ESAT-style practice paper

Set A Physics

TIME ALLOWED
40
MINUTES

27 multiple-choice questions

An average of 89 seconds per question.

Instructions

- Attempt all 27 questions.
- Calculators are *not* permitted.
- No formula booklet is provided.
- Use scrap paper or a whiteboard for rough working.

Information

- Each question has one correct answer and is worth one mark.
- No marks are deducted for incorrect answers.
- The questions are not arranged in order of difficulty.
- The ESAT itself is taken on a computer, with erasable sheets for rough working.

Questions

Question 1 *Mechanics* 2
Question 2 *Atomic Physics & Radioactivity* 3
Question 3 *Thermal Physics* 4
Question 4 *Atomic Physics & Radioactivity* 5
Question 5 *Magnetism* 6
Question 6 *Electricity* 7
Question 7 *Atomic Physics & Radioactivity* 8
Question 8 *Mechanics* 9
Question 9 *Electricity* 10
Question 10 *Mechanics* 11
Question 11 *Waves & Optics* 12
Question 12 *Electricity* 13
Question 13 *Thermal Physics* 14
Question 14 *Atomic Physics & Radioactivity* 15
Question 15 *Waves & Optics* 16
Question 16 *Mechanics* 17
Question 17 *Mechanics* 18
Question 18 *Thermal Physics* 19
Question 19 *Mechanics* 20
Question 20 *Thermal Physics* 21
Question 21 *Mechanics* 22
Question 22 *Waves & Optics* 23
Question 23 *Electricity* 24
Question 24 *Magnetism* 25
Question 25 *Mechanics* 26
Question 26 *Waves & Optics* 27
Question 27 *Mechanics* 28

Mechanics

1. A stone is dropped from rest at a height h above the surface of a planet.

The gravitational field strength near the surface is g and is constant over this distance.

Air resistance is negligible.

Which expression gives the time taken for the stone to reach the surface?

A $\sqrt{\dfrac{h}{g}}$

B $\sqrt{\dfrac{2h}{g}}$

C $\sqrt{\dfrac{h}{2g}}$

D $\sqrt{\dfrac{2g}{h}}$

E $\dfrac{2h}{g}$

F $\dfrac{h}{2g}$

Atomic Physics & Radioactivity

2. An ion has a mass number of 37 and a charge of 1^-.

The ion contains 18 electrons.

Which row gives the number of protons and the number of neutrons in the ion?

	Protons	**Neutrons**
A	17	19
B	17	20
C	18	18
D	18	19
E	19	17
F	19	18

Thermal Physics

3. A sealed rigid metal can contains air. The can is taken from a warm room and placed in a freezer. The air inside the can is cooled, but no air enters or leaves the can, and the volume of the can does not change.

Consider the following statements about the air inside the can while it cools.

I The average speed of the air particles decreases

II The density of the air inside the can decreases

III The pressure of the air on the inside walls of the can decreases

IV The rate at which momentum is transferred to the walls remains unchanged

Which of the statements are true?

A I only

B III only

C I and II only

D I and III only

E II and III only

F I and IV only

G I, II and III only

H I, III and IV only

Atomic Physics & Radioactivity

4. A bismuth-212 nucleus, $^{212}_{83}\text{Bi}$, emits one β^- particle.

The resulting nucleus then emits one α particle.

Which row gives the nuclide formed and the number of neutrons in its nucleus?

	nuclide formed	**number of neutrons**
A	$^{212}_{84}\text{Po}$	128
B	$^{212}_{82}\text{Pb}$	130
C	$^{208}_{84}\text{Po}$	124
D	$^{208}_{82}\text{Pb}$	126
E	$^{208}_{81}\text{Tl}$	127
F	$^{204}_{82}\text{Pb}$	122

Magnetism

5. A rectangular conducting loop moves to the right at constant speed without rotating.

The adjacent regions P and Q contain uniform magnetic fields of equal magnitude: out of the page in P and into the page in Q.

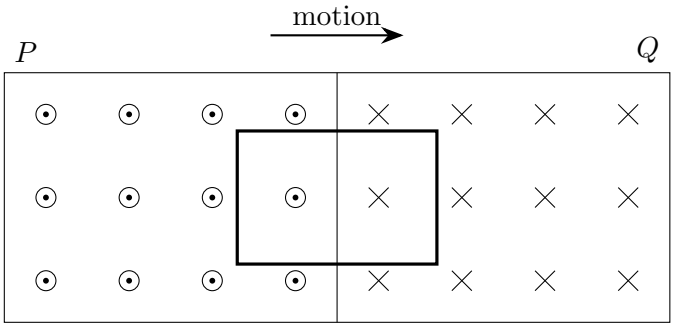
The field is zero outside these regions, and each region is wider than the loop in the direction of motion.

As the loop enters P from the left, the current in the loop is clockwise and has magnitude I.

The diagram shows a later position, with the loop's left-hand vertical side in P and its right-hand vertical side in Q.

The resistance of the loop is constant.

What is the current in the loop in the position shown?



A no current

B clockwise, with magnitude I

C anticlockwise, with magnitude I

D clockwise, with magnitude $2I$

E anticlockwise, with magnitude $2I$

F clockwise, with magnitude $4I$

G anticlockwise, with magnitude $4I$

Electricity

6. Two resistors have resistances 6.0 Ω and 3.0 Ω.

The resistors are first connected in series with a 24 V battery, and then disconnected and connected in parallel with the same battery.

The battery and connecting wires have negligible resistance, and the resistance of each resistor remains constant.

In each arrangement, a charge of 120 C flows through the battery.

What is the total energy dissipated in the 6.0 Ω resistor in the two arrangements?

A 960 J

B 1440 J

C 1920 J

D 2880 J

E 3840 J

F 4800 J

G 5760 J

Atomic Physics & Radioactivity

7. Three radioactive sources X, Y and Z are tested separately using the arrangement below.

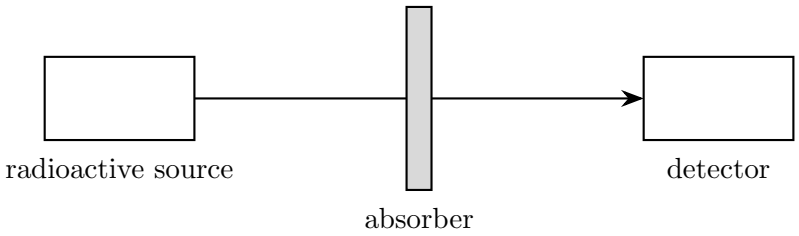
Each source emits only alpha, only beta or only gamma radiation, and each type is emitted by one source.

The absorbers are a sheet of paper, a 3 mm thick sheet of aluminium and a 2 cm thick sheet of lead, each used on its own.

The table gives the count rate due to each source, in counts per minute, after the background count rate has been subtracted.

source	paper	aluminium	lead
X	0	0	0
Y	240	0	0
Z	240	230	30

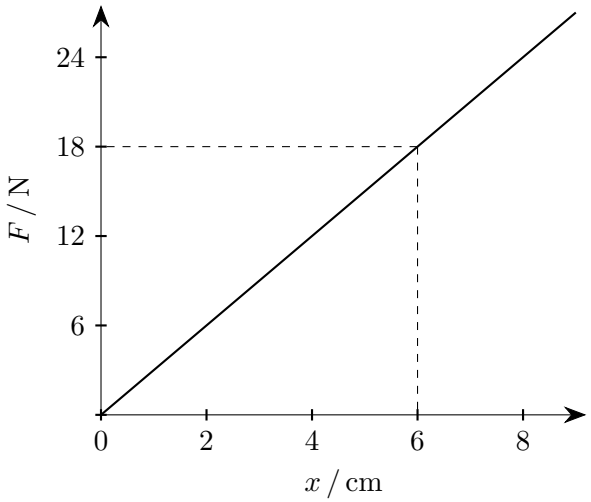
Which row correctly identifies the radiation emitted by each source?



	source X	**source Y**	**source Z**
A	alpha	gamma	beta
B	beta	alpha	gamma
C	alpha	beta	gamma
D	gamma	alpha	beta
E	beta	gamma	alpha
F	gamma	beta	alpha

Mechanics

8. The graph shows the force F applied to a spring and the extension x of the spring.
The spring obeys Hooke's law throughout the range shown.
What are the spring constant and the energy stored in the spring when $x = 6.0\,\text{cm}$?



	spring constant	energy stored
A	$3.0\,\text{N m}^{-1}$	54 J
B	$3.0\,\text{N m}^{-1}$	0.54 J
C	$30\,\text{N m}^{-1}$	0.54 J
D	$300\,\text{N m}^{-1}$	1.08 J
E	$300\,\text{N m}^{-1}$	0.54 J
F	$3000\,\text{N m}^{-1}$	1.08 J
G	$3000\,\text{N m}^{-1}$	54 J

Electricity

9. An NTC thermistor and a fixed resistor are connected in series to an ideal 12 V battery. The thermistor's resistance is initially 12 kΩ. It is then warmed until its resistance is 3 kΩ. The power transferred by the thermistor is the same at both resistances.
What is the resistance of the fixed resistor?

A 3 kΩ

B 4 kΩ

C 6 kΩ

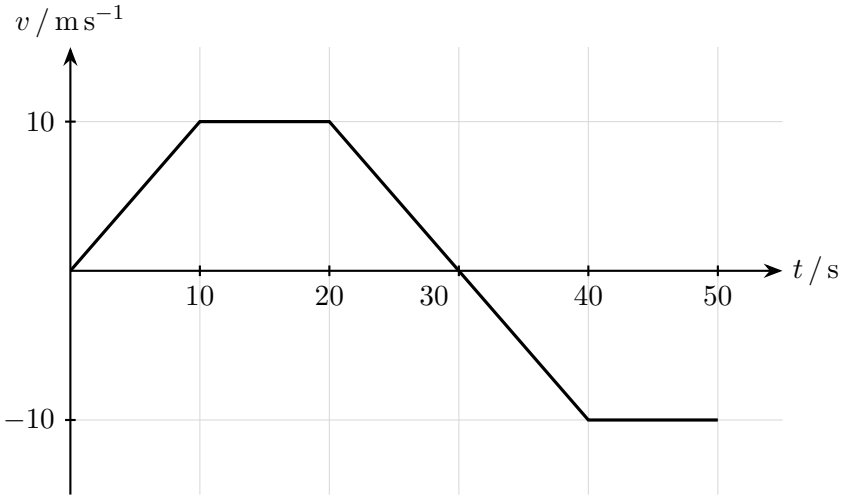
D 9 kΩ

E 12 kΩ

Mechanics

10. The velocity–time graph below shows a cyclist moving along a straight road during a 50 s journey. Positive velocity is in the direction in which the cyclist initially moves.

What is the cyclist's average speed for the whole journey?



A $1.0\,\mathrm{m\,s^{-1}}$

B $4.0\,\mathrm{m\,s^{-1}}$

C $5.0\,\mathrm{m\,s^{-1}}$

D $7.0\,\mathrm{m\,s^{-1}}$

E $9.0\,\mathrm{m\,s^{-1}}$

F $10.0\,\mathrm{m\,s^{-1}}$

Waves & Optics

11. An object is initially 30 cm in front of a plane mirror.

The mirror is moved 6 cm directly away from the object.

The object is then moved 2 cm directly towards the mirror. Both movements are perpendicular to the mirror.

How far does the object's final image move from its initial position?

A 2 cm

B 4 cm

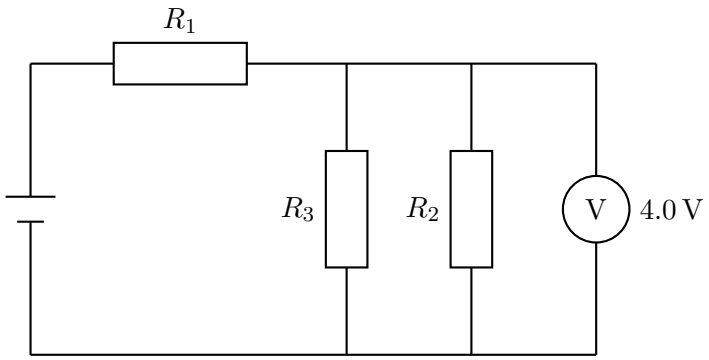
C 8 cm

D 10 cm

E 12 cm

Electricity

12. The diagram shows three identical resistors, each of resistance $8.0\,\Omega$, connected to a battery.
Resistor R_1 is in series with the parallel combination of R_2 and R_3.
The ideal voltmeter connected across R_2 reads $4.0\,\text{V}$.
What is the power dissipated in R_1?



A $2.0\,\text{W}$

B $4.0\,\text{W}$

C $8.0\,\text{W}$

D $12\,\text{W}$

E $18\,\text{W}$

Thermal Physics

13. Two otherwise identical thin metal containers of hot water stand in a cooler room, one with a matt black outer surface and one with a shiny silver outer surface.

Both contain equal masses of water at the same initial temperature.

Both receive the same incident infrared radiation, and their rates of energy loss by processes other than radiation are initially equal.

Which statements are correct initially?

I The black container emits more infrared radiation per second

II The silver container absorbs more infrared radiation per second

III The water in the black container cools faster

A I only

B II only

C III only

D I and II only

E I and III only

F II and III only

G I, II and III

Atomic Physics & Radioactivity

14. A sample of a radioactive isotope X has mass number A and half-life T.

Each nucleus of X decays by emitting an alpha particle to form a stable solid daughter nucleus Y.

At time $t = 0$, an open container holds a mass m_0 of pure isotope X.

All emitted alpha particles escape from the container, while all nuclei of Y remain inside.

Take the mass of each nucleus to be proportional to its mass number, and neglect the mass of electrons.

What is the total mass of the material remaining in the container at time $t = 2T$?

A $\dfrac{m_0}{4}$

B $\dfrac{3m_0}{4}$

C $m_0\left(1 - \dfrac{4}{A}\right)$

D $m_0\left(1 - \dfrac{3}{A}\right)$

E $m_0\left(1 - \dfrac{2}{A}\right)$

F $m_0\left(1 - \dfrac{1}{A}\right)$

G $m_0\left(1 - \dfrac{3}{4A}\right)$

Waves & Optics

15. An ultrasound transducer is held against the surface of a block of material to detect internal flaws. The transducer emits a short ultrasound pulse at time $t = 0$. The pulse travels through the material at a constant speed of $2400\,\mathrm{m\,s^{-1}}$.

The emitted pulse reflects off two parallel cracks inside the block, crack 1 and crack 2, which are at different depths directly ahead of the transducer. The transducer detects the echo from crack 1 at $t = 30\,\mu\mathrm{s}$ and the echo from crack 2 at $t = 80\,\mu\mathrm{s}$.

A fraction of the echo returning from crack 1 is reflected internally at the surface of the block back into the material, travels back to crack 1, and reflects off crack 1 a second time before returning to the transducer.

At what time is this multiple-reflection echo detected by the transducer, and what is the distance between crack 1 and crack 2?

	time	**distance**
A	$60\,\mu\mathrm{s}$	$60\,\mathrm{mm}$
B	$60\,\mu\mathrm{s}$	$120\,\mathrm{mm}$
C	$90\,\mu\mathrm{s}$	$60\,\mathrm{mm}$
D	$90\,\mu\mathrm{s}$	$120\,\mathrm{mm}$
E	$110\,\mu\mathrm{s}$	$60\,\mathrm{mm}$
F	$110\,\mu\mathrm{s}$	$120\,\mathrm{mm}$

Mechanics

16. A car of mass 1200 kg tows a caravan of mass 800 kg along a straight horizontal road.

The car and the caravan are joined by a light, rigid coupling that is parallel to the road.

The driving force on the car is 3000 N forwards.

The total resistive force on the car is 400 N and the total resistive force on the caravan is 600 N, both acting backwards.

What is the magnitude of the tension in the coupling?

A 600 N

B 800 N

C 1200 N

D 1400 N

E 1800 N

F 2000 N

G 2600 N

Mechanics

17. Two loaded trolleys P and Q have total masses of 12 kg and 18 kg respectively.
The trolleys move in the same direction along a straight track.
At one instant, the momentum of P is twice the momentum of Q.
What is the ratio of the kinetic energy of P to the kinetic energy of Q at this instant?

A 2 : 3

B 4 : 3

C 2 : 1

D 3 : 1

E 6 : 1

Thermal Physics

18. A liquid flows steadily along a glass tube. An electrical heating coil inside the tube transfers energy to the liquid as it flows past. The liquid enters the tube at 18 °C and leaves it at 30 °C. These temperatures do not change with time.

In the first experiment, the potential difference across the heating coil is 12 V and the current in it is 4.0 A. The liquid flows through the tube at a rate of 0.80 g per second.

In the second experiment, the flow rate is increased to 2.0 g per second. The potential difference across the heating coil is changed to 14 V and the current in it is then 6.0 A. The liquid again enters at 18 °C and leaves at 30 °C.

In each experiment, all the energy transferred by the heating coil goes either to the flowing liquid or to the surroundings. The rate at which energy is transferred to the surroundings is the same in both experiments.

What is the specific heat capacity of the liquid?

A $1000\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}}$

B $1500\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}}$

C $2500\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}}$

D $3000\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}}$

E $3500\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}}$

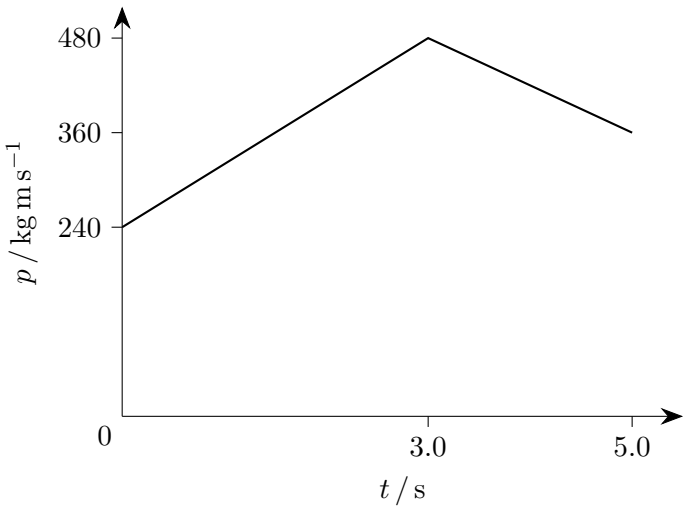
F $5000\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}}$

Mechanics

19. A cyclist and bicycle have a combined mass of 60 kg and travel in a straight line.

The graph shows how their momentum p varies with time t.

What is their speed at $t = 3.0\,\text{s}$, and what is the magnitude of the resultant force on them between $t = 3.0\,\text{s}$ and $t = 5.0\,\text{s}$?



	speed / m s^{-1}	**magnitude of resultant force** / N
A	6.0	40
B	6.0	60
C	6.0	80
D	8.0	40
E	8.0	60
F	8.0	80

Thermal Physics

20. A mass m of liquid water at an initial temperature of $20\,^{\circ}\mathrm{C}$ is placed in a container.

A block of ice of mass m at an initial temperature of $-20\,^{\circ}\mathrm{C}$ is added to the water.

The thermal capacity of the container and any heat exchange with the surroundings are negligible.

The system is allowed to reach thermal equilibrium.

What is the value of the ratio $\dfrac{\text{mass of liquid water}}{\text{mass of ice}}$ at thermal equilibrium?

(specific heat capacity of water $= 4200\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}}$; specific heat capacity of ice $= 2100\,\mathrm{J\,kg^{-1}\,^{\circ}C^{-1}}$; specific latent heat of fusion of ice $= 3.36 \times 10^5\,\mathrm{J\,kg^{-1}}$)

A $\dfrac{7}{9}$

B 1

C $\dfrac{9}{8}$

D $\dfrac{8}{7}$

E $\dfrac{9}{7}$

F $\dfrac{5}{3}$

Mechanics

21. A sealed metal ball has a hollow space inside it that contains only air.

The mass of the ball is 2.4 kg, and the mass of the air inside it is negligible.

The density of the metal is $8000\,\mathrm{kg\,m^{-3}}$.

The ball is lowered into a displacement can full of water until it is fully submerged, and no water enters the ball.

The volume of water that overflows from the can is $500\,\mathrm{cm}^3$.

What is the volume of the hollow space inside the ball?

A $100\,\mathrm{cm}^3$

B $200\,\mathrm{cm}^3$

C $300\,\mathrm{cm}^3$

D $400\,\mathrm{cm}^3$

E $500\,\mathrm{cm}^3$

F $600\,\mathrm{cm}^3$

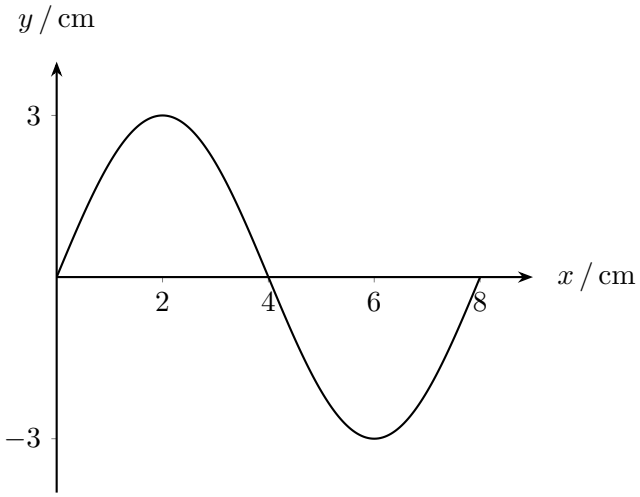
Waves & Optics

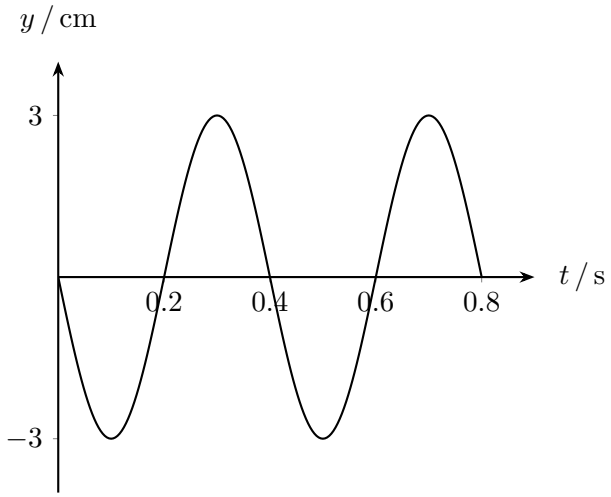
22. A transverse wave travels along a stretched rope.

The left-hand graph shows the displacement y of the rope against position x along the rope at time $t = 0$. The point P of the rope is at $x = 0$.

The right-hand graph shows how the displacement of point P varies with time t.

Which row gives the speed of the wave and the direction in which it travels along the rope?





A speed $5.0\,\text{cm}\,\text{s}^{-1}$; in the positive x-direction

B speed $5.0\,\text{cm}\,\text{s}^{-1}$; in the negative x-direction

C speed $20\,\text{cm}\,\text{s}^{-1}$; in the positive x-direction

D speed $20\,\text{cm}\,\text{s}^{-1}$; in the negative x-direction

E speed $40\,\text{cm}\,\text{s}^{-1}$; in the positive x-direction

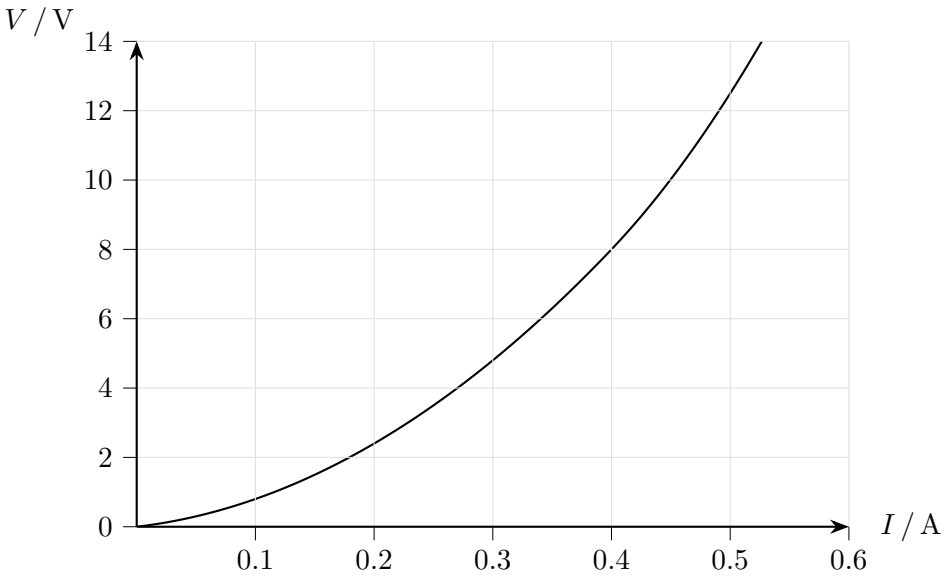
F speed $40\,\text{cm}\,\text{s}^{-1}$; in the negative x-direction

Electricity

23. The graph shows how the voltage V across a filament lamp varies with the current I through it.

The lamp is now connected in series with a fixed resistor of resistance $10\,\Omega$ and a battery of electromotive force $12\,\text{V}$ and negligible internal resistance.

What is the resistance of the lamp when it is operating in this circuit?



A $10\,\Omega$

B $15\,\Omega$

C $20\,\Omega$

D $25\,\Omega$

E $30\,\Omega$

F $40\,\Omega$

Magnetism

24. An ideal transformer takes power from a 200 V supply at a current of 10 A.

Its secondary has five times as many turns as its primary.

The secondary is connected by transmission cables of total resistance 50 Ω to the primary of a second ideal transformer.

The second transformer has nine times as many primary turns as secondary turns.

What is the current in the secondary of the second transformer?

A 10 A

B 16 A

C 18 A

D 20 A

E 22 A

Mechanics

25. A solid object rests on one of its flat faces.

It is replaced by a geometrically similar object made from a material whose density is $\frac{27}{8}$ times the density of the original material.

The replacement object has the same mass as the original and rests on the corresponding face.

If the original object exerts pressure p on the surface, what pressure does the replacement object exert?

A $\frac{8}{27}p$

B $\frac{4}{9}p$

C $\frac{2}{3}p$

D $\frac{3}{2}p$

E $\frac{9}{4}p$

F $\frac{27}{8}p$

Waves & Optics

26. A wireless router emits a signal of frequency 5.0 GHz.

The signal travels through air at $3.0 \times 10^8\,\mathrm{m\,s^{-1}}$.

The wavelength ranges in the table are used to classify the signal.

region	**wavelength range**
radio waves	greater than 1 m
microwaves	1 mm to 1 m
infrared	700 nm to 1 mm

Which row gives the wavelength of the signal and the region in which it lies?

	wavelength	**region**
A	0.060 cm	infrared
B	0.60 cm	microwaves
C	6.0 cm	microwaves
D	6.0 cm	radio waves
E	60 cm	microwaves
F	60 cm	radio waves

Mechanics

27. A sledge of mass 20 kg is released from rest at the top of a straight slope.
The slope is 12 m long, and its bottom is 6.0 m vertically below its top.
A constant frictional force of 40 N acts up the slope.
Air resistance is negligible.
Take $g = 10\,\mathrm{N\,kg^{-1}}$.
What is the speed of the sledge when it reaches the bottom of the slope?

A $6\,\mathrm{m\,s^{-1}}$

B $6\sqrt{2}\,\mathrm{m\,s^{-1}}$

C $2\sqrt{30}\,\mathrm{m\,s^{-1}}$

D $2\sqrt{42}\,\mathrm{m\,s^{-1}}$

E $8\sqrt{3}\,\mathrm{m\,s^{-1}}$