

The 9<sup>th</sup> article of Student Disciplinary Regulations of YÖK Law No.2547 states "Cheating or helping to cheat or attempt to cheat in exams" de facto perpetrators take one or two semesters suspension penalty.

Students are NOT permitted to bring calculators, mobile phones, smart watches and/or any other unauthorized electronic devices into the exam room.

Question Sheet **A A A A A**

Name Surname

Student No

Physics Group No

Department

Exam Hall

Instructor's Name Surname

Student Signature:

$$g = 10 \text{ (m/s}^2\text{)}$$

$$\vec{v} = \frac{\Delta \vec{r}}{\Delta t}; \vec{a} = \frac{\Delta \vec{v}}{\Delta t}; \vec{v} = \frac{d\vec{r}}{dt}; \vec{a} = \frac{d\vec{v}}{dt}; \vec{v} = \vec{v}_0 + \vec{a}t; \vec{r} = \vec{r}_0 + \vec{v}_0t + \frac{1}{2}\vec{a}t^2; v^2 = v_0^2 + 2\vec{a} \cdot (\vec{r} - \vec{r}_0)$$

$$F_r = m \frac{v^2}{r}; F_s = -kx; f_s \leq \mu_s N; f_k = \mu_k N; P = \vec{F} \cdot \vec{v}; W = \Delta K; W = \int \vec{F} \cdot d\vec{r}; \bar{P} = \frac{\Delta W}{\Delta t}; W = -\Delta U$$

1) The force  $F$  is given in terms of time  $t$  and displacement  $x$  by the equation,  $F = A \cos(Bx) + C \sin(Dt)$ . Find the dimension of  $D/B$ .

$$B \rightarrow [L^{-1}] \quad D \rightarrow [T^{-1}]$$

- A)  $[L^{-1} T^{-1}]$  B)  $[L^2 T^{-1}]$  C)  $[L T^{-1}]$  D)  $[T^{-2}]$  E)  $[L^{-1} T^{-2}]$

2) Vectors  $\vec{A}$  and  $\vec{B}$  are given by  $\vec{A} = 2\hat{i} - \hat{j} + 3\hat{k}$  and  $\vec{B} = \hat{i} - 2\hat{j} - 2\hat{k}$ . Find the unit vector of  $(\vec{A} \times \vec{B})$ .

$$\vec{A} \times \vec{B} = -4\hat{k} + 4\hat{j} + \hat{k} + 2\hat{i} + 3\hat{j} + 6\hat{i} = 8\hat{i} + 7\hat{j} - 3\hat{k}$$

$$\hat{u} = \frac{\vec{A} \times \vec{B}}{|\vec{A} \times \vec{B}|} = \frac{8\hat{i} + 7\hat{j} - 3\hat{k}}{\sqrt{122}}$$

- A)  $\frac{8\hat{i} - \hat{j} - 5\hat{k}}{\sqrt{90}}$  B)  $\frac{4\hat{i} - 7\hat{j} + 3\hat{k}}{\sqrt{74}}$  C)  $\frac{8\hat{i} - 7\hat{j} + \hat{k}}{\sqrt{114}}$  D)  $\frac{8\hat{i} + 7\hat{j} - 3\hat{k}}{\sqrt{122}}$  E)  $\frac{8\hat{i} - 7\hat{j} + 3\hat{k}}{\sqrt{122}}$

3) At  $t = 0$  a body is started from origin with some initial velocity. The displacement  $x$  (m) of the body varies with time  $t$  (s) as  $x = -\frac{2}{3}t^2 + 16t + 2$ . How long does the body take to come to rest?

$$a = \frac{dx}{dt} = -\frac{4}{3}t + 16 \rightarrow \text{constant}$$

$$u_f = u_i + at \quad / \quad u(t) = -\frac{4}{3}t + 16 \quad t=0 \Rightarrow u=16$$

$$0 = 16 - \frac{4}{3}t \quad t = 12s$$

4) For motion of an object along  $x$ -axis, the velocity  $v$  depends on the displacement  $x$  as;  $v = 5x^2 - 2x$ . What is the acceleration at  $x = 1$  (m).

$$a = \frac{dv}{dt} = \frac{dv}{dx} \frac{dx}{dt} = (10x - 2)(5x^2 - 2x) = 50x^3 - 20x^2 - 10x^2 + 4x$$

$$t=1 \Rightarrow a = 50 - 20 - 10 + 4 = 24 \text{ m/s}^2$$

- A) 26 (m/s<sup>2</sup>) B) 16 (m/s<sup>2</sup>) C) 24 (m/s<sup>2</sup>) D) 18 (m/s<sup>2</sup>) E) 20 (m/s<sup>2</sup>)

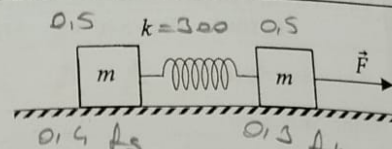
5) The trajectory equation of a projectile motion is given by;  $y = \sqrt{3}x - \frac{1}{20}x^2$ . If the horizontal component of the initial velocity of the object at  $t = 0$  is 10 (m/s), find the flight time of the object in seconds.

$$y = \sqrt{3}x - \frac{1}{20}x^2 \Rightarrow x_{1,2} = \frac{-\sqrt{3} \pm \sqrt{3+0}}{-\frac{1}{10}} \Rightarrow x_1 = 0, x_2 = 20\sqrt{3} \text{ m}$$

$$20\sqrt{3} = x_1 + u_{10}t + \frac{1}{2}a_x t^2 \Rightarrow t = 2\sqrt{3} \text{ s}$$

- A)  $\sqrt{3}$  B)  $2\sqrt{3}$  C) 2 D) 3 E)  $3\sqrt{2}$

**Questions 6-7** Two masses of  $m = 0.5$  (kg) connected to each other by a spring with constant  $k = 300$  (N/m) rest on a horizontal surface with friction coefficients  $\mu_s = 0.4$  and  $\mu_k = 0.3$ . The spring is not extended. Once the mass attracted by the force  $F$  is put into motion, it moves at a constant speed.



6) What is the value of the horizontal force  $F$  in terms of Newton before the mass on the left side moves?

$a = \text{constant} \Rightarrow a = 0$

$F - f_k - f_s = 0 \Rightarrow F = 1.5 + 2 = 3.5 \text{ N}$   
 $\downarrow$   
 $0.3 \cdot 0.5 \cdot 10 \quad \rightarrow \quad 0.4 \cdot 0.5 \cdot 10$

- A) 3.5      B) 3.0      C) 4.0      D) 4.5      E) 5.0

7) In this case, how many meters is the spring extended?

$F - f_k = k \Delta x \Rightarrow 3.5 - 1.5 = 300 \cdot \Delta x \Rightarrow \Delta x = 2/300 \text{ m}$

- A)  $\frac{1}{300}$       B)  $\frac{1}{200}$       C)  $\frac{1}{350}$       D)  $\frac{2}{300}$       E)  $\frac{1}{400}$

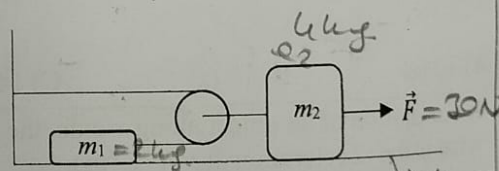
8) A man wants to cross the river by boat that has a constant speed. If he crosses the river in minimum time, it takes 1 minutes with a 12 meters drift. If the man takes the shortest route to cross the river, it takes 2 minutes. Find the magnitude of the velocity of boat relative to the water in m/s.

shortest time  $u_b \uparrow$   $u_r \rightarrow$   $u_{b,r} \nearrow$   $u_r = 12/1 = 12 \text{ m/min}$   $d = 1 u_b$   
 shortest route  $u_b \uparrow$   $u_r \rightarrow$   $u_{b,r} \nearrow$   $u_{b,r} = (u_b^2 - u_r^2)^{1/2} \Rightarrow t = 2 = \frac{d}{u_{b,r}} = \frac{d}{(u_b^2 - u_r^2)^{1/2}}$   
 $u_b^2 = \frac{4}{3} u_r^2 \Rightarrow u_b = \frac{2}{\sqrt{3}} \cdot \frac{12}{60} \text{ m/s}$

- A)  $\frac{2}{3\sqrt{3}}$       B)  $\frac{3}{5\sqrt{3}}$       C)  $\frac{2}{5}$       D)  $\frac{3}{5}$       E)  $\frac{2}{5\sqrt{3}}$

9)  $F = 30$  (N) force is applied horizontally to the  $m_2 = 4$  (kg) block on a frictionless surface. Find the acceleration of a mass of  $m_1 = 2$  (kg) in  $\text{m/s}^2$ .

$a_1 = 2a_2$   
 $30 - 2T = m_2 a_2 \Rightarrow 30 - 8a_2 = 4a_2$   
 $T = m_1 a_1$   
 $a_2 = 2.5 \text{ m/s}^2$   
 $a_1 = 5 \text{ m/s}^2$



- A) 7      B) 2      C) 5      D) 2.5      E) 8

10) The velocity components of a particle moving in the  $xy$ -plane are given by  $v_x = 11 + 2t$  (m/s) and  $v_y = 5$  (m/s). The particle is at the origin at  $t = 0$ . Find the radial acceleration of the particle in  $t = 1$  second in unit of  $(\text{m/s}^2)$ ?

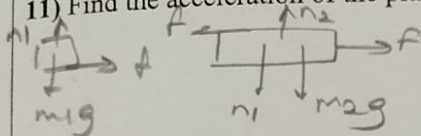
$a_x = \frac{dv_x}{dt} = 2 \text{ m/s}^2$   $a_y = 0$   $a_{tot} = (a_x^2 + a_y^2)^{1/2} = 2$   
 $a_{tot} = \frac{dv}{dt} = \frac{d}{dt} \left( (11+2t)^2 + 5^2 \right)^{1/2}$   
 $a_t = \frac{1}{2} \left( (11+2t)^2 + 5^2 \right)^{-1/2} \cdot 2(11+2t) \cdot 2$   
 $a_t = \frac{2(11+2t)}{\sqrt{(11+2t)^2 + 5^2}}$   
 $a_t = \frac{26}{\sqrt{194}} \Rightarrow a_r = \frac{10}{\sqrt{194}}$

- A)  $\frac{36}{\sqrt{194}}$       B)  $\frac{6}{\sqrt{184}}$       C)  $\frac{20}{\sqrt{184}}$       D)  $\frac{52}{\sqrt{146}}$       E)  $\frac{10}{\sqrt{194}}$



**Questions 11-12-13** A block with the mass  $m_1 = 1$  (kg) is placed at the right end of a plank with the mass  $m_2 = 2$  (kg). The length of the plank is 2 (m). Coefficient of friction between the block and the plank is 0.4 and the ground over which the plank is placed is smooth. A constant force  $F = 30$  (N) is applied on the plank in horizontal direction.

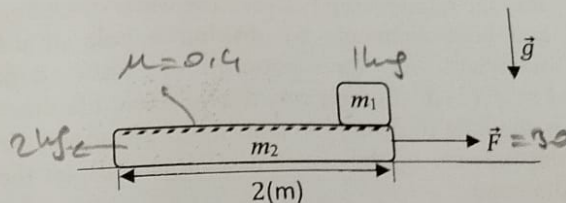
11) Find the acceleration of the plank relative to the block.



$$n_1 = 10 \quad f = \mu n = 4 \text{ N} \quad a_2 = \frac{30 - 4}{2} = 13 \text{ m/s}^2$$

$$a_1 = \frac{4}{1} = 4 \text{ m/s}^2$$

$$a_{21} = a_2 - a_1 = 13 - 4 = 9 \text{ m/s}^2$$



- A) 6 (m/s<sup>2</sup>)    **B) 9 (m/s<sup>2</sup>)**    C) 7 (m/s<sup>2</sup>)    D) 8 (m/s<sup>2</sup>)    E) 5 (m/s<sup>2</sup>)

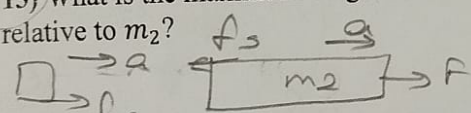
12) Find the time when the block will separate from the plank.

$$x_A = x_1 + v_1 t + \frac{1}{2} a t^2 \rightarrow ?$$

$$t = \sqrt{\frac{4}{9}} \text{ s}$$

- A) 2 (s)    B)  $\frac{2}{\sqrt{6}}$  (s)    C)  $\frac{1}{\sqrt{2}}$  (s)    D)  $\frac{2}{\sqrt{5}}$  (s)    **E)  $\frac{2}{3}$  (s)**

13) What is the maximum magnitude of the force  $\vec{F}$  that must be applied to keep the mass  $m_1$  motionless relative to  $m_2$ ?



$$F - f_s = m_2 a \Rightarrow F = 12 \text{ N}$$

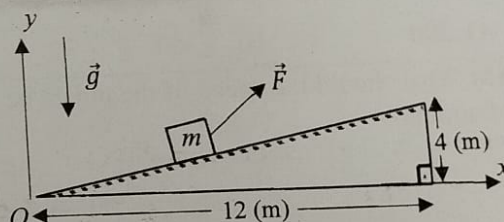
$$a_1 = a_2 = a$$

$$f_s = \mu m_2 g = m_2 a \Rightarrow a = \mu g = 4 \text{ m/s}^2$$

- A) 12 (N)**    B) 10 (N)    C) 8 (N)    D) 6 (N)    E) 15 (N)

**Questions 14-15** As shown in the figure, a block with the mass  $m = 1$  (kg) is pulled upwards on the inclined plane by the variable force  $\vec{F}(x) = 4\hat{i} + x\hat{j}$  (N) where  $x$  is in meters.

14) Until the block reaches to point (6,2) from point (0,0) what is the work done by the force  $\vec{F}$ ?

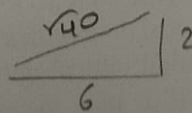


$$W = \int \vec{F} \cdot d\vec{r} = \int_0^6 4 dx + \int_0^2 x dy = 4x \Big|_0^6 + \frac{3y^2}{2} \Big|_0^2 = 30 \text{ Joule}$$

- A) 25.5 (J)    **B) 30 (J)**    C) 27.5 (J)    D) 26 (J)    E) 32 (J)

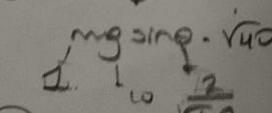
15) When the block reaches point (6,2), the change in its kinetic energy is 5 (J), What is constant friction force in Newtons?

$$W_F - W_g - W_{fk} = \Delta K = 5$$



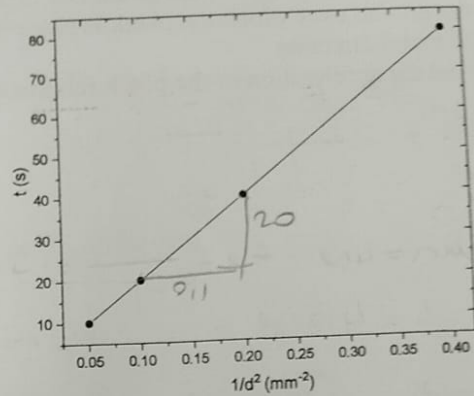
$$30 - 20 - f_k \cdot \sqrt{40} = 5$$

$$f_k = \frac{5}{\sqrt{40}} = \frac{5}{2\sqrt{10}} \text{ N}$$



- A)  $\frac{5}{2\sqrt{10}}$**     B)  $\frac{5}{10\sqrt{40}}$     C)  $\frac{5}{4\sqrt{10}}$     D)  $\frac{5}{2\sqrt{40}}$     E)  $\frac{5}{\sqrt{10}}$

**16) LABORATORY QUESTION:** There is equal amount of water in four identical cylindrical containers. As a result of the experiment carried out to find the relationship between the water discharge times and hole diameters by drilling a hole of different diameters at the bottom of each container,  $t = f(1/d^2)$  graph was drawn. Here  $t$  is time and  $d$  is the hole diameter. According to this graph, find the dependence of the water discharge time on the hole diameter.



$$t = t_0 \propto \frac{1}{d^2} = \frac{200}{d^2}$$

A)  $t = \frac{160}{d^2}$

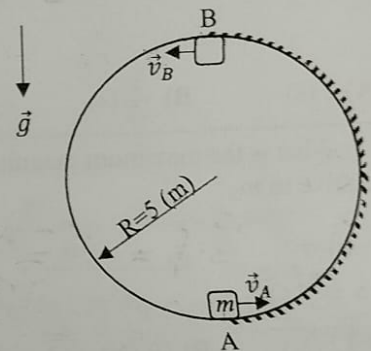
B)  $t = \frac{170}{d^2}$

C)  $t = \frac{180}{d^2}$

D)  $t = \frac{190}{d^2}$

**E)  $t = \frac{200}{d^2}$**

**Questions 17-18-19** An object with mass  $m = 2$  (kg) moves in a vertical plane on the rail system with radius 5 (m) as shown in the figure. The object passes through point A with the velocity  $\vec{v}_A$ .



**17)** If the work done by friction force between A and B is  $-100$  (J), how many Joules is the change in the kinetic energy of the object between points A and B?

$$W = \Delta K$$

$$W_g + W_{fr} = \Delta K = -300 \text{ joule}$$

$$-\Delta U - 100 = \Delta K$$

A) 200

**B) -300**

C) -200

D) -400

E) 300

**18)** What should the speed of the object be while passing through point A so that the speed at point B is the minimum?

$$v_B = 0 \Rightarrow U_B = \text{min}$$

$$W = \Delta K \Rightarrow -300 = \frac{1}{2} m (U_B^2 - U_A^2) \Rightarrow U_B = \sqrt{350} \text{ m/s}$$

A)  $\sqrt{300}$  (m/s)

B)  $\sqrt{200}$  (m/s)

C)  $\sqrt{150}$  (m/s)

**D)  $\sqrt{350}$  (m/s)**

E)  $\sqrt{250}$  (m/s)

**19)** If the speed of the object passing through point B is  $v_B = \sqrt{60}$  (m/s), find the reaction force applied to the object at point B.

$$mg + n = \frac{mv_B^2}{R} \Rightarrow n = 40$$

A) 12 (N)

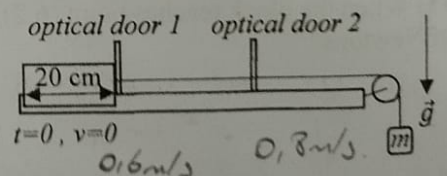
B) 10 (N)

C) 44 (N)

**D) 4 (N)**

E) 24 (N)

**20) LABORATORY QUESTION:** In the Newton's laws experiment with air rail, as shown in the figure, the 20 (cm) long car starts moving from rest and leaves the first optical door with a speed of  $v = 0.6$  (m/s). If the car enters to the second optical door at a speed of 0.8 (m/s), in how many seconds will it pass the second door?



$$U_f^2 = U_i^2 + 2a\Delta x \Rightarrow 0 = 0.9 \text{ m/s}^2 / U_f^2 = U_i^2 + 2a\Delta x \Rightarrow U_f = 1 \text{ m/s}$$

A)  $\frac{1}{3}$

B)  $\frac{1}{4}$

**C)  $\frac{2}{9}$**

D)  $\frac{2}{3}$

E)  $\frac{2}{5}$

$$t = 2/9 \text{ s}$$