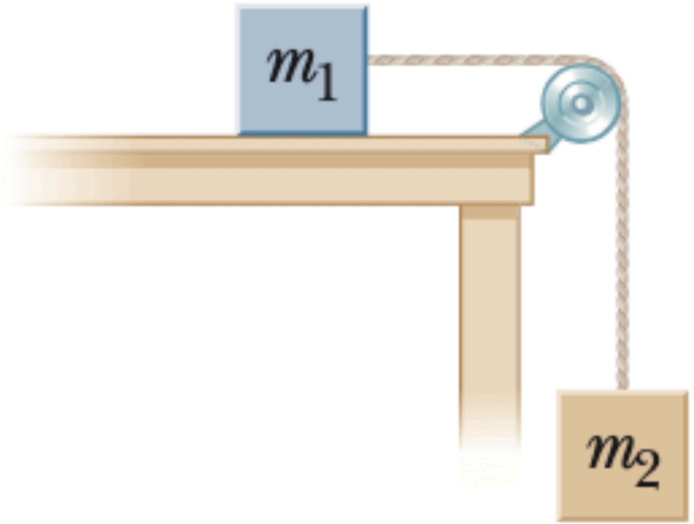
$$\Rightarrow T = m_1 a + \mu_k m_1 g$$

$$= m_1 \left[\frac{F - \mu_k(m_1 + m_2)g}{m_1 + m_2} \right] + \mu_k m_1 g$$

$$= 20 \text{ N}$$

Question 1.4

A **10 kg** hanging weight is connected by a string over a pulley to a **4 kg** block that is sliding on a flat table as shown in the figure. If the coefficient of kinetic friction is **0.200**, find the tension in the string. Disregard any pulley mass or friction in the pulley.



A) 25.7 N

B) 33.6 N

C) 72.3 N

D) 90.2 N

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Answer 1.4

1. We assume the acceleration of the system is positive when moving clockwise
2. We simplify the problem by applying Newton's second law to each block separately.

$$\sum F_x = T - f_k = T - \mu_k m_1 g = m_1 a$$

$$\sum F_y = -T + m_2 g = -T + m_2 g = m_2 a$$

3. Add the two equations to eliminate T and solve for a:

$$m_2 g - \mu_k m_1 g = (m_1 + m_2)a$$

$$\Rightarrow a = \frac{m_2 g - \mu_k m_1 g}{m_1 + m_2}$$

4. Substitute the expression of a into one of the equations to find T:

$$
\begin{aligned}
T &= m_1 a + \mu_k m_1 g \\
&= m_1 \left[\frac{m_2 g - \mu_k m_1 g}{m_1 + m_2} \right] + \mu_k m_1 g \\
&= 33.6 \quad \mathrm{N}
\end{aligned}
$$

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Question 2.5

A **1000 kg** car follows a curved path and the centripetal force is **10000 N**. If the car is moving at a constant speed of **30 m/s**, what is the radius of the curve?

A) 90 m B) 150 m C) 300 m D) 500 m

Answer 2.5

$$\sum F_r = F_r = m\frac{v^2}{r}$$

$$\Longrightarrow r = m\frac{v^2}{F_r} = 90 \text{ m}$$

Question 2.6

The same centripetal force is being applied to two masses, $\mathbf{M_1}$ and $\mathbf{M_2}$, which are traveling at the same speed along two curved paths with radiuses $\mathbf{R_1}$ and $\mathbf{R_2}$, respectively. If $\mathbf{R_1 = 2\ R_2}$ then the relation between masses is:

A) $\mathbf{M_1=4M_2}$

B) $\mathbf{M_1= 2M_2}$

C) $\mathbf{M_1= 1/2\ M_2}$

D) $\mathbf{M_1= 1/4\ M_2}$

Answer 2.6

Since F_r and v are similar for both cases, we can set up the following proportion:

$$F_r = M_1 \frac{v^2}{R_1} = M_2 \frac{v^2}{R_2}$$

$$\Rightarrow \frac{M_1}{R_1} = \frac{M_2}{R_2}$$

Using $R_1 = 2R_2$, we find:

$$\frac{M_1}{2R_2} = \frac{M_2}{R_2}$$

$$\Longrightarrow M_1 = 2M_2$$

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Question 3.7

A dart is loaded into a spring-loaded toy dart gun by pushing the spring in by a distance $\boldsymbol{d}$. For the next loading, the spring is compressed a distance $\boldsymbol{3d}$. The work required to load the second dart compared to that required to load the first will be:

A) the same B) three times as much C) six times as much D) nine times as much

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Answer 3.7

- The work done by an external force on a spring is given by:

$$W_{\text{ext}} = \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2$$

- For the first dart moving from $x_i = 0$ to $x_f = d$:

$$W_{\text{ext1}} = \frac{1}{2}kd^2 - 0 = \frac{1}{2}kd^2$$

- For the second dart moving from $x_i = 0$ to $x_f = 3d$

$$W_{\text{ext2}} = \frac{1}{2}k(3d)^2 - 0 = \frac{9}{2}kd^2$$

- Therefore, the work ration is:

$$\frac{W_{\text{ext2}}}{W_{\text{ext1}}} = \frac{\frac{9}{2}kd^2}{\frac{1}{2}kd^2} = 9$$

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Question 3.8

A force $\mathbf{F} = (\,6\hat{\mathbf{i}} - 2\hat{\mathbf{j}}\,)\ \mathbf{N}$ acts on a particle that undergoes a displacement $\Delta\mathbf{r} = (\,3\hat{\mathbf{i}} + \hat{\mathbf{j}}\,)\ \mathbf{m}$. The work done by the force on the particle is:

A) 4 J B) 8 J C) 12 J D) 16 J

Answer 3.8

$$W = \vec{\boldsymbol{F}} \cdot \Delta\vec{\boldsymbol{r}} = F_x \Delta x + F_y \Delta y$$

$$= 6 * 3 - 2 * 1$$

$$= 16 \text{ J}$$

Question 3.9

A **10 kg** block at rest is pulled across a rough horizontal surface with a constant force of **50 N**. The coefficient of kinetic friction between the block and the surface is **0.30**. The speed of the block after it has been pulled a distance of **5 m** (in **m/s**):

A) 2.42　　B) 4.54　　C) 7.07　　D) 29.4

Answer 3.9

$$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + Fd - f_k d$$
$$= 0 + Fd - \mu_k mgd$$

Solving for v_f:

$$v_f = \sqrt{\left(\frac{2}{m}\right)(Fd - \mu_k mgd)}$$
$$= \sqrt{\left(\frac{2}{10}\right)(50 * 5 - 0.3 * 10 * 9.8 * 5)} = 4.54 \quad \mathrm{m/s}$$

Question 3.10

A **5 kg** concrete block is connected by a rope to a motor. The block is being pulled upward with acceleration of **1.20 m/s²**. A constant friction force of **2 N** opposes its upward motion. If the speed of the block is **2 m/s**, the power of the motor is (in **watt**):

A) 102 B) 106 C) 110 D) 114

Answer 3.10

The power delivered to the elevator by the cable is given by:

$$P = Tv$$

To find T, we use Newton's second law:

$$\sum F_y = T - mg - f = ma$$

$$\Rightarrow T = m(a+g) + f$$

Therefore,

$$P = [m(a+g) + f]v$$
$$= [5 * (1.2 + 9.8) + 2] * 2 = 114 \text{ W}$$

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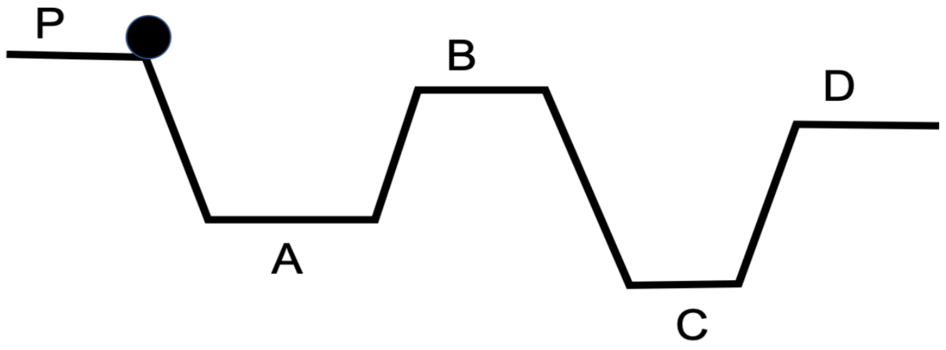
Question 4.11

A ball is pushed from point P and it reaches point D, at what point the ball will have maximum speed?



A) A B) B C) C D) D

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Answer 4.11

Since the surface is frictionless, the total mechanical energy is conserved:

$$E_i = E_f$$

$$K_i + U_i = K_f + U_f$$

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f$$

Solving for v_f:

$$v_f = \sqrt{v_i^2 + 2g(h_i - h_f)}$$

Therefore, the maximum speed is when $h_i - h_f$ is maximum, which occurs at point C:

Question 4.12

When a spring is stretched by **2 cm**, the energy stored is **100 J**. If it is stretched further by **2 cm**, its energy increases by:

A) 100 J B) 200 J C) 300 J D) 400 J

Answer 4.12

$$W_{\text{ext}} = \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2$$

Setting $x_i = 0$,

$$W_1 = \frac{1}{2}kx_1^2 - 0$$

$$W_2 = \frac{1}{2}k(2x_1)^2 - \frac{1}{2}kx_1^2$$

$$= (4)\frac{1}{2}kx_1^2 - \frac{1}{2}kx_1^2$$

$$= (3)\frac{1}{2}kx_1^2 = 3W_1 = 3 * (100 \text{ J}) = 300 \text{ J}$$

Question 4.13

A ball is thrown straight up into the air. At what position is its kinetic energy (K. E.) is maximum?

A) the lowest point.

B) K. E. is constant at all points of the flight.

C) midway between the lowest point and the highest point.

D) the highest point.

Answer 4.13

See Answer 1.11.

Question 4.14

A **70 kg** diver steps off a **10 m** tower and drops straight down into the water. If he comes to rest **5 m** beneath the surface of the water, determine the average resistance force exerted by the water on the diver.

A) 1.12 KN B) 2.06 KN C) 0.69 KN D) 3.18 KN

Answer 4.14

$$\Delta E = -f_k d$$

$f_k = 0$, During the free fall in the air until it reaches the surface (s) of the water, we have:

$$K_i + U_i = K_s + U_s$$

$$0 + U_i = K_s + 0 \qquad (1)$$

After entering the water, we have:

$$K_f + U_f - K_s - U_s = -f_k h_f$$

from (1) and since $K_f = 0$ and $U_s = 0$, we get:

$$U_f - U_i = -f_k h_f$$

$$f_k = \frac{U_i - U_f}{h_f} = \frac{mgh_i - mgh_f}{h_f}$$

$$= mg\frac{h_i - h_f}{h_f}$$

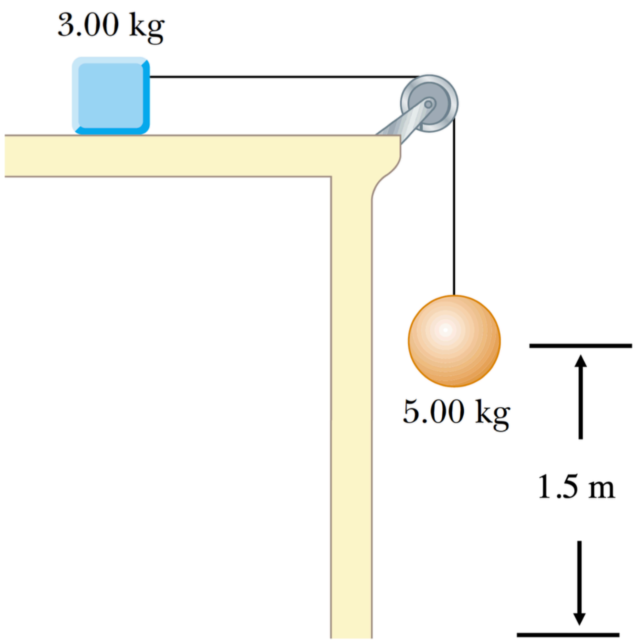
$$= 70 * 9.8 * \frac{10 - (-5)}{-5}$$

$$\vec{f}_k = -2.06 \text{ KN } \hat{j}$$

The magnitude of the average resistive force is 2.06 KN.

Question 4.15

The coefficient of friction between the **3 kg** block and the surface is **0.4**. The system starts from rest. What is the speed of the **5 kg** ball when it has fallen **1.5 m**?



A) 7.4 m/s

B) 11.3 m/s

C) 2.3 m/s

D) 3.74 m/s

Answer 4.15

Since there is a friction, the conservation of energy of the system becomes:

$$\Delta E = -f_k d$$

$$E_f - E_i = -(\mu_k m_1 g)h$$

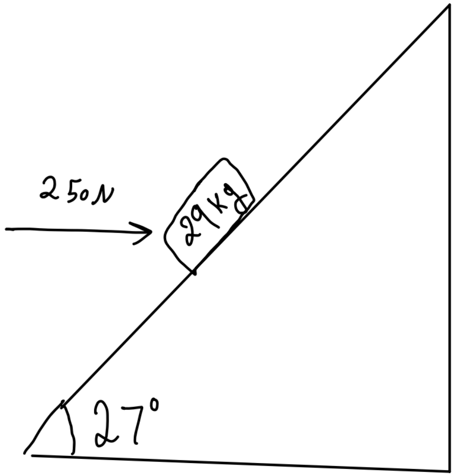
$$U_f + K_f - U_i - K_i = -(\mu_k m_1 g)h$$

$$\left[(0+0) + \left(\frac{1}{2}m_1 v^2 + \frac{1}{2}m_2 v^2\right)\right] - [(m_2 g h + 0) - (0+0)] = -(\mu_k m_1 g)h$$

$$\frac{1}{2}(m_1 + m_2)v^2 = m_2 g h - (\mu_k m_1 g)h$$

$$\implies v = 3.74 \text{ m/s}$$

Question 5.16



A 250-N force is directed horizontally as shown to push a 29-kg box up an inclined plane at a constant speed. Determine the magnitude of the normal force on the box (n).

a) 366.7 N
b) 543.1 N
c) 234.2 N
d) 451.9 N
e) 131.5 N

Answer 5.16

$$\sum F_y = N - F\sin\theta - mg\cos\theta = 0$$

$$\Rightarrow N = F\sin\theta + mg\cos\theta$$

$$= 366.7N$$