PHYSICS

NCERT - NCERT PHYSICS(GUJRATI)

WORK, ENERGY AND POWER

Examples

1. Find the angle between force $F = \left(3\hat{i} + 4\hat{j} - 5\hat{k}\right)$ unit and displacement $d = \left(5\hat{i} + 4\hat{j} + 3\hat{k}\right)$ unit. Also find the projection of F and d.

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2. It is well known that a raindrop falls under the influence of the downward gravitational force and the opposing resistive force. The latter is known to be proportional to the speed of the drop but is otherwise undetermined. Consider a drop of mass $1.00g$ falling from a height $1.00km$. It hits the ground with a speed of $50.0ms^{-1}$.

What is the work done by the unknown resistive force?

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4. Acyclist comes to a skidding stop in 10m. During this process, the forceon the cycle due to the road is 200 N and is directy opposed to the motion.

How much work does the cycle do on the road?

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6. In a ballistics demonstration a police officer fires a bullet of mass $50.0g$ with speed $200ms^{-1}$ (see Table 6.2) on soft plywood of thickness 2.00 cm. The kinetic energy. What is the emergent speed of the bullet?

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7. A woman pushes a trunk on a railway platform which has a rough surface. She applies a force of 100 N over a distance of 10m. Thereafter, she gets progressively tired and her applied force reduces linearly with distance to 50 N. The total distance through which the trunk has been moved is 20m. Plot the force applied by the woman and the frictional force, which is 50 N versus displacement. Calculate the work done by the two forces over 20 m.

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8. A block of mass $m = 1kg$, moving on a horizontal surface with speed $v_t = 2ms^{-1}$ enters a rough patch ranging from $x = 0.10m$ to $x = 2.01m$. The retarding force F_r on the block in this range is inversely proportional to x over this range,

$F_r = \frac{-k}{x}$ for $0.1 < x < 2.01m = 0$ for $x < 0.1m$ and $x > 2.01m$

where $k = 0.5J$. What is the final kinetic energy and speed v_f of the block as it crosses this patch?

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9. A bob of mass m is suspended by a light string of length L. It is imparted a horizontal velocity v_o at the lowest point A such that it completes a semi-circular trajectory in the vertical plane with the string becoming slack only on reaching the topmost point, C. This is shown in Fig. 6.6. Obtain an expression for

v_o

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The speeds at points B and C.

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The ratio of the kinetic energies (K_B/K_C) at B and C. Comment on the nature of the trajectory of the bob after it reaches the point C.

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12. To simulate car accidents, auto manufacturers study the collisions of moving cars with mounted springs of different spring constants.

Consider a typical simulation with a car of mass 1000 kg moving with a speed $18.0k\frac{m}{h}$ on a smooth road and colliding with a horizontally mounted spring of spring constant $6.25 \times 10^3 Nm^{-1}$. What is the maximum compression of the spring?

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13. Consider Example 6.8 taking the coefficient of friction , μ to be and calculate the maximum compression of the spring .

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14. Examine Tables 61. -6.3 and express (a) the energy required to break one bond in DNA in eV, (b) The kinetic energy of an air molecule $(10^{-21} J)$ in eV , (c) The daily intake of a human adult in kilocalories .

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16. Examine Tables 6.1-6.3 and express

The daily intake of human adult in kilocalories.

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17. An elevator can carry a maximum load of 1800 kg (elevator + passengers) is moving up with a constant speed of $2ms^{-1}$. The frictional force opposing the motion is 4000 N. Determine the minimum power delivered by the motor to the elevator in watts as well as in horse power.

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18. In a nuclear reactor a neutron of high speed (typically $10^7 ms^{-1}$) must be slowed to of interacting with isotope .$_{92}^{235}U$ and causing it to fission . Show that a neutron can lose most of its kinetic energy in an elastic collision with a light nuclei like deuterium or carbon which has a mass of only a few times the neutron mass . the material making up the light nuclei , usually heavy water (D_2O) or graphite is called a moderator .

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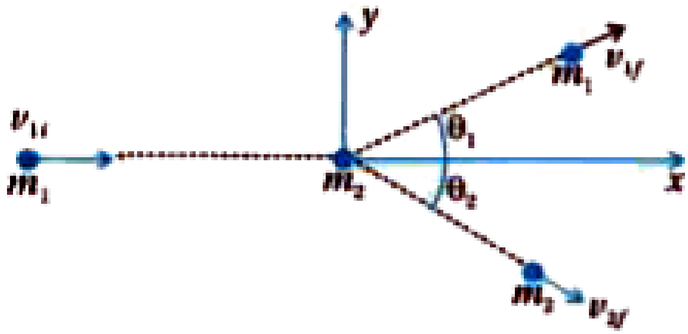
19. Consider the collision depicted in figure to be between two billiard balls are equal masses $m_1 = m_2$. The first ball is called the cue while the second ball is called the target . The billiard player wants to 'sink ' the target ball in a corner pocket , which is at angle $\theta_2 = 37^\circ$ .Assume that the collision is elastic and that friction and rotational motion are not important . Obtain θ_1 .



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Exercises

1. The sign of work done by a force on a body is important to understand .State carefully if the following quantities are positive or negative :

(a) work done by a man in lifting a bucket out of a well by means of a rope tied to the bucket .

(b) work done by gravitational force in the above case ,

(c) work done by friction on a body siding down an inclined plane , (d) workdone by an applied force on a body moving on a rough horizontal plane woth uniform velocity .

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6. A body of mass 2 kg initially kg intially at rest moves under the action of an applied horizontal force of 7 N on a table with coefficient of kinetic friction = 0.1 Compute the

(a) work done by the applied force in 10 s.

(b) work done by friction in 10 s .

work done by the net force on the body in 10 s.

(d) Change in kinetic energy of the body in 10 s and interpret your details .

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Change in kinetic energy of the body in 10s.

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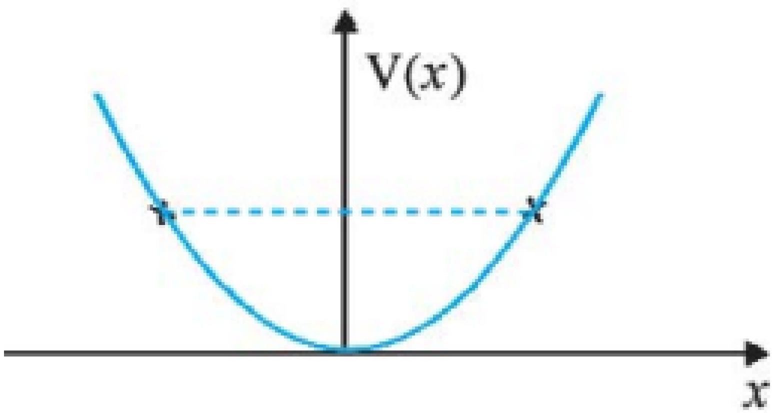
10. Given in Fig. 6.11 are examples of some potential energy functions in one dimension. The total energy of the particle is indicated by a cross on the ordinate axis. In which the particle cannot be found for the given energy. Also, indicate the minimum total energy the particle must have in each case. Think of simple physical contexts for which these potential energy shapes are relevant.



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11. Answer the following :

The casing of a rocket in flight burns up due to friction. At whose expense is the heat energy required for burning obtained ? The rocket or the atmosphere?

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12. Comets move around the sun in highly elliptical orbits . The gravitational force on the comet due to the sun is not normal to the comet's velocity in general. yet the work done by the gravitational force over energy complete orbit of the comet is zero . Why ?

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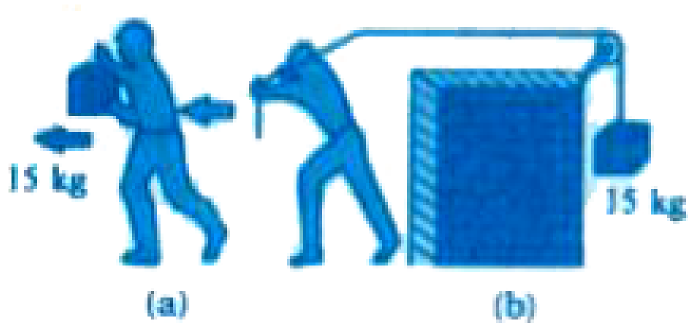
13. An artificial satellite orbiting the earth in very thin atmosphere loses its energy gradually due to dissipation against atmospheric resistance , however small .Why then does its speed increase progressively as it comes closer and closer the earth ?



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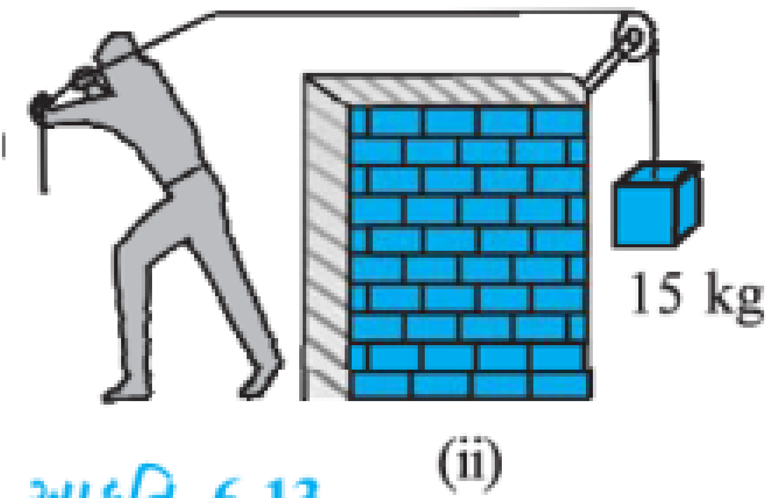
14. Answer the following :

In Fig.6.13. (i) the man walks 2m carrying a mass of 15kg on his hands. In Fig. 6.13. (ii), he walks the same distance pulling the rope behind him. The rope goes over a pulley, and a mass of 15 kg hangs at its other end. In which case is the work done greater?



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15. When a conservative force does positive work on a body , the potential energy of the body increases /decreases/ remains unaltered .

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16. Work done by a body against friction always results in a loss of its kinetic/potential energy .

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17. The rate of change of total momentum of a many -particle system is proportional to the external force/sum of the internal forces on the system .

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18. In an inelastic collision of two bodies, the quantities which do not change after the collision are the total kinetic energy/total linear momentum/total energy of the system of two bodies.

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19. State if each of the following statements is true or false. Give reasons for your answer.

In an elastic collision of two bodies, the momentum and energy of each body is conserved.

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20. State if each of the following statements is true or false. Give reasons for your answer.

Total energy of a system is always conserved, no matter what internal and external forces on the body are present.

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21. State if each of the following statements is true or false. Give reasons for your answer.

Work done in the motion of a body over a closed loop is zero for every force in nature.

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22. State if each of the following statements is true or false. Give reasons for your answer.

In an inelastic collision, the final kinetic energy is always less than the initial kinetic energy of the system.

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23. Answer carefully, with reasons :

In an elastic collision of two billiard balls, is the total kinetic energy conserved during the short time of collision of the balls (i.e. when they are in contact)?

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24. Answer carefully, with reasons :

Is the total linear momentum conserved during the short time of an elastic collision of two balls?

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25. Answer carefully, with reasons :

What are the answers to (a) and (b) for an inelastic collision?

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26. Answer carefully, with reasons :

If the potential energy of two billard balls depends only on the separation distance between their centres, is the collision elastic or inelastic? (Note, we are talking here of potential energy corresponding to the force during collision, not gravitational potential energy).

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27. A body is initially at rest. It undergoes one-dimensional motion with constant acceleration. The power delivered to it at time t is proportional to

A. $t^{\frac{1}{2}}$

B. t

C. $t^{\frac{3}{2}}$

D. t^{2}

Answer: B

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28. A body is moving unidirectionally under the influence of a source of constant power. Its displacement in time t is proportional to

A. $t^{\frac{1}{2}}$

B. t

C. $t^{\frac{3}{2}}$

D. t^2

Answer: C

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29. A body constrained to move along the z-axis of a coordinate system is subject to a constant force F given by

$F = -\hat{i} + 2\hat{j} + 3\hat{k} N$

where $\hat{i}, \hat{j}, \hat{k}$ are unit vectors along the x-, y- and z-axis of the system respectively. What is the work done by this force in moving the body a distance of 4m along the z-axis?

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30. An electron and a proton are detected in a cosmic ray experiment, the first with kinetic energy 10 keV, and the second with 100 keV. Which is faster, the electron or the proton? Obtain the ratio of their speeds. (electron mass $= 9.11 \times 10^{-31} kg$, proton mass $= 1.67 \times 10^{-27} kg, 1 eV = 1.60 \times 10^{-19} J$).

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31. A rain drop of radius 2mm falls from a height of 500 m above the ground. It falls with decreasing acceleration (due to viscous resistance of the air) until at half its original height, it attains its maximum (terminal) speed, and moves with uniform speed thereafter. What is the work done by the gravitational force on the drop in the first and second half of its speed on reaching the ground is $10ms^{-1}$?

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32. A molecule in a gas container hits a horizontal wall with speed $200ms^{-1}$ and angle 30° with the normal , and rebounds with the same speed . Is momentum conserved in the collision ? Is the collision elastic or inelastic ?

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33. A pump on the ground floor of a building can pump up water to fill a tank of volume $30m^3$ in 15 min. If the tank is 40 m above the ground, and the efficiency of the pump is 30%, how much electric power is consumed by the pump?

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34. The bob A of a pendulum released from 30° to the vertical hits another bob B of the same mass at rest on a table as shown in Fig. 6.15. How high does the bob A rise after the collision ? Neglect the size of the bobs and assume the collision to be elastic.

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35. The bob of a pendulum is released from a horizontal position. If the length of the pendulum is 1.5m, what is the speed with which the bob arrives at the lowermost point, given that it dissipated 5% of its initial energy against air resistance?

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36. A trolley of mass 300 kg carrying sandbag of 25 kg is moving uniformly with a speed of 27 km/h on a frictionless track. After a while, sand starts leaking out of a hole on the floor of the trolley at the rate of $0.05 kgs^{-1}$. What is the speed of the trolley after the entire sand bag is empty?

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37. A body of mass 0.5 kg travels in a straight line with velocity $v = ax^{\frac{3}{2}}$ where $a = 5m^{\frac{1}{2}}s^{-1}$. What is the work done by the net force during its displacement from x=0 to x= 2m?

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38. The blades of a windmill sweep out a circle of area A.

If the wind flows at a velocity v perpendicular to the circle, what is the mass of the air passing through it in time t?

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39. The blades of a windmill sweep out a circle of area A.

What is the kinetic energy of the air?

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40. The blades of a windmill sweep out a circle of area A.

Assume that the windmill converts 25% of the wind's energy into electrical energy, and that $A = 30m^2, v = 36k\frac{m}{h}$ and the density of air is $1.2kgm^{-3}$. What is the electrical power produced?

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41. A person trying to lose weight (dieter) lifts a 10 kg mass , one thousand times , to a height of 0.5 m each time .Assume that the potential energy lost each time she lowers the mass is dissipated . (a) How much work does she do against the gravitational force ? (b) Fat supplies 3.8×10^7 J of energy per kilogram which is converted to mechanical energy with a 20 % efficiency rate . How much fat will the dieter use up ?

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43. A family uses 8 kW of power.

Direct solar energy is incident on the horizontal surface at an average rate of 200 W per square meter. If 20% of this energy can be converted to useful electrical energy, how large an area is needed to supply 8 kW?

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44. A family uses 8 kW of power.

Compare this area to that of the roof of a typical house.

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Exercises Additional Exercises

1. A bullet of mass $0.012kg$ and horizontal speed $70ms^{-1}$ strikes a block of wood of mass $0.4kg$ and instantly comes to rest with respect to the block. The block is suspended from the ceiling by means of thin wires. Calculate the height to which the block rises. Also, estimate the amount of heat produced in the block.

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2. Two inclined frictionless tracks, one gradual and the other steep meet at A from where two stones are allowed to slide down from rest, one on each track (Fig. 6.16). Will the stones reach the bottom at the same time? Will they reach there with the same speed? Explain. Given $\theta_1 = 30^\circ, \theta_2 = 60^\circ$ and $h = 10m$, what are the speeds and times taken by the two stones?

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3. A bolt of mass $0.3kg$ falls from the ceiling of an elevator moving down with an uniform speed of $7ms^{-1}$. It hits the floor of the elevator (length of the elevator = 3m) and does not rebound. What is the heat produced by the impact? Would your answer be different if the elevator were stationary?

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4. A trolley of mass 200 kg moves with a uniform speed of 36 km/h on a frictionless track. A child of mass 20 kg runs on the trolley from one end to the other (10 m away) with a speed of $4ms^{-1}$ relative to the trolley in a direction opposite to the its motion, and jumps out of the trolley. What is the final speed of the trolley? How much has the trolley moved from the time the child begins to run?

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5. Which of the following potential energy curves in Fig. 6. 18 cannot describe the elastic collision of two billiard balls? Here r is the distance between centres of the balls.

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