Erasmus+

Development of innovative training solutions in the field of functional evaluation aimed at updating of the curricula of health sciences schools

TEACH

MODULE BIOMECHANICS FOUNDATIONS

Didactic Unit B: FORCES AND PRESSURE

Politechnika Śląska

IBV INSTITUTO DE BIOMECÁNICA DE VALENCIA

VNIVERSITAT DE VALÈNCIA

AMSE THE ASSOCIATION OF MEDICAL SCHOOLS IN EUROPE

CLASS INDEX

- Fundamental kinetic variables

- Testing your knowledge about kinetic equations

FUNDAMENTAL KINETIC EQUATIONS

Kinetics answer the questions about why a body moves

Force is the physical magnitude used to quantify the causes of the changes in the movement of bodies.

$$\vec{F} = m\vec{a} = mass * acceleration$$

Energy is a measurement of the ability of someone or something to do work.

Kinetic Energy (E_K)**:** Energy that an object possesses because of its motion.

$$Kinetic\ Energy: \frac{1}{2}mv^2$$

Potential energy (E_p) is energy which results from position or configuration.

$$Potential\ Energy = mgh$$

Work*:* A force is doing work if, when acting, there is a movement of the point of application in the direction of the force (same direction or the force has a component in the direction of the motion).

$$Work = F\Delta d cos\emptyset$$

Power is defined as the rate of doing work or the rate of using energy.

$$Power = \frac{Work}{time} = \frac{Force * distance *}{time} = Force * velocity$$

Torque is defined by the measurement of the twisting action caused by a force that can cause an object to rotate about an axis.

$$Torque(\tau) = F * r * sin\theta$$

KINETIC EQUATIONS EXERCISES

Kinetic Energy

https://www.khanacademy.org/science/ap-physics-1/ap-work-and-energy/kinetic-energy-ap/e/kinetic-energy-exercises-ap1?modal=1

Finding changes in gravitational potential energy

https://www.khanacademy.org/science/ap-physics-1/ap-work-and-energy/conservative-forces-and-gravitational-potential-energy-ap/e/gravitational-potential-energy-ap-physics-1?modal=1

KINETIC EQUATIONS EXERCISES

Work done by a force

https://www.khanacademy.org/science/ap-physics-1/ap-work-and-energy/introduction-to-work-ap/e/work-equation-ap-physics-1?modal=1

Torque

https://www.khanacademy.org/science/ap-physics-1/ap-torque-angular-momentum/torque-and-equilibrium-ap/e/torque-calculations-ap-physics-1

KINETIC EQUATIONS EXERCISES

Kinetic Energy

QUESTION 1

A $2.0\,\mathrm{kg}$ guinea pig runs at a speed of $1.0\,\frac{\mathrm{m}}{\mathrm{s}}$.

What is the guinea pig's kinetic energy?

Round answer to two significant digits.

______ J

QUESTION 2

A elephant kicks a $5.0\,\mathrm{kg}$ stone with $150\,\mathrm{J}$ of kinetic energy.

What is the stone's speed?

Round answer to two significant digits.

______ $\frac{\mathrm{m}}{\mathrm{s}}$

KINETIC EQUATIONS SOLUTIONS

Kinetic Energy

QUESTION 1: SOLUTION

Let's use the kinetic energy equation.

$$K = \frac{1}{2} m v^2$$

$$= \frac{1}{2}(2.0\,\mathrm{kg})(1.0\,\frac{\mathrm{m}}{\mathrm{s}})^2$$

$$= 1.0\,\frac{\mathrm{kg}\cdot\mathrm{m}^2}{\mathrm{s}^2}$$

$$= 1.0\,\mathrm{J}$$

The correct answer is $1.0\,\mathrm{J}$.

QUESTION 2: SOLUTION

Let's use the kinetic energy equation and solve for speed, v.

$$K = \frac{1}{2} m v^2$$

$$v^2 = \frac{2K}{m}$$

$$v = \sqrt{\frac{2K}{m}}$$

$$= \sqrt{\frac{2(150\,\mathrm{J})}{5.0\,\mathrm{kg}}}$$

$$= \sqrt{\frac{2\left(150\,\frac{\mathrm{kg}\cdot\mathrm{m}^2}{\mathrm{s}^2}\right)}{5.0\,\mathrm{kg}}}$$

$$= \sqrt{60\,\frac{\mathrm{m}^2}{\mathrm{s}^2}}$$

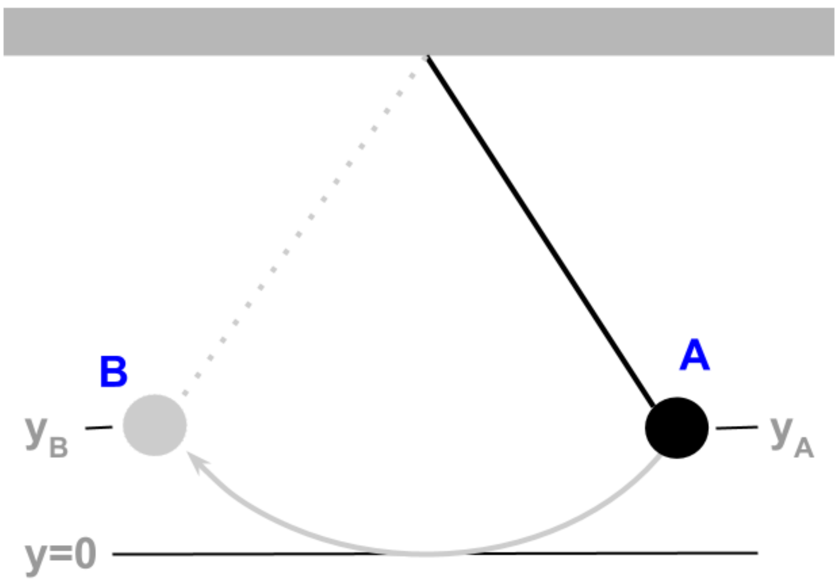
$$= 7.7\,\frac{\mathrm{m}}{\mathrm{s}}$$

The correct answer is $7.7\,\frac{\mathrm{m}}{\mathrm{s}}$.

KINETIC EQUATIONS EXERCISES

Finding changes in gravitational potential energy

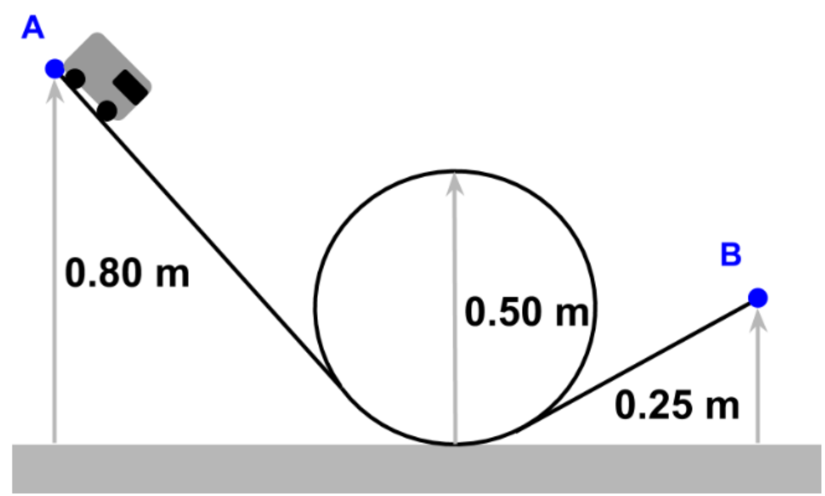
A $1.5\,\mathrm{kg}$ pendulum swings from point A of height $y_A = 0.10\,\mathrm{m}$ to point B of the same height. The heights are relative to the lowest height.



What is the change in gravitational potential energy from A to B?

QUESTION 3

A $1.0\,\mathrm{kg}$ toy car is released at the top of a frictionless track on the left and rolls off of the track from its right side ramp. The car starts at a height of $0.80\,\mathrm{m}$, goes through a $0.50\,\mathrm{m}$ diameter loop, and exits the ramp at a height of $0.25\,\mathrm{m}$.



What is the change in the car's gravitational potential energy from A to B?

Round answer to two significant digits.

QUESTION 4

KINETIC EQUATIONS SOLUTIONS

Finding changes in gravitational potential energy

The change in gravitational potential energy ΔU_g only depends on the relative heights at A and B.

The height above the lowest height is $y_A = 0.10\,\mathrm{m}$ at A and $y_B = 0.10\,\mathrm{m}$ at B.

Since the height doesn't change, Δy is zero and ΔU_g is also zero.

The correct answer is $0\,\mathrm{J}$.

QUESTION 3: SOLUTION

The change in gravitational potential energy ΔU_g only depends on the relative heights at A and B.

The height above the ground is $y_A = 0.80\,\mathrm{m}$ at A and $y_B = 0.25\,\mathrm{m}$ at B.

We can use these heights to find ΔU_g of the car.

$$\Delta U_g = mg\Delta y$$

$$= mg(y_B - y_A)$$

$$= (1.0\,\mathrm{kg})\left(9.8\,\frac{\mathrm{m}}{\mathrm{s}^2}\right)(0.25\,\mathrm{m} - 0.80\,\mathrm{m})$$

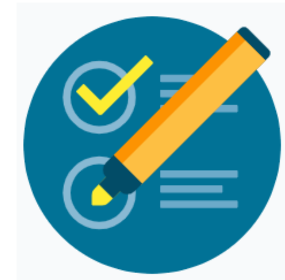
$$= -5.4\,\mathrm{kg}\cdot\frac{\mathrm{m}^2}{\mathrm{s}^2}\left(\frac{1\,\mathrm{J}}{1\,\mathrm{kg}\cdot\frac{\mathrm{m}^2}{\mathrm{s}^2}}\right)$$

$$= -5.4\,\mathrm{J}$$

QUESTION 4: SOLUTION

The correct answer is $-5.4\,\mathrm{J}$.

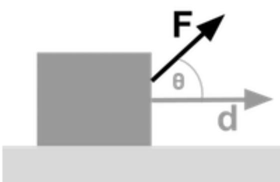
KINETIC EQUATIONS EXERCISES



Work done by a force

QUESTION 5

A box moves $5\ \mathrm{m}$ horizontally when force $F = 10\ \mathrm{N}$ is applied at an angle $\theta = 30^\circ$.



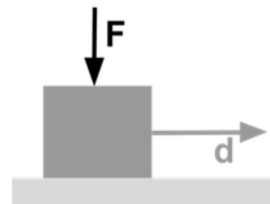
What is the work done on the box by F during the displacement?

Choose 1 answer:

- (A) $50\ \mathrm{J}$
- (B) $-43\ \mathrm{J}$
- (C) $-50\ \mathrm{J}$
- (D) $43\ \mathrm{J}$

QUESTION 6

A box moves $1000\ \mathrm{m}$ horizontally as a force $F = 2000\ \mathrm{N}$ is applied downward.



What is the work done on the box by F during the displacement?

Choose 1 answer:

- (A) $2,000,000\ \mathrm{J}$
- (B) $2000\ \mathrm{J}$
- (C) $-2,000,000\ \mathrm{J}$
- (D) $0\ \mathrm{J}$

KINETIC EQUATIONS SOLUTIONS

Work done by a force

QUESTION 5: SOLUTION

We can use the work equation to determine the work W done by F. Only the component of force parallel to the displacement does work.

$$W = Fd\cos\theta$$

$$\begin{aligned} W &= Fd\cos\theta \\ &= (10\,\mathrm{N})(5\,\mathrm{m})\cos(30^\circ) \\ &\approx 43\,\mathrm{N}\cdot\mathrm{m} \\ &\approx 43\,\mathrm{J} \end{aligned}$$

The answer is $43\,\mathrm{J}$.

QUESTION 6: SOLUTION

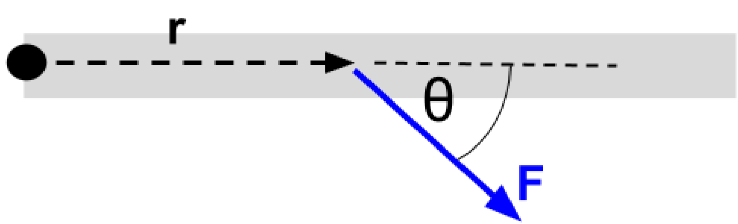
Only force parallel with the displacement does work. The force F is perpendicular with the displacement, so it does zero work on the box.

The answer is $0\,\mathrm{J}$

KINETIC EQUATIONS EXERCISES

Torque

A $25\ \mathrm{N}$ force F is applied to a bar that can pivot around its end as shown below.



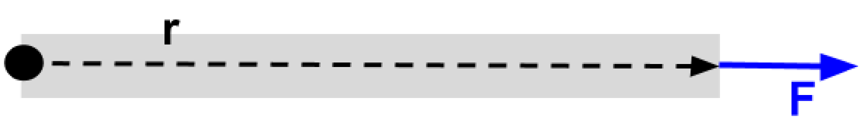
The force is $r = 0.75\ \mathrm{m}$ away from the end and at an angle $\theta = 60^\circ$.

What is the torque on the bar?

Answer using a coordinate system where counterclockwise is positive.

QUESTION 7

A $25\ \mathrm{N}$ force F is applied to a bar that can pivot around its end as shown below.



The force is parallel to the bar and is $r = 0.75\ \mathrm{m}$ away from the end.

What is the torque on the bar?

Answer using a coordinate system where counterclockwise is positive.

QUESTION 8

KINETIC EQUATIONS SOLUTIONS

Torque

QUESTION 7: SOLUTION

The applied force rotates the bar clockwise around the end. Thus, the torque is clockwise and negative.

We can determine the magnitude using:

$$\tau = rF\sin\theta$$

Let's substitute our known values to solve for the magnitude of τ.

$$\tau = rF\sin\theta$$

$$= (0.75\,\mathrm{m})(25\,\mathrm{N})\sin 60^\circ$$

$$= 16\,\mathrm{N}\cdot\mathrm{m}$$

Since the direction is negative, the torque is $-16\,\mathrm{N}\cdot\mathrm{m}$.

The correct answer is $-16\,\mathrm{N}\cdot\mathrm{m}$.

QUESTION 8: SOLUTION

We can determine the magnitude of torque using:

$$\tau = rF\sin\theta$$

Since F is parallel to the lever arm and θ is zero, the force produces zero torque.

The correct answer is $0\,\mathrm{N}\cdot\mathrm{m}$.