2.3 WORK, ENERGY, AND POWER *HW/Study Packet*

SL/HL	
Required: READ Hamper pp 47-57 Tsokos, pp 99-11	Supplemental: Cutnell and Johnson, pp 160-183 DO Tsokos pp 112-118 #2,4,5,9,10,15,18,23

REMEMBER TO….

- ✓ *Work through all of the 'example problems' in the texts as you are reading them*
- ✓ *Refer to the **IB Physics Guide** for details on what you need to know about this topic*
- ✓ *Refer to the **Study Guides** for suggested exercises to do each night*
- ✓ *First try to do these problems using only what is provided to you from the **IB Data Booklet***
- ✓ *Refer to the solutions/key ONLY after you have attempted the problems to the best of your ability*

UNIT OUTLINE

I. WORK
- A. FORCES AND DISPLACEMENTS
- B. FORCE-DISPLACEMENT GRAPHS

II. ENERGY
- A. KINETIC AND POTENTIAL ENERGIES
- B. CONSERVATION OF ENERGY
- C. ENERGY TRANSFORMATIONS

III. POWER
- A. POWER AND ENERGY
- B. EFFICIENCY

FROM THE IB DATA BOOKLET

$$W = Fs\,cos\theta \qquad E_P = \frac{1}{2}k\Delta x^2 \qquad \text{power} = Fv \qquad \text{Efficiency} = \frac{\text{useful work out}}{\text{total work in}}$$

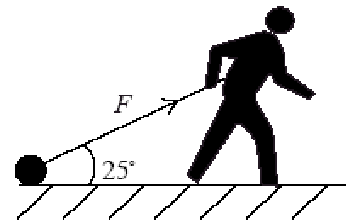
$$E_K = \frac{1}{2}mv^2 \qquad \Delta E_P = mg\Delta h \qquad = \frac{\text{useful power out}}{\text{total power in}}$$

WHAT YOU SHOULD BE ABLE TO DO AT THE END OF THIS TOPIC

- □ State the definition of work done by a force.
- □ Recognize that work done by a varying force is given by the area under the F-s graph.
- □ State definitions of kinetic energy, gravitational potential energy, and elastic potential energy.
- □ Appreciate that gravitational potential energy is calculated relative to an arbitrary 'zero' level.
- □ Understand and apply the law of conservation of energy and the work-energy theorem.
- □ List different forms of energy and describe examples of energy transformations.
- □ Recognize that, in the presence of external forces, the work done is the change in energy.
- □ Definepower in terms of work done per unit time and force applied to a moving object.
- □ Solve problems with springs by approaching them from an elastic potential energy point of view.
- □ Calculate the efficiency of certain processes.
- □ Distinguish between elastic and inelastic collisions in terms of energy transformations.
- □ Determine work done and energy/power dissipated in situations where a resistive force acts.

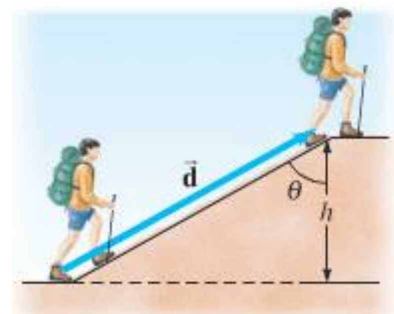
HOMEWORK PROBLEMS:

1. An athlete trains by dragging a heavy load across a rough horizontal surface. The athlete exerts a force of magnitude *F* on the load at an angle of 25° to the horizontal. Once the load is moving at a steady speed, the average horizontal frictional force acting on the load is 470 N. The load is moved a horizontal distance of 2.5 km in 1.2 hours. Calculate the work done on the load by the force *F*. **[1.2 MJ]**



2. A hiker walks up a 150 m hill and then back down again.

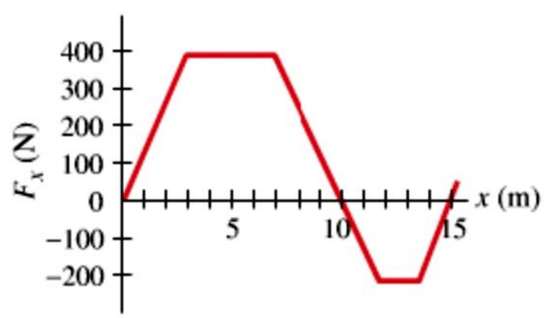
a) Determine the amount of work the hiker must do on a 15.0 kg backpack while walking up to the summit of a 150 m hill. **[22 kJ]**



b) Determine the amount of work done on the backpack when walking from the summit back down to where the hiker started. **[-22 kJ]**

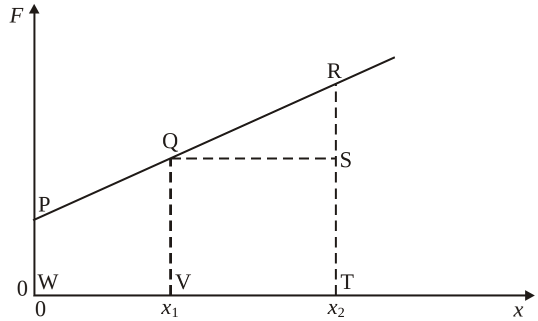
3. The force on an object, acting along the x axis, varies as shown. Determine the work done by this force to move the object

a) From 0.0 m to 10.0 m **[2800 J]**



b) From 0.0 m to 15.0 m **[about 2100 J]**

4. The diagram below shows the variation with displacement x of the force F acting on an object in the direction of the displacement.



Determine an expression for the work done by the force when the displacement changes from x_1 to x_2, in terms of the letter variables on the graph. **[W = (VT)(ST) + ½(SQ)(RS)]**

5. A body of mass m is in a gravitational field of strength g. The body is moved through a distance h at constant speed v in the opposite direction to the field. Derive an expression in terms of

a) m, g and h, for the work done on the body. **[W = mgh]**

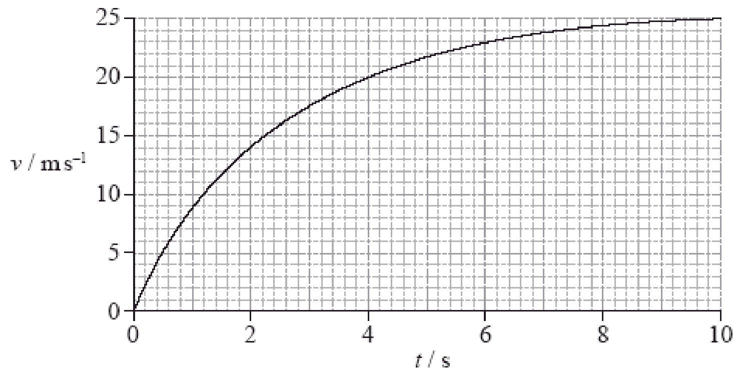
b) m, g and v, for the power required to move the body. **[P = mgv]**

c) A mass falls near the Earth's surface at constant speed in still air. Discuss the energy changes, if any, that occur in the gravitational potential energy and in the kinetic energy of the mass.

6. An object of mass m_1 has a kinetic energy K_1. Another object of mass m_2 has a kinetic energy K_2. If the momentum of both objects is the same, determine the ratio $\frac{K_1}{K_2}$ in terms of the given variables.

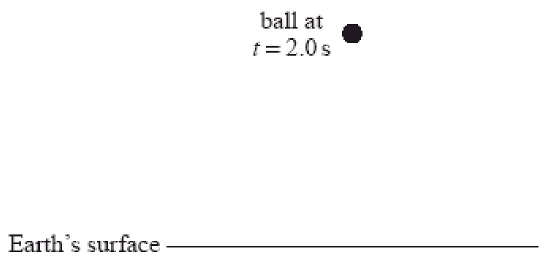
[m_2/m_1]

7. The graph shows the variation with time *t* of the speed *v* of a ball of mass 0.50 kg that has been released from rest above the Earth's surface. The force of air resistance is **not** negligible.



a) Determine the distance fallen after 2.0 s and the acceleration of the ball at 2.0 s.
[s = 15 m, a ~ 4.0 ms^{-2}]

b) In the space below, draw and label arrows to represent the forces on the ball at 2.0 s.



c) Calculate the magnitude of the force of air resistance on the ball at 2.0 s. **[about 3 N]**

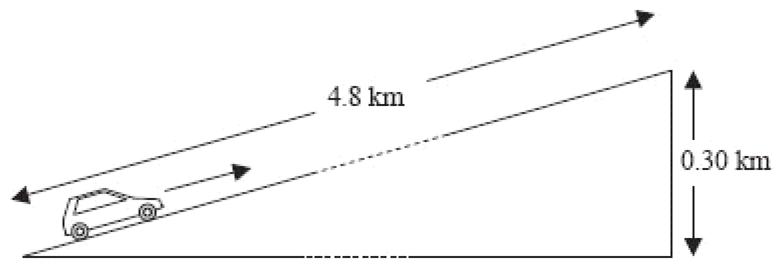
d) State and explain whether the air resistance on the ball at *t* = 5.0 s is smaller than, equal to **or** greater than the air resistance at *t* = 2.0 s.

e) After 10 s the ball has fallen 190 m. Show that the sum of the potential and kinetic energies of the ball has decreased by 780 J. Where has this energy gone?

8. A car is travelling with constant speed v along a horizontal straight road. There is a total resistive force F acting on the car.

a) Deduce that the power P to overcome the force F is $P = Fv$.

b) The car drives up a straight incline that is 4.8 km long. The total height of the incline is 0.30 km. The car moves up the incline at a steady speed of 16 m s^{-1}. During the climb, the average friction force acting on the car is 5.0×10^2 N. The total weight of the car and the driver is 1.2×10^4 N.



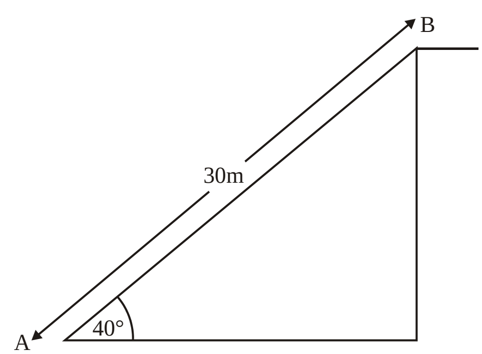
c) Determine the time it takes the car to travel from the bottom to the top of the incline. **[300 s]**

d) Determine the work done against the gravitational force in travelling from the bottom to the top of the incline. **[3.6×10^6 J]**

e) Using your answers to (c) and (d), calculate a value for the minimum power output of the car engine needed to move the car from the bottom to the top of the incline. **[20 kW]**

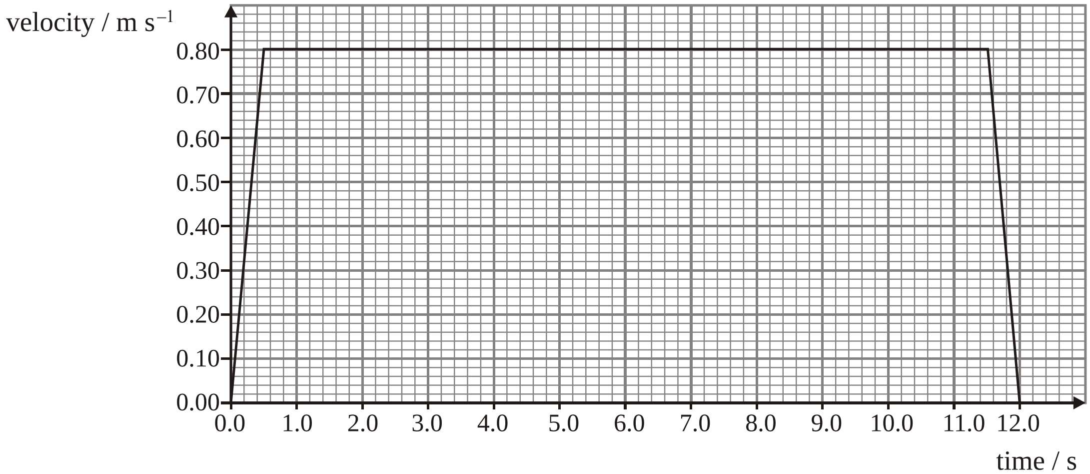
9. The diagram represents an escalator. People step on to it at point A and step off at point B. The escalator is 30 m long and makes an angle of 40° with the horizontal. At full capacity, 48 people step on at point A and step off at point B every minute.

a) Calculate the potential energy gained by a person of weight 7.0×10^2 N in moving from A to B. **[1.3×10^4 J]**



b) Estimate the energy supplied by the escalator motor to the people every minute when the escalator is working at full capacity. **[6.2×10^5 J]**

10. An elevator (lift) starts from rest on the ground floor and comes to rest at a higher floor. Its motion is controlled by an electric motor. A simplified graph of the variation of the elevator's velocity with time is shown below. The mass of the elevator is 250 kg.



Calculate:

a) the acceleration of the elevator during the first 0.50 s. **[1.6 m s^{-2}]**

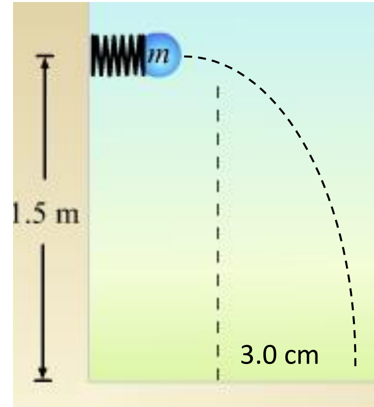
b) the total distance travelled by the elevator. **[9.2 m]**

c) the minimum work required to raise the elevator to the higher floor. **[23 kJ]**

d) the minimum average power required to raise the elevator to the higher floor. **[1.9 kW]**

e) the efficiency of the electric motor that lifts the elevator, given that the input power to the motor is 5.0 kW. **[38%]**

11. A spring is attached horizontally to a wall as shown, 1.5 m above the floor. A small ball of mass 50.0 g is pushed onto the spring, compressing it, then released. If the horizontal displacement of the ball's trajectory is 3.0 cm (see diagram), and the spring is compressed 11 cm before released, determine the spring constant k of the spring. **[0.0121 Nm^{-1}]**



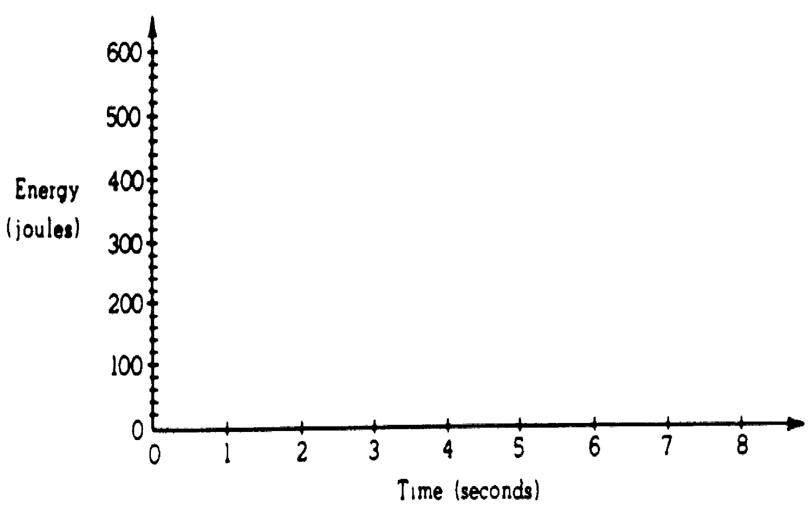
DRAWING NOT TO SCALE

12. From the top of a cliff 80.0 meters high, a football of mass 0.700 kilogram is dropped vertically from rest.

a) Calculate the potential, kinetic, and mechanical (total) energies of the ball at time t = 0 s. **[549 J, 0 J, 549 J]**

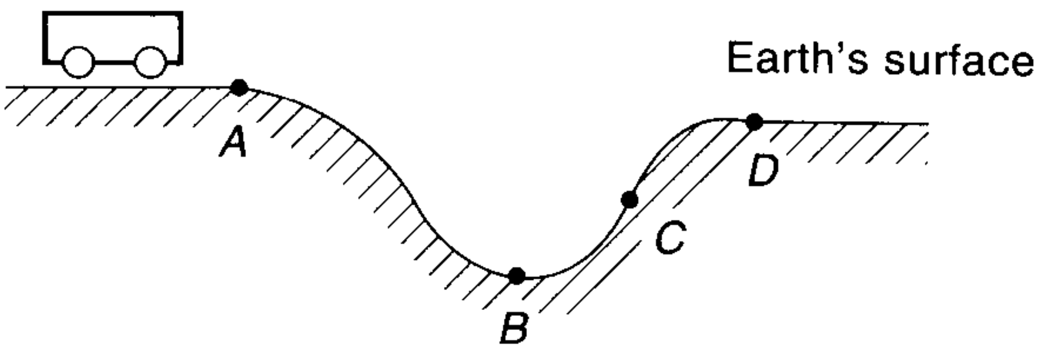
b) Calculate the potential, kinetic, and mechanical (total) energies of the ball at the *instant just before it hits the ground.* **[0J, 549 J, 549 J]**

c) On the axes below, draw and label the kinetic, potential, and mechanical (total) energies of the ball as functions of time until the ball hits.



d) Explain in detail how the answers to questions 1-3 would differ (if at all) if the ball were kicked horizontally at a certain speed instead of dropped straight down from rest.

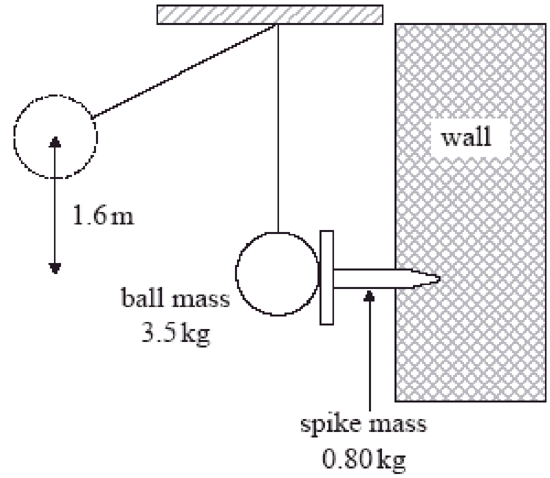
13. A 2.0 kg cart is placed on a frictionless track at point A in the diagram, and released from rest. Assume the gravitational potential energy of the mass to be zero at point B. The scale of the diagram is 1 mm = 1 m. Fill in the table below.



POINT	v (m/s)	h (m)	KE (J)	PE (J)	ME (J)
A					
B					
C					
D					

14. A large swinging ball is used to drive a horizontal iron spike into a vertical wall. The centre of the ball falls through a vertical height of 1.6 m before striking the spike in the position shown.

The mass of the ball is 3.5 kg and the mass of the spike is 0.80 kg. Immediately after striking the spike, the ball and spike move together.



a) Determine the speed of the ball when it strikes the spike. **[5.6 ms^{-1}]**

b) Given that the speed of the ball and spike immediately after the collision is 4.6 ms^{-1}, determine the energy dissipated as a result of the collision. **[9.4 J]**

c) As a result of the ball striking the spike, the spike is driven a distance 7.3×10^{-2} m into the wall. Calculate, assuming it to be constant, the friction force *F* between the spike and wall.

[6.2 ×10^{2} N]

d) The machine that is used to raise the ball has a useful power output of 18 W. Calculate how long it takes for the machine to raise the ball through a height of 1.6 m. **[3.1 s]**