T3 solutions

Chapter 3: Nature of Dynamic Forces

(Take $g = 9.8\ m/s^2$ unless otherwise given)

1. State the Law of Inertia. Newton's 1st Law — Fig 3.5 (the right-hand side definition)

2. The mass of a metal ball measured is 5 kg. What is its mass ~~if you weight it~~ in Mars? $g = 3.7\ m/s^2$ in MARS.
   mass is independent of gravity. Answer is 5kg.

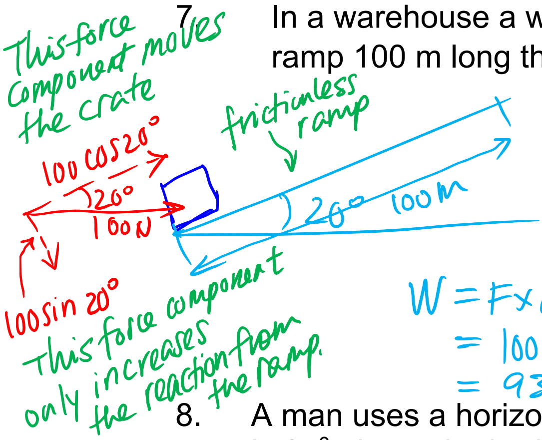
3. A force of 20N is used to push a 70 kg crate a distance of 3 m across a level warehouse floor. How much work is done? 20N ⟶ □
   $W = F \times d = 20 \times 3 = 60J$

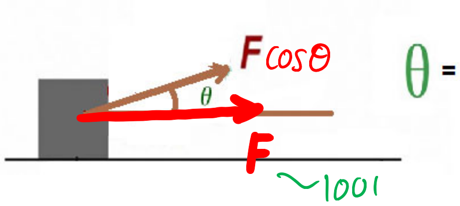
4. A force of 285N is used to push a 90 kg crate a distance of 4 m across a level warehouse floor.
   a. How much work is done? $W = F \times d = 285 \times 4 = 1140J$ or $1.14kJ$
   b. What is the change in crate's potential energy? No change in P.E. as there is no work done against or for gravity.

5. How much work is done in raising a 2-kg box from the ground to a height of 2 m?
   F is required to move the box which weighs mg. F ↑ ↓ mg
   $W = F \times d = mgh = 2 \times 9.8 \times 2 = 39.2J$

6. How much (a) work is done in raising a 9kg wooden plank from the ground to a height of 1.78 m and how potential energy does the ~~book~~ plank have in its new position?
   $P.E. = \underbrace{m}_{9}\underbrace{g}_{9.8}\underbrace{h}_{1.78} = 157J$

7. In a warehouse a worker uses a horizontal force of 100N to push a crate up a ramp 100 m long that is 20^0 above the horizontal as shown in Figure 3.7.





$W = F \times d = 100\cos 20^\circ \times 100 = 9397J$ or $9.4kJ$

Figure 3.7

8. A man uses a horizontal force of 275N to push a crate up a ramp 7 m long that is 25^0 above the horizontal. Refer to Figure 3.8.
   DIY ⟶ (similar to Q7)
   a. How much work does the man perform? Answer: 1745 J
   b. If the man takes 15 s to push the crate up the ramp, what is his power output in watts? $P = \frac{Work}{t} = \frac{1745}{15} W = 116 W$

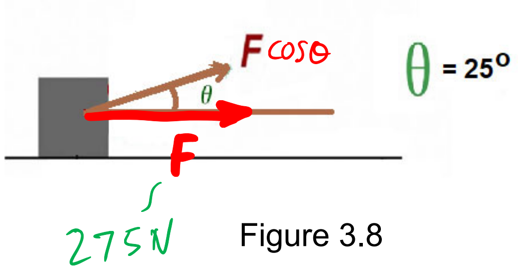


Figure 3.8

9. A cargo weighing 2Kg broke free from the top of the cargo ramp as shown in Figure 3.9. . Ignoring friction, determine the velocity of the cargo the instant it reaches the bottom of the ramp.

method 1

$v^2 - u^2 = 2as \sim 10$

$u = 0$, $F \sim 3.4N$, $m \sim 2kg$

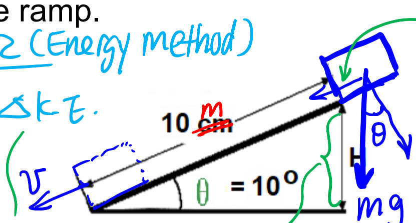
$v^2 = 2 \times 1.7 \times 10 = 34$

$v = \sqrt{34} = 5.83\ m/s$

method 2 (Energy method)

$\Delta P.E. = \Delta K.E.$

$mgh = \frac{1}{2}mv^2$



$10\sin 10°$

$2 \times 9.8 = 19.6N$

$19.6\sin\theta$

$19.6\sin 10°$

$3.40N$

Figure 3.9

$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$v^2 = 2gh = 2 \times 9.8 \times 10\sin 10° = 34$

$\therefore v = \sqrt{34} = 5.83\ m/s$

10. State the conservation of energy principle

Energy can neither be created nor destroyed.

11. Name the energy converted when a ball drops from a still position 2m above the ground. Potential energy → kinetic energy → sound & heat energy.

12. A 40 kg wooden crate is being pushed across a wooden floor with a force of 200N. If frictional coefficient $\mu_k = 0.3$, find the acceleration of the crate.

200N → 40kg

$F = 0.3 \times 40 \times g = 117.6N$

$F_{resultant} = 200 - 117.6 = 82.4N \Rightarrow a = \frac{F}{m} = \frac{82.4}{40} = 2.06\ m/s^2$

13. An 85 kg wooden crate is being accelerated at 0.118 m/s^2 across a wooden floor by a force of M. If frictional coefficient $\mu_k = 0.3$ and, find M in Newton.

M → 85kg → $0.118\ m/s^2$

Friction $= 0.3 \times 85 \times g = 250N$

$F_{resultant} = ma = 85 \times 0.118 = 10.0N$ $M - 250 = 10$ $\Rightarrow M = 260N$

14. A wooden board is being nailed by a 2 kg hammer head. The hammer's speed is 10 m/s when it strikes the nail. The nail moved 2 cm into the board, find the average force the hammer is exerting on the nail. Work done is by the K.E. of the hammer. $\therefore Fd = \frac{1}{2}mv^2 \Rightarrow F = \frac{1}{2} \times 2 \times 10^2 \times \frac{1}{0.02} = 5000N$ or $5kN$

15. A 2.5 kg snowball moving at a speed of 30 m/s strikes and sticks to a 75 kg man standing on the frictionless surface of a frozen pond. What is the man's final velocity after the snowball hits him?

Conservation of total momentum

Initial momentum $= 2.5 \times 30 = 75\ kgm/s$

Final momentum $= (2.5 + 75) \times v$

$77.5v = 75$

$v = 0.97\ m/s$

16. A 2000 kg solar car strikes a fence at a speed of 20 m/s and comes to a stop in 4 s. What is the average force acted on the car?

Force is the rate of change of momentum $\therefore F = \frac{2000 \times (-20)}{4} = -10000N$ or $-10kN$

17. A certain solar car has a mass of 495 kg and travelling at velocity of 65 km/hr. Its engines develop a total thrust of 650N. If air resistance is ignored, how long does this solar car takes to reach its velocity starting from rest?

method 1

$a = \frac{F}{m} = \frac{650}{495} = 1.31\ m/s^2$

$v = u + at \Rightarrow 18.06 = 1.31 \times t \Rightarrow t = 13.8s$ $u = 0$

$v = \frac{65000}{3600}\frac{m}{s} = 18.06\ m/s$

18. A 0.65 kg ball moving in the + x-direction at 11m/s is hit by a bat. Its final velocity is 21 m/s in the –x-direction. The bat acts on the ball for 0.22 s. Find the average force F exerted on the ball by the bat. (See next page)

19. Name 4 principal type of gears and one of their applications (Refer to module notes)

Q17 method 2

Impulse results in momentum change

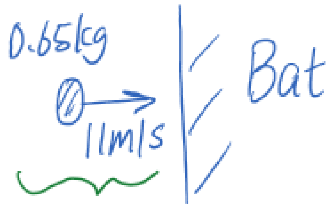
$F \times \Delta t$ $\qquad \Delta(mv)$ or $m\Delta v$ since m is constant

$\Rightarrow 650 \times \Delta t = 495 \times \left(\frac{65000}{3600} - 0\right)$

$\Delta t = \frac{495 \times 18.06}{650} = 13.8s$

Q18 Solution

Before

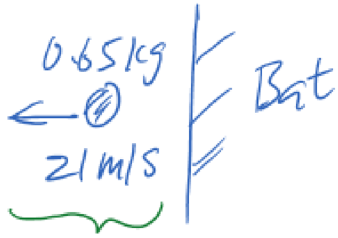


momentum P

$= 0.65 \times 11$

$= 7.15 \text{ kgm/s}$

After



momentum P

$= -0.65 \times 21$

$= -13.65 \text{ kgm/s}$

$\underbrace{\text{Applied Impulse}}_{\vec{F} \times \Delta t_{\sim 0.22s}}$ results in $\underbrace{\text{momentum change}}_{\Delta p = -13.65 - 7.15 = -20.8 \text{ kgm/s}}$

$$F = \frac{-20.8 \text{ kgm/s}}{0.22 \text{ s}}$$

$$= -94.5 \text{ N}$$

the force acted on the ball is in the $-ve$ x direction. This is expected.