



Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. mechanical advantage
2. velocity ratio
3. fixed pulley
4. inclined plane
5. pitch
6. continuous lever
7. perfect machine
8. friction

K • 4

Each carries 0.5 mark.

2 Label the diagram

- | | |
|--------------------------|--------------------------------|
| 1. single fixed pulley | 4. halves the effort |
| 2. changes the direction | 5. fixed + movable |
| 3. single movable pulley | 6. halves it and turns it down |

K • 3

Each carries 0.5 mark.

3 Multiple choice

- i. **d. to change the direction of the force**

U • 1

A single fixed pulley has $VR = 1$ and MA of 1 or a little less. Its use is to let us pull down (helped by our own weight) to lift a load up.

- ii. **c. three**

K • 1

In a block and tackle, the number of rope segments holding the load equals the number of pulleys, so $VR = 3$.

- iii. **c. three**

A • 1

$VR = l \div h = 6 \text{ m} \div 2 \text{ m} = 3$.

- iv. **a. 100%**

K • 1

In a perfect (ideal) machine there is no friction, so output work = input work and $\eta = 100\%$. No real machine reaches it, and none can exceed it.

- v. **a. wheel and axle, and lever**

U • 1

The wheel turns on an axle (wheel and axle), and the barrow is a lever with its fulcrum at the wheel's axle, the load in the middle and the effort at the handles.

4 Very short answers

- a. **MARKING SCHEME**

K • 1

✓ $VR = R/r$, with R the radius of the wheel and r of the axle.

- b. **MARKING SCHEME**

U • 1

✓ Each is a ratio of two like quantities (force ÷ force, distance ÷ distance), so the units cancel.

- c. **MARKING SCHEME**

U • 1

✓ Levers and wedges.



5 Short answers

a. MARKING SCHEME

U • 2

- ✓ Any one difference, e.g. VR is effort distance $\div$ load distance; MA is load $\div$ effort.
- ✓ Any second difference, e.g. VR depends only on the design of the machine and is not changed by friction; MA is lowered by friction.

b. MARKING SCHEME

U • 2

- ✓ A winding road is a long, gentle inclined plane: for the same height a longer road has a larger VR ($l \div h$).
- ✓ So vehicles need less force to climb it with heavy loads (and it is safer to drive).

c. MARKING SCHEME

U • 2

- ✓ It works like a lever: the axis is the fulcrum, the effort acts on the wheel (arm R) and the load on the axle (arm r).
- ✓ It can turn round through 360° , with new points taking the place of the effort and load points, so it works as a lever continuously.

6 Long answer

ANSWER

U • 4

The diagram shows a wheel of radius R and an axle of radius r fixed on the same axis, with the effort rope wound on the wheel and the load rope on the axle. In one complete turn, the effort rope unwinds by the circumference of the wheel, $2\pi R$ (the effort distance), and the load rope winds up by the circumference of the axle, $2\pi r$ (the load distance). So $VR = \text{effort distance} \div \text{load distance} = 2\pi R \div 2\pi r = R \div r$.

MARKING SCHEME

- ✓ A labeled diagram: wheel (R) and axle (r) on one axis, effort on the wheel's rope, load on the axle's rope.
- ✓ In one turn, the effort moves the circumference of the wheel, $2\pi R$.
- ✓ In one turn, the load moves the circumference of the axle, $2\pi r$.
- ✓ $VR = 2\pi R \div 2\pi r = R \div r$.

7 Numerical problems

a. ANSWER

A • 4

Load = weight of the box = $mg = 90 \times 10 = 900 \text{ N}$.

MA = load $\div$ effort = $900 \div 300 = 3$.

VR = $l \div h = 20 \div 5 = 4$.

Efficiency = $MA \div VR \times 100\% = 3 \div 4 \times 100\% = 75\%$.

MARKING SCHEME

- ✓ Load = $mg = 90 \times 10 = 900 \text{ N}$.
- ✓ MA = $900 \div 300 = 3$.
- ✓ VR = $l \div h = 20 \div 5 = 4$.
- ✓ Efficiency = $MA \div VR \times 100\% = 75\%$.

b. ANSWER

A • 4

Four rope segments hold the load, so VR = 4.

i. From $\eta = MA \div VR \times 100\%$: $80 = MA \div 4 \times 100$, so MA = 3.2.

ii. MA = load $\div$ effort, so effort = $1000 \div 3.2 = 312.5 \text{ N}$.

iii. Output work = load $\times$ load distance = $1000 \text{ N} \times 6 \text{ m} = 6000 \text{ J}$. (The effort moves $4 \times 6 = 24 \text{ m}$, so the input work is $312.5 \times 24 = 7500 \text{ J}$; $6000 \div 7500 = 80\%$.)

MARKING SCHEME

- ✓ VR = 4 (four rope segments hold the load).
- ✓ MA = $\eta \times VR \div 100 = 0.8 \times 4 = 3.2$.
- ✓ Effort = $1000 \div 3.2 = 312.5 \text{ N}$.
- ✓ Output work = $1000 \text{ N} \times 6 \text{ m} = 6000 \text{ J}$.



8 Think

ANSWER

HA - 2

Three reasons. Each extra pulley adds **friction** and **weight** (the lower block must be lifted too), so the efficiency falls. The rope you must pull gets enormously long: with 100 segments, lifting a load 1 m would need 100 m of rope. And the lift becomes very **slow**. Real cranes use a few pulleys and a motor-driven drum, a wheel and axle, to wind the rope.

MARKING SCHEME

- ✓ Each extra pulley adds friction and weight (the lower block must be lifted too), so the efficiency falls.
- ✓ The rope to be pulled becomes very long (100 m for 1 m of lift with 100 segments) and the lift very slow.

9 Activity: Three planks, one height (Activity 8.3)

(not marked)

WHAT STUDENTS SHOULD FIND

$VR = l \div 60$ is 3.3, 5 and 6.7. The longest plank (400 cm) needs the least effort, so its MA is the largest too: as the plank gets longer and gentler, both VR and MA increase. MA is always a little less than VR, because of friction between the block and the plank.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Simple Machines Around Us** (exhibit): Sort the everyday tools by the simple machine inside each: lever, wedge, screw, wheel.
- **Pulley Systems** (exhibit): Lift the load with one pulley, then with several: more rope sections share its weight.
- **Build a Gear Train** (exhibit): Build a gear train and turn it: each gear turns the other way from its neighbor.
- **Gears - Motion Passed Along** (exhibit): Turn the small gear: the big one turns more slowly, but with a stronger turning force.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	10	14	9	2	35

