Past-paper walk-through

Energy conservation ▪ 5.1

eXercise

Questions in this set

- 9702/11 N25 Q19 ▪ 1 mark
- 9702/12 N25 Q19 ▪ 1 mark
- 9702/12 N25 Q20 ▪ 1 mark
- 9702/14 N25 Q16 ▪ 1 mark
- 9702/14 N25 Q18 ▪ 1 mark
- 9702/11 J25 Q18 ▪ 1 mark
- 9702/12 J25 Q19 ▪ 1 mark
- 9702/12 J25 Q20 ▪ 1 mark
- 9702/13 J25 Q17 ▪ 1 mark
- 9702/14 J25 Q14 ▪ 1 mark

Questions in this set

- 9702/14 J25 Q15 ▪ 1 mark
- 9702/21 N24 Q3 ▪ 11 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 19

9702/11 N25 ▪ Q19 ▪ 1 mark

A sailboat is pushed by the wind at a constant velocity v across a lake.
The force of the wind and the velocity of the sailboat are in the same direction.
Which additional information is required to determine the work done per unit time by the wind acting on the sailboat? **[1]**

A the force exerted by the wind

B the distance travelled by the sailboat per unit time

C the total energy input to the sailboat by the wind

D the weight of the sailboat

Solution 19

A the force exerted by the wind ✓

B the distance travelled by the sailboat per unit time

C the total energy input to the sailboat by the wind

D the weight of the sailboat

Why

- Work per unit time is power, and for a force along the motion $P = Fv$.
- The speed v is already given in the question, so the only missing quantity is the force.
- B just restates the speed, and C and D are not needed at all.

Question 19

9702/12 N25 ▪ Q19 ▪ 1 mark

The diagram shows a block on a slope.

A constant force of 1.8 N in a direction parallel to the slope is exerted on the block.

This causes the block to move along the slope at a constant speed.

The block moves a distance of 8.0 m along the slope and gains height *h*. The work done against the frictional force acting on the block is 4.8 J.

The weight of the block is 4.0 N.

What is the value of *h*? **[1]**

A 1.2 m

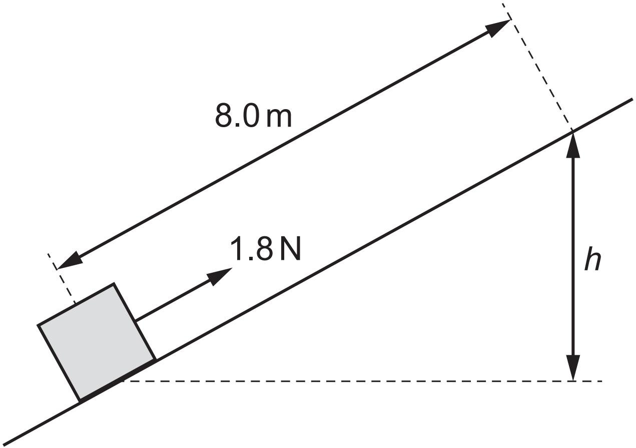
B 2.4 m

C 3.6 m

Question 19

D 4.8 m

Question 19



Solution 19

A 1.2 m

B 2.4 m ✓

C 3.6 m

D 4.8 m

Why

- The applied force does $1.8 \times 8.0 = 14.4$ J of work.
- At constant speed that all goes to friction and to lifting the block: $14.4 = 4.8 + 4.0h$.
- So $h = 9.6/4.0 = 2.4$ m.

Question 20

9702/12 N25 ▪ Q20 ▪ 1 mark

The motor of a crane lifts a load of mass 600 kg. The load rises vertically at a constant speed of 12 m per minute.

What is the useful power output of the motor? **[1]**

A 0.12 kW

B 1.2 kW

C 7.2 kW

D 71 kW

Solution 20

A 0.12 kW

B 1.2 kW ✓

C 7.2 kW

D 71 kW

Why

- Convert the speed: 12 m per minute is $12/60 = 0.20$ m s^{-1}.
- At constant speed the useful force equals the weight, so $P = mgv$.
- $P = 600 \times 9.81 \times 0.20 = 1180$ W, about 1.2 kW.

Question 16

9702/14 N25 ▪ Q16 ▪ 1 mark

The diagram shows a block P of mass M connected by a string over a frictionless pulley to a block Q of mass m.

Block P moves up the slope with a constant velocity v. The slope is at angle θ to the horizontal.

The acceleration of free fall is g.

The resistive forces on the blocks are negligible.

Which expressions give the energy transferred per unit time to block P?

1 mgv 2 $Mgv\sin\theta$ 3 $(M+m)gv$ **[1]**

A 1 and 2

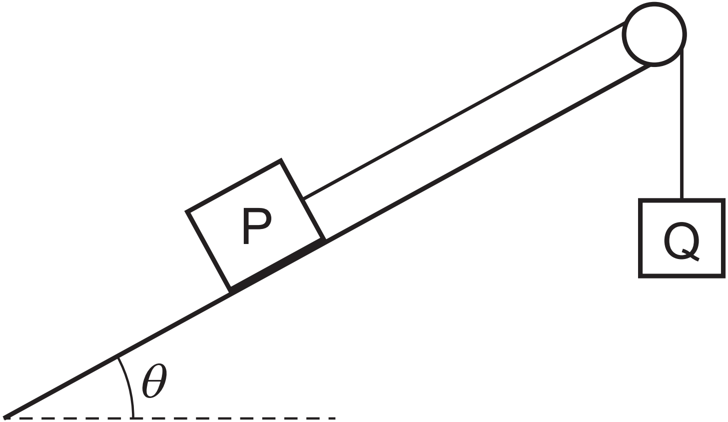
B 1 only

C 2 and 3

Question 16

D 2 only

Question 16



Solution 16

A 1 and 2 ✓

B 1 only

C 2 and 3

D 2 only

Why

- Q descends at speed v, so it releases energy at a rate mgv – statement 1.
- P rises a vertical height $v \sin\theta$ each second, gaining potential energy at $Mgv \sin\theta$ – statement 2.
- At constant speed with no friction $mg = Mg \sin\theta$, so the two expressions are equal and both are right.

Question 18

9702/14 N25 ▪ Q18 ▪ 1 mark

The total energy supplied to an electric motor is E. Energy Q is wasted and the remaining energy does useful work.

What is the efficiency of the motor? **[1]**

A $\frac{Q}{E}$

B $\left(\frac{Q}{E}\right) - 1$

C 1 - \left(\frac{Q}{E}\right)

D \frac{(1 - Q)}{E}

Solution 18

A $\frac{Q}{E}$

B $\left(\frac{Q}{E}\right) - 1$

C 1 - \left(\frac{Q}{E}\right) ✓

D \frac{(1 - Q)}{E}

Why

- The useful energy is what is left after the waste: $E - Q$.
- Efficiency is useful over total, so it is $(E - Q)/E$.
- That simplifies to $1 - Q/E$.

Question 18

9702/11 J25 ▪ Q18 ▪ 1 mark

The points X, Y and Z are on a rough, horizontal surface.
A box P is pushed across the surface from X to Y and then from Y to Z.
The distance from X to Y is 3.0 m. The work done against the frictional force in moving the box from X to Y is 150 J.
The work done against the frictional force in moving the box from Y to Z is 200 J.
An identical box Q is pushed in a straight line from X to Z.
The magnitude of the frictional force between the boxes and the surface is constant.
How much extra work is done against the frictional force in moving P than Q? **[1]**

A 100 J

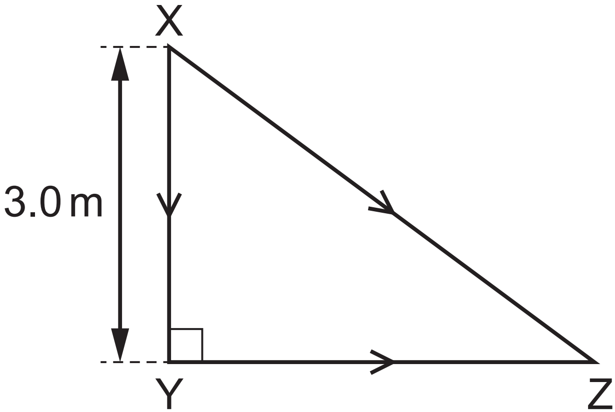
B 250 J

C 350 J

Question 18

D 600 J

Question 18



Solution 18

A 100 J ✓

B 250 J

C 350 J

D 600 J

Why

- Friction is $150/3.0 = 50$ N, so the 200 J from Y to Z means YZ $= 4.0$ m.
- X, Y and Z form a 3–4–5 right-angled triangle, so the direct path XZ is 5.0 m.
- P travels 7.0 m and Q only 5.0 m, so the extra work is $50 \times 2.0 = 100$ J.

Question 19

9702/12 J25 ▪ Q19 ▪ 1 mark

A box of mass 4.9 kg is pushed at a constant velocity from point P at the bottom of an inclined plane to point Q at the top.
The box is pushed by a force of 64 N acting parallel to the slope.
The slope is inclined at an angle of $20°$ to the horizontal and the box moves through a vertical height of 5.8 m.
What is the work done against the frictional force acting on the block between P and Q? **[1]**

A 280 J

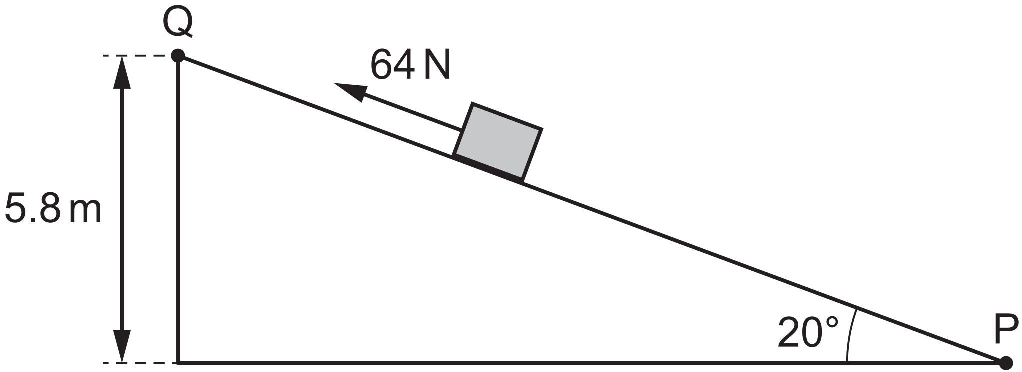
B 810 J

C 960 J

Question 19

D 1100 J

Question 19



Solution 19

A 280 J

B 810 J ✓

C 960 J

D 1100 J

Why

- The distance along the slope is $5.8/\sin 20° = 17.0$ m.
- The pushing force does $64 \times 17.0 = 1085$ J of work.
- At constant speed the rest goes to friction: $1085 - (4.9 \times 9.81 \times 5.8) = 810$ J.

Question 20

9702/12 J25 ▪ Q20 ▪ 1 mark

Which expression gives the efficiency of a system? **[1]**

A

$$\frac{\text{total energy input}}{\text{useful energy output}}$$

B

$$\frac{\text{useful energy output} + \text{wasted energy output}}{\text{total energy input}}$$

C

$$\frac{\text{useful energy output}}{\text{total energy input}}$$

Question 20

D

$$\frac{\text{wasted energy output}}{\text{total energy input}}$$

Solution 20

A

$$\frac{\text{total energy input}}{\text{useful energy output}}$$

B

$$\frac{\text{useful energy output} + \text{wasted energy output}}{\text{total energy input}}$$

C

$$\frac{\text{useful energy output}}{\text{total energy input}}$$

✓

D

$$\frac{\text{wasted energy output}}{\text{total energy input}}$$

Why

- Efficiency is useful output energy divided by total input energy.

Question 17

9702/13 J25 ▪ Q17 ▪ 1 mark

17 An electric motor uses 1.7 kW of power when operating normally.

The efficiency of the motor is 53%.

What is the useful output power of the motor?

A 0.032 kW **B** 0.90 kW **C** 3.2 kW **D** 90 kW

Solution 17

Answer: **B**

Why

- Useful output power is the efficiency multiplied by the input power.
- $0.53 \times 1.7 = 0.90$ kW.
- C divides by the efficiency instead of multiplying, which would make the motor a source of energy.

Question 14

9702/14 J25 ▪ Q14 ▪ 1 mark

14 In which situation is work done on an object?

A The object slides with a constant velocity along a horizontal frictionless surface in a vacuum.

B A person holds the object at arm's length and at a fixed height above the ground.

C A person pushes the object up a frictionless ramp.

D The stationary object floats partially submerged in water.

Solution 14

Answer: **C**

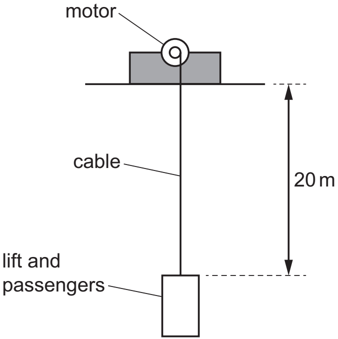
Why

- Work is done only when a force has a component along the movement.
- Pushing the object up the ramp moves it in the direction of the push, so work is done on it.
- A has no force, B has no movement, and D is stationary – none does work.

Question 15

9702/14 J25 ▪ Q15 ▪ 1 mark

15 An electric motor operating a lift has an output power of 20 kW.



Question 15

1500 kg

The lift and passengers have a combined mass of 1500 kg. The motor raises the lift at constant speed through a distance of 20 m.

How long does it take?

A 6 s **B** 15 s **C** 30 s **D** 60 s

Solution 15

Answer: **B**

Why

- The useful work is the gain in gravitational potential energy: $1500 \times 9.81 \times 20 = 2.94 \times 10^5$ J.
- Time is work divided by power: $2.94 \times 10^5 / 20\,000$.
- That gives 14.7 s, which rounds to 15 s.

Question 3

9702/21 N24 ▪ Q3 ▪ 11 marks

3 (a) State what is meant by the work done by a force [1]
(b) A block of mass m is raised vertically at constant speed. The vertical height gained by the block is Δh, as shown in Fig. 3.1. Δh block, mass m Fig. 3.1
Derive an expression, in terms of m and Δh, for the change in gravitational potential energy ΔEP of the block. State the meaning of any other symbols you use.
[2]
(c) An electric motor has an input power of 900 W. The motor takes 1.0 minute to lift a load of weight 240 N at constant speed through a vertical height of 150 m. Resistive forces are negligible.
(i) Show that the work done by the motor on the load in 1.0 minute is 36 kJ.
[1] , ,
(ii) Determine the useful output power of the motor.

Question 3

power = W [2]
(iii) Use your answer in (c)(ii) to determine the efficiency of the motor.
efficiency = [2]
(iv) Some of the power wasted in the motor is dissipated by the resistance of its coil.
This dissipated power is 280 W.
The coil of the motor is made from wire of total length 23 m. The wire has a cross-sectional area of 2.6 × 10–8 m2 and is made from metal of resistivity 1.7 × 10–8 Ω m.
Calculate the current in the coil.
current = A [3]

, ,

(a) State what is meant by the work done by a force. **[1]**

Question 3

(b) A block of mass m is raised vertically at constant speed through a height Δh. Derive an expression, in terms of m and Δh, for the change in gravitational potential energy ΔE_P of the block. State the meaning of any other symbols you use. **[2]**

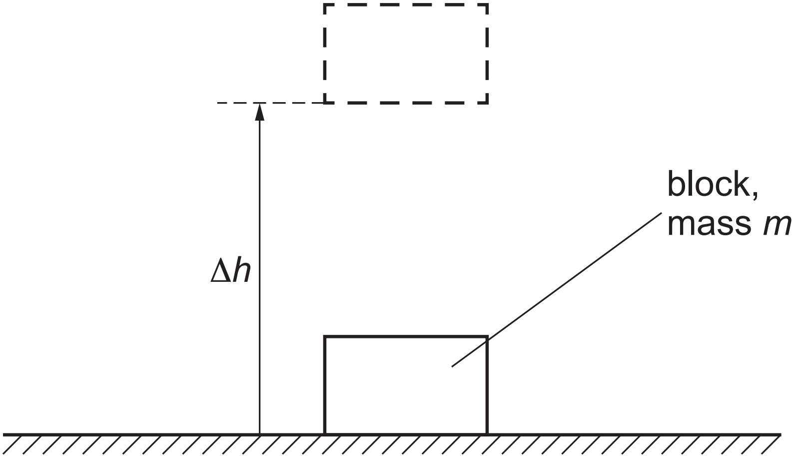
(c)(i) An electric motor raises the block with a force of 240 N through a vertical distance of 150 m. Calculate the work done on the block. **[1]**

(c)(ii) The motor takes 60 s to raise the block. Calculate the useful output power of the motor. **[2]**

(c)(iii) The input power to the motor is 900 W. Calculate the efficiency of the motor. **[2]**

(c)(iv) The cable supplying the motor has length 23 m, cross-sectional area 2.6×10^{-8} m^2 and resistivity 1.7×10^{-8} Ω m. The power dissipated in the cable is 280 W. Calculate the current in the cable. **[3]**

Question 3



Solution 3

(a)

Mark scheme

- product of force and displacement in direction of force

Solution 3

(b)

Worked steps

Start from the definition of work and identify each symbol as you introduce it.

- The block moves at constant speed, so the lifting force equals the weight: $F = mg$, where g is the acceleration of free fall.
- Work done by that force $= F \times \Delta h$.
- All of it becomes gravitational potential energy, so $\Delta E_{\mathrm{P}} = mg\Delta h$.

Mark scheme

- weight/force $=$ mg, and g identified as acceleration of free fall
- ΔEP identified as work (done by lifting force/weight), and so $=$ mg $\times$ Δh

Solution 3

(c)(i)

Worked steps

- $W = Fs = 240 \times 150$
- $W = 36\,000 \text{ J} = 36 \text{ kJ}$

Mark scheme

- $240 \times 150 = 36\,\text{kJ}$

Solution 3

(c)(ii)

Worked steps

- $P = \dfrac{W}{t} = \dfrac{36\,000}{60}$
- $P = 600\ \mathrm{W}$

Mark scheme

- $\mathrm{P} = \mathrm{W} / \mathrm{t}$
- $= 36\,000 / 60$
- $= 600\,\mathrm{W}$

Solution 3

(c)(iii)

Worked steps

- Efficiency $= \dfrac{\text{useful output power}}{\text{total input power}} = \dfrac{600}{900}$
- Efficiency $= 0.67$ (67%)

Mark scheme

- efficiency = useful output power / total input power
- = 600 / 900
- = 0.67

Solution 3

(c)(iv) Worked steps

Two steps: the cable's resistance from its dimensions, then the current from the power.

- $R = \dfrac{\rho L}{A} = \dfrac{1.7 \times 10^{-8} \times 23}{2.6 \times 10^{-8}} = 15\ \Omega$
- $P = I^2 R$, so $I = \sqrt{\dfrac{P}{R}} = \sqrt{\dfrac{280}{15}}$
- $I = 4.3$ A

Solution 3

Mark scheme

- $P = I2R$ and $R = \rho L / A$
- $280 = I2 \times (1.7 \times 10–8 \times 23) / (2.6 \times 10–8)$
- $I = 4.3$ A
- 9702/21
- October/November 2024